Allomaternal Investments and Child Outcomes in the United Kingdom

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Declaration

I, Emily Hazuki Emmott, confirm that the work presented in this thesis is my own. Where information has been derived from other sources, I confirm that this has been indicated in the thesis.

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Abstract

Due to the fact that human mothers often have multiple, vulnerable offspring with long periods of dependency, it is argued that mothers need assistance from allomothers to successfully provide and care for their children. Cross-cultural observations and quantitative research converge on support for the idea that mothers in high fertility, high mortality populations need assistance from other individuals for successful childrearing. It is also clear within the literature that there is variation across populations in terms of who matters: who provides the help, how they help, and how much impact they have on childrearing.

The current thesis extends from previous studies by exploring the effects of allomothers on childrearing in a contemporary developed context: With economic development and the demographic transition, questions arise regarding the importance of allomothers for successful childrearing, and whether humans in these settings still operate as cooperative breeders. This thesis specifically focuses on quantitatively investigating the effects of fathers, stepfathers and grandparents on child development in the UK. First, using the Avon Longitudinal Study of Parents and Children, I investigate how direct investments from fathers and stepfathers affect multiple child outcomes. Second, using the UK Millennium Cohort Study, I investigate how direct and indirect investments from maternal and paternal grandparents affect parental investment levels, as well as multiple child outcomes.

Taken together, my findings suggest that allomothers do indeed impact child development in the UK. However, the important allomothers seem to be those within the nuclear household. This is in contrast with many high-fertility, high mortality populations where grandmothers, especially maternal grandmothers, are often the most important allomothers regarding child survival, and fathers less so. Within its limits, the current thesis highlights who matters for childrearing in the UK today.

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Glossary

cooperative breeding	Breeding system where individuals who are not the parents help to raise children.
allomother	Any individual who is not the mother that helps to raise children.
alloparent	Any individual who is not the mother or father that helps to raise children.
direct investment	Any behaviour that is provided directly to the child to increase its quality, such as care-giving and teaching.
indirect investment	Any behaviour or resources that are provided to the mother or allomother to increase the quality of the child, such as financial provisioning.
fitness	Representation of the individual's ability to propagate their genes, relating to the ability to survive and reproduce.
inclusive fitness	Representation of the individual's ability to propagate their genes through themselves and their kin.
kin selection	An evolutionary process where behaviours which benefit others should evolve so long as the benefit gained by the receiver, multiplied by relatedness, exceeds the costs incurred by the actor ($rB>C$), based on maximising inclusive fitness.
paternity certainty	Representation of the certainty of the relatedness between a male and his supposed offspring.
mating effort	Any behaviour carried out to increase the opportunity to gain mates, or increase reproductive opportunities with a mate.
embodied capital	Somatic quality; relating to biological and cultural fitness, including physical and mental health, human capital and cultural capital.

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Chapter 1: Introduction

1.1 Overview of the Project

In the West, research on childrearing has traditionally focused on the role of the mother, and neglected the 'family' as a whole. Several factors may have contributed to this bias, such as the lingering effect of post-World War II preconceptions that fathers had little effect on child development (Lamb & Tamis-Lemonda, 2004), as well as the notion that 'nuclear families are best,' leading to minimal attention on the effects of grandparents and other extended kin (Szinovacz, 1998). As a result, the importance of caregivers other than the mother had often been overlooked.

Over the last several decades, however, research on childcare has slowly expanded its focus to include various caregivers within the nuclear and extended family. In evolutionary anthropology, for example, fathers and grandmothers have independently been argued to be important for childrearing in humans. For instance, the pair-bonding hypothesis proposes that social and emotional bonding between men and women who reproduce together evolved to facilitate provisioning and childrearing assistance from fathers (e.g., Lovejoy, 1981; Lancaster & Lancaster, 1987), while the grandmother hypothesis proposes that our long post-menopausal lifespan evolved to facilitate provisioning and childrearing assistance from grandmothers (e.g., Hawkes et al., 1998). In recent years, these ideas have been combined and expanded: Humans have been argued to be cooperative breeders where mothers generally need assistance from others for successful childrearing (e.g., Hrdy, 2005a).

Quantitative research explicitly investigating cooperative breeding in humans have often come from high fertility, high mortality populations. The focus on such populations stems from the fact that this subject is often explored by human behavioural ecologists, who are generally interested in the effects of behaviour on fertility and mortality (Sear, Lawson & Dickins, 2007). Discussed further in the chapter, such studies have generally shown that non-maternal caregivers can have positive impacts on child survival (e.g., Mace & Sear, 2005), though who helps, how they help, and how much they matter seem to vary between populations.

As previous research has generally focused on high fertility, high mortality populations, questions arise regarding the importance of different caregivers in contemporary developed populations. With societal changes such as smaller family sizes, nuclear family norms, increased female employment and state welfare, which caregivers matter for child

outcomes in developed populations? Do people in such populations still function as cooperative breeders, where childrearing is a collective activity between multiple individuals? The overall aim of this thesis is to investigate if and how non-maternal caregivers in the nuclear and extended family affect child development in contemporary developed populations, using a human behavioural ecological framework. Specifically, I focus on investigating the effects of fathers, stepfathers and grandparents on child development outcomes in contemporary United Kingdom.

In the rest of the chapter, I expand on the theoretical background and present findings from previous studies in high fertility, high mortality populations. Furthermore, I elaborate on the aims and methods of the current thesis.

1.2 The Context Surrounding This Project

1.2.1 The Need for Allomothers for Successful Childrearing in Humans

If human infants were as neurologically developed as new-born chimpanzees at the time of birth, we would experience an estimated gestation length of 18 to 21 months instead of the average nine months (Portmann, 1969). At birth, human neonatal brain size is less than 30% of adult brains (Read & Harvey, 1989), growing to 70% at around three years and 95% at around six years (Swindler, 1998). This is a much reduced rate of brain development compared to chimpanzee infants, where their brain size reaches 70% of adult size within the first year (Swindler, 1998). The prolonged postnatal brain development, coupled with the overall greater encephalisation, mean that human infants up to the age of 18 months require an estimated 8.7% more energy than chimp counterparts (Foley et al., 1991).

In essence, humans are born prematurely compared to any other primate (Swindler, 1998): Our neonates are incredibly helpless, only able to carry out basic functions such as suckling, sleeping and simple signalling through crying. This prematurity of human infants is coupled with an extraordinarily slow development and maturation period. In terms of motor development, human children only begin lifting their heads at around one to three months, start crawling at around seven to ten months, and finally begin walking at around 18 months (Berk, 2012). Chimps, on the other hand, can sit themselves up and crawl around by around two months (Dienske & de Jonge, 1982; Plooij, 1984), and begin walking quadrupedally by around five months (Plooij, 1984). In terms of physical growth, chimpanzees reach their full stature at around 11 to 12 years, while humans keep growing

into their late adolescence and even into early adulthood (Swindler, 1998). It has been suggested that humans are the only species to have a period of "childhood" due to our unusually long maturation period (Bogin, 1990).

Our slow physical growth is combined with an extended period of learning and skill acquisition unseen in chimpanzees (Kaplan et al., 2000). The time and effort it takes to acquire the necessary techniques and knowledge mean that humans are unable to sufficiently provide for themselves for the first ten to 20 years of their life: In hunter-gatherer societies, for example, the sophisticated skill required for finding and processing food means that individuals produce less than they consume for the first 15 to 22 years (Kaplan et al., 2009). Even in contemporary industrialised societies, children often require intense education for a number of years in order to achieve employment and consequent self-sufficiency. In the UK, for example, children are legally required stay in some form of education until age 16, set to rise to 18 in 2015 (Sullivan & Unwin, 2011), meaning they are unlikely to be fully independent until late adolescence at the earliest. In reality, most children receive support long into their adulthood: In 2009, 27% of UK first-time house buyers relied on their parents for financial contribution towards their deposit (Humphrey & Scott, 2013). In 2012, 41% of the surveyed over-55s provided financial assistance to family members or friends, with their adult children being the most likely recipient for this assistance, and 46% of over-55s provided non-financial support for their family members (AVIVA, 2012).

This combination of prematurity and slow maturation means that human offspring are heavily dependent on others for care and provisioning, where children require sustained, high levels of investment from others to effectively reach adulthood. In fact, the level of investment required is so high that it has been hypothesised that human mothers were, in our evolutionary history, unable to successfully raise their children without external help from *allomothers* (Hrdy, 2005a; 2005b; Mace & Sear, 2005; Hrdy, 2007;). An allomother, meaning "other mother," is anyone who is not the biological mother who cares and provides for the child. In humans, the need for allomothering is exacerbated by the fact that, at least in natural fertility populations, mothers often have multiple dependent offspring (Hrdy, 2005a). This multiple dependency of offspring is unseen in other apes, and is perhaps only possible through caring and provisioning assistance from others (Hrdy, 2005a). This has led some researchers to view humans as a cooperative breeding species, where individuals help raise offspring that are not their own.

In the non-human animal literature, cooperative breeding has a specific definition. For any species to be classed as cooperative breeders, it is required that allomothers within

the breeding system forgo their own reproduction to assist in caring and providing for the offspring of others (Komdeur, 2010). Under this definition, it is estimated that 1.8% of mammalian species are cooperative breeders (Lukas & Clutton-Brock, 2012). The most common system across these species is to have one alpha-breeding pair within a group with several subordinate helpers, as found, for example, in marmosets, tamarins (Bales et al., 2000) and meerkats (Clutton-Brock et al., 2001). In contrast, species where allomothers assist in the care and provisioning of others' offspring without forgoing their reproduction, for instance by pooling together resources, are classified as communal breeders (Komdeur, 2010). It is estimated that 1.2% of mammals are communal breeders (Lukas & Clotton-Brock, 2012), including species such as African lions (Packer, Pusey & Ebery, 2001) and spotted hyenas (Holekamp et al., 1997).

The definition of cooperative breeding has been less consistent in the human literature. While some define human cooperative breeding broadly to be a system where non-genetic parents help raise children (Hrdy, 2007; Kaptijn et al., 2010), others give more specific definitions where 10% of households must have allomothers who not only care for others' offspring, but delay or forgo their own reproduction (Strassman & Kurapati, 2010). Under the broader definition, or cooperative breeding *sensu lato*, traits associated with communal breeding in the animal literature would be included, and the delaying or forgoing of reproduction is not necessary. In contrast, the definition under cooperative breeding *sensu stricto* is analogous to that of the animal literature, and requires individuals to sacrifice their reproduction to care for the offspring of others. As discussed above, the slow developmental trajectory, the heavy investment requirements and the multiple dependencies of human offspring lead us to expect that mothers need external help to successfully raise their children. Is this really the case in humans, and if so, what is the appropriate definition of cooperative breeding in humans?

For human mothers who generally live in large social groups, there are many different potential allomothers who could assist with the care and provisioning of her child. From a child's point of view, these include siblings, cousins, aunts, uncles, grandparents, fathers, neighbours, and even strangers. However, there seems to be great cross-cultural variations in who these allomothers tend to be, and how they assist in childrearing. In the following section, I briefly review the patterns of allomaternal care across several cultures. The purpose here is not to provide a comprehensive ethnography of childrearing across cultures, but to highlight the different trends and patterns in childrearing across populations in order to assess the appropriate definition of cooperative breeding in humans.

1.2.2 Patterns of Allomaternal Care across Cultures

Hunter-gatherers

The Hadza of Tanzania practice a system where allomaternal care is a necessity. In general, weaned toddlers who are too heavy to be carried but too young to take foraging are left behind at camp while the mothers go on foraging trips (Marlow, 2005). These toddlers are often looked after by teenage girls and boys who decide to stay in camp for that day (Blurton Jones, Hawkes & O'Connell, 2005). An observational study of children under four years of age found that, while Hadza mothers did seem to be the primary caregivers being responsible for 72% of the observed child holding, allomothers were clearly contributing to care: Maternal grandmothers, fathers and other adult females accounted for 6.7%, 6.1% and 7.5% of the recorded holding, respectively (Marlow, 2005).

Like the Hadza, mothers in the !Kung of Botswana and Namibia are the primary caregivers of children. In this population, children are usually with mothers, including during gathering trips and sleeping at night, until they are weaned at around age four (Konner, 2005). Overall, !Kung mothers accounted for around 80% of the observed physical contact with young children. However, other caregivers were often in proximity to provide assistance or joint care (Konner, 2005). Once weaned, older children up to the age of around 15 stay in camp and mainly play. Unlike the Hadza, older !Kung children are not responsible for the care of younger children, but a few adults stay behind in camp to provide any allomaternal care (Blurton Jones, 1993).

Other hunter-gather populations practice allomaternal care more extensively. In the Agta pygmies of the Philippines, only 51.7% of observed carer-child interactions were between children and their mothers. The other 48.3% were mainly between fathers, grandparents, siblings and other non-relatives, with elder sisters accounting for 10.4% of the observed childcare activities and non-relatives accounting for 18.8% (Griffin & Griffin, 1992). In the Efe pygmies of the Democratic Republic of Congo, infants were found to have an average of 14 allomaternal carers at four months, and 11 allomaternal carers at 12 months (Henry, Morelli & Tronick, 2005). Most of these carers were older children, who may or may not be siblings of the infant, accompanying women on foraging trips and helping to care for infants. However, there seemed to be a shift in the allomaternal role as children grow older, when adolescents began to contribute more through provisioning of food rather than direct holding and caregiving (Henry, Morelli & Tronick, 2005). Interestingly, Efe mothers are known to frequently pass around each other's children and breastfeed them, where over 75% of infants are fed at some point by women who are not their

mothers (Tronick, Morelli & Winn, 1987). This type of care has also been reported in the Ongee of the Andaman Islands in India, where children are carried and breastfed by many different women (Cipriani, 1966).

In the Aka pygmies of the Central African Republic, breastfeeding others' infants do occur but less frequently than the Efe (Hewlett, 1989; N. Chaudhary & G. D. Salali, personal communication, 08/10/2013). Nevertheless, the sharing of infant and child care seems to be as pervasive as the Efe (Hewlett, 1989). In one study, Aka infants were found to have 21 different carers on average (Meehan, 2009), which included fathers, grandmothers, siblings and some unrelated individuals (Meehan, Quinlan & Malcom, 2013). Older individuals in camp seemed to be especially important for childcare, as they spend less time hunting/gathering and spend more of their time looking after children (Bahuchet, 1990). These allomothers tended to target care during times when mothers were engaged in work activities (Meehan, 2009), which is presumably when allomaternal care is most necessary.

Fig 1.1: An Aka allomother nursing an infant (top right) who belongs to another woman (bottom left). Personal photograph by Nikhil Chaudhary, 2013.

Shifting focus from allomaternal care to allomaternal provisioning, all hunter-gathers practice extensive food sharing, often involving unrelated individuals. In the Hadza, for example, post-menopausal women bring back a large amount of gathered foods which is a very important source of nutrition and energy for nursing mothers whose food production is diminished due to breastfeeding (Blurton Jones, Hawkes & O'Connell, 2005). Similarly, teams of men who hunt successfully bring their game back to camp where it is widely shared. While the meat is allocated to specific households within camp, it is common for other camp members to join in with the eating, and occasionally visitors from other camps who heard news of a successful hunt would arrive for a share (Hawkes, O'Connell & Blurton Jones, 2001). In the !Kung, women forage and men hunt about two to three days a week, and share whatever they bring back to camp (Blurton Jones, 1993). In the Aka, hunting and foraging activities are usually communal, with two to forty participants. Communally hunted game is shared between those who took part in the hunt, and other gathered foods are shared across the whole camp (Bahuchet, 1990). In the Ache of Paraguay, men are primarily responsible for food acquisition and hunt/forage for around six hours a day, while women forage for around two hours. Like other hunter-gatherers, game and other food items are shared extensively across the group. This pooling of food is thought to be a mutually beneficial strategy in ensuring that families have enough to eat even when they have been unsuccessful at hunting and gathering. It has been estimated that Ache children must rely on food provisioned to them from outside the nuclear family for a total of two weeks per year (Hill & Hurtado, 2009).

Overall, hunter-gatherers seem to have a wide network of allomothers who provide food and care for infants and children, although there is clear variation in the level of dependence on allomothers. Some seem to have a greater tendency towards mothers as the primary carer with allomothers providing additional support, while others seem to raise children collectively between their camp members.

South-Asian Rural Mountain Agriculturalists

Agricultural production systems in rural mountainous areas typically require high levels of intense labour for successful subsistence (Levine, 1988). Consequently, childcare activities, especially breastfeeding, are difficult to combine with provisioning activities associated with working the land. The Tibetan population in the Humla district of Nepal is one group who occupy this kind of environment. The people of Humla respond to the impractical combination of labour and childcare by expecting mothers to rest and eat

nutritious foods, concentrate on childcare and withhold from agricultural labour for at least the first month after birth, and preferably for a year (Levine, 1987). Prolonged breastfeeding is greatly valued in this population, and women usually do not wean children until halfway through their next pregnancy, and can breastfeed up to eight years of age (Levine, 1987).

Women in these contexts face a trade-off between agricultural labour and childcare, and whether they opt for labour or childcare depends on the wealth of the household, availability of replacement labourers, availability of allomothers, and the seasonal labour demands (Levine, 1988). Mothers whose labour is required due to high labour demands and/or the relative poverty of the household leave their children at home with allomothers, who are preferably other adult household members such as grandmothers. If other household members are unavailable, mothers may ask her sisters, friends or neighbours- but if all those options are unavailable, infants are left alone for hours at a time (Levine, 1987; 1988). When infants are left in the care of allomothers, they are fed supplementary foods of mashed cereal as mothers are unavailable to breastfeed.

Similarly, in the Garo Hill farmers of Meghalaya, India, mothers must juggle agricultural labour and childcare. In one particular study, mothers spent 1/3 of their day working in the fields (Sriram & Ganapathy, 1997). When engaging in agricultural labour, women could either take their children to the fields or leave them at home. In general, it was more common for women to leave their children at home with older siblings and/or other relatives as allomothers (Sriram & Ganapathy, 1997), highlighting the difficulty between childcare and mountain agricultural labour.

In these populations, allomothers are a necessity in order for mothers to fully contribute to subsistence activities. Interestingly, women in both populations seemed to favour childcare by the mother instead of relying on allomothers (Levine, 1988; Sriram & Ganapathy, 1997). For example, Humla women often complained that they had to begin supplementing breast milk with mashed foods earlier than they would have liked due to labour contribution needs (Levine, 1987; 1988). Furthermore, wealthier women with greater autonomy regarding their activities often chose to concentrate on childcare rather than labour (Levine, 1988). Thus, the preferred situation for mothers in these contexts may be to have an allomother who helps with provisioning rather than care, but this is unattainable for many women who are constrained by their economic circumstances.

Sub-Saharan Agriculturalists

Across rural sub-Saharan African populations who rely on agriculture with some animal husbandry, such as the Yoruba and Hausa of Nigeria, Giryama of Kenya and Fulani of Bukina Faso, women are generally responsible for food cultivation, food processing and childrearing. In these populations, mothers usually collaborate in multiple tasks such as food preparation, and depend on each other for assistance in childcare (LeVine et al., 1994). Specifically focusing on the Hausa of Nigeria, a cultural norm exists where mothers must not show affection or interest towards their first-borns, in that they are not allowed to use the first-borns name and must avoid looking at their child as much as possible. This creates a situation where allomothers are almost a necessity, and children within this population had on average 4.8 different carers including their mother (LeVine et al., 1994).

Another common norm in sub-Saharan Africa, especially in rural areas, is to have siblings and other children as allomothers. In the Gussi of Western Kenya, mothers are expected to be close to their infants at all times and arrange their work patterns around breastfeeding their babies. Infants are viewed to have exclusive bonds with the mothers, and allomothers are not seen as adequate substitutes for the mother (LeVine et al., 1994). At the same time, allomaternal help is viewed as a necessity for mothers, and the job of helping to care for infants and toddlers is often given to their older sisters who are usually between ages five to nine years. This sibling allomothering usually occurs when mothers are engaged in activities where the infant cannot be held by the mother and/or when the mother is not close by. After weaning, which is usually around one to two years of age, mothers officially assign a sibling allomother to the toddler who is partly responsible for their care (LeVine et al., 1994).

In these agricultural populations, mothers are viewed as being primarily responsible for the care and upbringing of children. Nonetheless, like the rural mountain agriculturalists, mothers must depend on allomothers during work activities where carrying infants is impractical. Compared to mountain agriculture, however, maternal work activities in sub-Saharan agriculture seem to be more compatible with childcare as children are usually kept close to their mothers, and it is not uncommon for infants to be taken to the fields (LeVine et al., 1994). This may explain the observed pattern of allomaternal care, where there is a greater reliance on sibling allomothering by young girls. Because mothers are not away from their infants for prolonged periods of time, mothers can rely on their older children to look after their younger ones.

Developed East Asian Populations

Throughout recent history, childcare in most East Asian populations has been viewed as the responsibility of the mother with help from family members (Hiroko, Liu & Yamashita, 2011; An 2013). Over the past few decades, this attitude has shifted towards the greater acceptance and demand of care from non-kin members.

In Japan, most women opt to become full time mothers with the sole responsibility of childcare. In 1998, 73% of employed women who gave birth resigned from work. However, this trend seems to be shifting slowly, and more women have stayed in employment over the following years (Allen, 2003). Consequently, the supply and demand for institutionalised care has steadily increased throughout the 1990s and onwards (An, 2013), where several unrelated allomothers provide care for a group of young children at childcare centres. Full-day or half-day childcare at these centres are available to children up to age five, with reduced fees depending on the parents' employment status and income (Izumi-Taylor, Lee & Franceschini III, 2011). Such group-oriented childcare is generally looked upon positively, with the belief that children can interact with their peers and develop positive social skills (Izumi-Taylor, Lee & Franceschini III, 2011), though most mothers prefer to be the primary caregiver for very young children. For instance, 63.2% of the surveyed working mothers reported that they felt guilty when their children aged three or younger were cared for outside the home (Funabashi, 2000 cited in Izumi-Taylor, Lee & Franceschini III, 2011).

Japanese mothers who do not make use of childcare centres may rely on kin members for allomaternal care. Grandparents are potentially a good source of help, especially as 3 generational households are relatively common in Japan. In 2009, 13% of all households were 3 generational, with the grandparent/s, parents and children residing under one roof (Barringer, Gardner & Levin, 1993). In such households, grandparents have been found to help out considerably with housework and childcare (Ishii-Kuntz, Makino & Tsuchiya, 2004). In Japan, grandparental childcare is the second most utilised childcare option after day-care centres, and some government policies seem to facilitate grandparent care by measures such as encouraging women to give birth in hospitals near their natal home (Allen, 2003).

Fathers, on the other hand, seem to be less available as caregivers. The rates of childcare participation by fathers in Japan is one of the lowest compared to other developed countries (Makino 1995), with only 1.23% of men taking paternity leave in 2008 compared to 90.6% for maternity leave (An, 2013). In 2006, the average time working

fathers took part in childcare was 1hr 39mins a day, compared to 2hrs 26mins for working mothers (An, 2013). Furthermore, 18.8% of Japanese fathers reported that they never spend time with their children on weekdays, which is a much higher proportion compared to 0.9% of American fathers who never interacted with their children during the week (Makino, 1995). Although fathers in Japan have gradually increased their participation in childcare over the last two decades (An, 2013), it seems many of them primarily concentrate on the provisioning role rather than allomaternal care.

The childcare situation in South Korea is similar to Japan, with a few notable exceptions. As in Japan, childcare in Korea has traditionally been viewed as a family matter where mothers relied on kin members as allomothers (Lee & Bauer, 2010), and this custom is still strong. In 2004, 61.9% of working mothers with infants depended on their kin, especially grandmothers, for childcare (Ministry of Gender Equality & Korean Institute for Health and Social Affairs, 2005 cited in Lee & Bauer, 2010). However, the demand for non-kin childcare has been increasing (Lee & Bauer, 201; An, 2013). As a consequence, there have been heavy investments into day-care centres: Between 1994 and 2009, the number of day-care centres in South Korea increased by 504 times (An, 2013).

There has also been a recent shift in government policy, where financial provisioning and subsidies for families with young children went from being means-tested into becoming universally available (Chin et al., 2012). For example, families are entitled to financial subsidies from the state if they have children up to age 6yrs, and if they have more than 2 children (An, 2013). In these contexts, the state, in a sense, acts as an allomother to assist in the provisioning of children.

Northern Europe and the USA

Across Northern Europe and the USA, families tend to be organised into nuclear groups of parents and children, often with neolocal residence (Reher, 1998). Over the last several decades, female employment has steadily increased meaning it is relatively common to have both parents in work. In 1999, for example, 60% of women with partners and children were in employment in the UK and USA (Allen, 2003).

In the USA, government interventions on family matters are generally disliked, and childcare responsibilities primarily fall on parents (OECD, 2000). At the same time, there is a strong perception that mothers are essential for positive child development. The general view is that mothers should look after young children, and that children younger

than 5 yrs. are better off at home (OECD, 2000; Izumi-Taylor, Lee & Franceschini III, 2011). However, this societal perception is likely to conflict with female employment trends, as most mothers in the USA are in paid work. In 2001, 61% of mothers with children under 3yrs old were in full-time or part-time employment (Phillips & Adams, 2001). These working mothers inevitably need allomaternal assistance in childcare.

Due to the preference of young children staying at home, families in the USA tend to opt for home-oriented childcare (Allen, 2003). If available, one option is to rely on relatives to provide allomaternal care. Indeed, 27% of children under 3yrs old were reported to be cared for by relatives at home (Phillips & Adams, 2001). Another option is home-oriented formal childcare. Family day-care is the one of the most commonly used type of care, which is childcare provided by a non-relative at their home where several children are cared for at once. Thirty-eight percent of infants and 17% of children under age of three were reported to be cared for in this way (Phillips & Adams, 2001). Finally, families may opt for private day-care centres, and 22% of children under 3yrs were cared for in this way (Phillips & Adams, 2001).

Like the USA, childcare in the UK is viewed to be the responsibilities for parents. Still, one survey revealed that only 6% of families never used any form of childcare where parents were the sole cares of children (Wheeloch & Jones, 2002). Indeed, many families reported using formal childcare regularly or occasionally (Wheeloch & Jones, 2002). To help with the costs of private childcare, the government provides family tax credits for low & middle income families where both parents are in work, and 12.5 hrs per week of free childcare is available for all 4 and 5 yrs. olds regardless of parental employment status (Lyonette, Kaufman & Crompton, 2011).

Despite these state benefits, the cost of childcare is still an issue for most families in the UK. In 2014, the majority of households using full-time childcare were found to spend 20 to 30% of their gross income on childcare (Rutter & Stocker, 2014). It was estimated that families with two young children in full-time care would spend £11,700 a year on average in childcare costs (Rutter & Stocker, 2014). Wealthier families who can afford full-time childcare are more likely to depend solely on the private system, while less wealthy families try to juggle maternal employment and childcare through measures such as part-time employment and heavier reliance on informal childcare (Lyonette, Kaufman & Crompton, 2011). For some lower-income families, the costs of childcare are so high that maternal employment brings little financial gains unless free allomaternal care is provided by relatives (Lyonette, Kaufman & Crompton, 2011). In fact, 85% of families who reported using formal childcare also used informal childcare provided by friends or relatives,

particularly grandparents (Wheeloch & Jones, 2002). Consequently, mothers in the UK are less likely to be in employment compared to the USA, and are more likely to work part-time if they are employed (Lyonette, Kaufman & Crompton, 2011).

In contrast to the USA and UK, while Nordic women are expected to organise the care of her children, they are not necessarily expected to be a major provider of it (Leira, 1994). Consequently, the clash between the cultural perceptions of motherhood and maternal employment is likely to be less severe. It is unsurprising, therefore, that maternal employment rates across Nordic countries are especially high. In the mid-90s, the employment rate of mothers who had children under 10yrs old stood at 84% for Denmark, 82% for Sweden and 77% for Finland and Norway.

There are also notable differences in the patterns of childcare. Unlike the USA and UK where the responsibility of childcare falls predominantly on the parents, childcare across the Nordic countries is generally perceived to be a joint venture between the state and the parents. The provision of care by the state is not only culturally accepted, but expected (Leira, 1994, Leira, 2002), and a near-universal provisioning of childcare by the state exists where subsidised or free organisational childcare is guaranteed. The utilisation of this state-provided childcare is very high. In the late 90s, 55% of children under 3 yrs. and 89% of pre-schoolers were cared for through state-provisioned childcare in Denmark. Comparable figures were 41% of under 3s and 84% of pre-schoolers for Sweden, 28% of under 3s and 73% of pre-schoolers for Norway, and 25% of under 3s and 67% of pre-schoolers for Finland (NOSOSKO 1999 cited in Leira, 2002). The take-up of state-provisioned childcare is thought to be slightly lower in Norway and Finland as families receive childcare allowances if they care for children at home (Leira, 2002).

In essence, the childcare systems in these countries are collectivised, where the childcare is a public issue and less so parental. However, this does not necessarily remove parental responsibilities as these systems are combined with generous parental leave policies (Leira, 2002) which enable parents to provide care without relying on allomothers. Overall, the extensive state provision of childcare combined with the generous parental leave policies mean there is less dependence on kin and other social support network as alloparents in the Nordic countries compared to the USA and UK.

1.2.3 Defining Cooperative Breeding in Humans

When exploring the pattern of childcare across cultures, some similarities and differences emerge. Firstly, mothers are often expected to be, and often are, the main caregiver. However, the strength of this expectation seems to vary across cultures. Secondly, across all the reviewed cultures, maternal work clashed with childcare, though the severity of the incompatibility varied. Thirdly, the solution to the work-childcare clash is to depend on allomothers for assistance in childrearing and/or provisioning. However, the general patterns of allomaternal care and provisioning differ greatly between cultures. Nevertheless, kin members, especially grandparents, are mentioned as allomothers across all populations.

In hunter-gatherer societies, allomothering seems to be a communal venture, where the care and provisioning of children come from multiple sources. They seem to have a wide network of allomothers across all age groups, who may or may not be relatives. In contrast, traditional agriculturalists tend to have a smaller network of allomothers with greater dependence on kin members. In developed populations, we see the expansion of childcare as an economic commodity. Rather than depending on the social network for allomaternal care, parents may purchase childcare services from unfamiliar individuals or organisations. At the same time, there is an emergence of "institutionalised allomothering" where the state assists with the care and provisioning of children.

The patterns of allomaternal care across these developed populations seem to depend on the cultural perception of motherhood and the availability of institutionalised allomaternal assistance. In developed East Asian societies, institutionalised childcare and provisioning is readily available and increasingly guaranteed, but the cultural view that mothers and their families are responsible for caregiving is strong. Consequently, mothers tend to quit work and show relatively greater dependence on kin members for allomaternal care and provisioning. In Nordic countries, institutionalised childcare and provisioning is also readily available, but the cultural perception of mothers as the main caregiver is weaker. Consequently, there is a high utilisation of formal childcare and less dependence on kin. Finally, in the USA and UK, the cultural perception of mothers as the main caregiver is strong, but institutionalised childcare and provisioning is less well established. This has led to families experiencing "patchwork childcare" (OECD, 2000) where parents rely on multiple types of private and kin-based care depending on factors such as wealth, availability and convenience.

With these commonalities and differences in the patterns of allomaternal care and provisioning, how should the human breeding system be defined? If we follow the animal literature, humans should be defined as communal breeders if allomothers provide help without affecting their reproduction, while cooperative breeding requires the allomothers to forgo or delay their reproduction. In some cases allomothering is unlikely to hinder reproduction, for example when mothers help each other in looking after children- following the pattern of communal breeding. In most cases, however, it is difficult to determine whether providing care and resources to children causes the allomothers to delay or forgo their reproduction. This is especially true when older siblings are allomothers. Due to the long developmental period seen in human offspring, humans in their mid-childhood to mid-teenagehood are often competent enough to provide childcare assistance but too young to reproduce. The fact that these sibling allomothers are unable to reproduce may entice some researchers to conclude that they are not delaying or forgoing their reproduction. However, the time and energy they currently expend through childcare could affect their future fertility. In the !Kung hunter-gatherers, for example, younger siblings have been found to have higher fertility than older siblings (Draper & Hames, 2000). This could be interpreted as allomothering provided by the older siblings hindering their reproduction. Equally, it could be that allomothering provided by the older siblings somehow permits for higher fertility in the younger siblings. It may not be about allomothering at all, but about other confounding factors such as the size and/or quality of their kin network. These issues are very difficult to tease apart, making sibling allomothering difficult to categorise as communal breeding or cooperative breeding.

One group of allomothers often proposed as forgoing reproduction are grandmothers. Humans are one of the handful of species where females experience menopause (Peccei, 2001; McAuliffe & Whitehead, 2005). While there are several theories regarding the evolution of the menopause (reviewed in Leidy, 1999), the grandmother hypothesis in particular posits that the extended post-reproductive lifespan in women evolved to remove the reproductive conflict between grandmothers and her daughters. The reproductive cessation facilitates and encourages allomothering by grandmothers, so they may care and provide for their grandchildren effectively (Hawkes et al., 1998; Peccei, 2001; Hawkes, 2004; Lahdenperä et al., 2012). If this is the case, almost all societies, and indeed all societies reviewed above, could be categorised as cooperatively breeding due to their dependence on grandparents as an allomother. However, there is continuing debate on whether grandmothers forgo reproduction for the purposes of allomothering, and some suggest that the menopause is simply a biological by-product of the prolonged human lifespan (*Skjærvø & Røskaft, 2013*). Recent research has provided conflicting results, where

some find support for the grandmother hypothesis (e.g., Hill & Hurtado, 1991; Shanley et al., 2007; Johnstone & Cant, 2010; Lahdenperä, 2012), while others find support for menopause as a biological by-product (e.g., Morton et al., 2013; *Skjærvø & Røskaft, 2013*). It is therefore currently unclear whether grandmothers are forgoing their reproduction, fitting into the cooperative breeding criteria.

Considering the difficulties in assessing whether allomothers forgo reproduction, the only definitive conclusion we can draw is that the patterns of allomothering within and across cultures seem to occupy a wide range within the spectrum of communal and cooperative breeding. It would be incorrect to label most human populations as communal breeders, and equally flawed to simply label them as cooperative. Therefore, I believe the most appropriate definition for the human breeding system is cooperative breeding *sensu lato*, where individuals who are not the parents of a particular child help in the care and provisioning of that child, irrespective of their reproductive status. This is in contrast to cooperative breeding *sensu stricto* which is widely used in the animal literature and occasionally in the human literature. Cooperative breeding *sensu lato* encompasses all allomothers, fully capturing the fundamental aspect of the human breeding systems- where mothers need and receive help for successful childrearing. Trying to assess whether allomothers are forgoing reproduction is not only extremely difficult, but not necessarily useful as it may overcomplicate the wider questions surrounding the causes and consequences of allomothering in humans.

Humans as cooperative breeders *sensu lato* is the underlying theme of this thesis. The questions which are addressed throughout the following chapters emerged from this notion that mothers, across all cultures, need external help to successfully raise their children. Allomothering is an obligate human trait at the community level, though who provides it and how is varied at the individual level. Keeping in mind that the patterns of allomothering are diverse, the fundamental aim of this thesis is to explore how allomothering functions in a contemporary developed context, specifically in the United Kingdom. I concentrate on family members as allomothers rather than friends or formal childcare, with the reasons behind this outlined in the subsequent sections. In the rest of this chapter, I introduce and expand on the theoretical framework used to develop this thesis, and present the current evolutionary theories on why allomothers provide help. This is followed by the discussion of the available literature on the effects of allomothers across cultures, and the subsequent presentation of the central questions and aims. Finally, the structure of the thesis is briefly outlined.

1.3 Theoretical Background of the Thesis

1.3.1 Human Behavioural Ecology

In exploring allomothering and its consequences, the theoretical framework of this thesis relies mainly on Human Behavioural Ecology (HBE). HBE is a sub-discipline of evolutionary anthropology, working with an assumption that *natural selection* has shaped human behaviour to maximise *inclusive fitness*. Natural selection is an evolutionary mechanism whereby the genes that are most effective at propagating themselves spread and become more common, while less effective genes are selected against and become less common. The genes which are effective at propagation tend to be those that produce traits which positively affect the fitness, or the survival and reproduction, of an individual. However, as selection favours genes that get passed on through generations, we must consider the inclusive fitness of an individual, defined as the survival and reproduction of the individual, their kin and their progeny. Such traits which maximise inclusive fitness are said to be *adaptive* (see Krebs & Davies, 1997 and Boyd & Silk, 1997 for overview).

This discipline originally emerged from the application of theories developed in the behavioural ecology of animals to explain human behaviour. It concerns itself with the ultimate functions of a particular behaviour based on how it affects inclusive fitness (Sear, Lawson & Dickins, 2007; Borgerhoff Mulder & Schacht, 2012), and should complement proximate approaches which are widespread across the social sciences. There are certain key assumptions which are fundamental to HBE:

Firstly, resources and energy are finite. Consequently, each behaviour has a trade-off where the more you carry out one behaviour the less energy or resources you have for the other. Life History Theory expands this notion further by contextualising the resource/energy trade-offs into the scheduling of key events during the lifetime (Sear, Lawson & Dickins, 2007; Laland & Brown, 2011; Borgerhoff Mulder & Schacht, 2012). There are four key Life History trade-offs. The first is *somatic effort vs. reproductive effort*, which addresses the trade-offs between investing in your own quality/survival and investing in reproduction. The second is *quantity of offspring vs. quality of offspring* (i.e., quantity-quality trade-off), which addresses the trade-off between the number of offspring and the quantity of offspring. The third is *mating effort vs. parenting effort*, which addresses the trade-off between acquiring/keeping mates for future offspring and investing in the quality of current offspring. Finally, the fourth is *direct fitness vs. indirect fitness*, which addresses the trade-off between investing in your own survival/reproduction and

investing towards the survival/reproduction of your kin (Sear, Lawson & Dickins, 2007; Laland & Brown, 2011; Borgerhoff Mulder & Schacht, 2012).

Secondly, optimal behaviours, or behaviours that maximise your inclusive fitness, are dependent on the individual environment (Sear, Lawson & Dickins, 2007; Laland & Brown, 2011; Borgerhoff Mulder & Schacht, 2012). For instance, the r/K selection theory poses that species which experience highly variable, unpredictable environments with high mortality risk should be r-selected, leading to a fast life history strategy with greater investment in reproductive effort, quantity of offspring and mating effort. Fast life history strategies are associated with traits such as early maturation and high fertility, which should be optimal in risky environments where reproductive success is primarily dependent on the number of offspring (Krebs & Davies, 1997). In contrast, species which experience stable, predictable environments with low mortality risk should be K-selected, leading to a slow life history with greater investments in somatic effort, quality of offspring and parenting effort. Slow life history strategies are associated with traits such as later maturation and low fertility, which should be optimal in low-risk environments where reproductive success is predominantly dependent on the competitive ability of individuals (Krebs & Davies, 1997).

Finally, HBE assumes that behaviour is flexible. Individuals should exhibit the most beneficial and least costly behaviour which is specific to their particular environment (i.e., adaptive behaviours) (Sear, Lawson & Dickins, 2007; Laland & Brown, 2011; Borgerhoff Mulder & Schacht, 2012). Referring back to r/K selection, humans as a whole are K-strategists with slow maturation, low fertility and a long life expectancy compared to typical r-strategists such as mice. Nevertheless, there is flexibility in life history strategies within humans. In unpredictable environments with high mortality, people tend to take a faster life history strategy with earlier age at first birth and higher fertility, while those in predictable, low mortality environments tend to take a slower life history strategy with later age at first birth and lower fertility (Draper & Harpending, 1988; Wilson & Daly, 1997; Belsky, 2010). Of course, we can extend this notion of optimality and flexibility to include any behaviour, not just those directly related to life history.

One important note to add to these assumptions under HBE is that individuals within a population may not express the same behaviour. This is because, even within a population where all individuals share the same ecology, the immediate environment of each individual would vary- such as access to resources, the amount of investments they received from parents, and so on. One particular consideration which is often overlooked under HBE is the variation in the ability to express optimal behaviour, and that optimality

is not necessarily achieved due to phenotypic constraints. Even so, individuals are expected to act as closely as they can to their particular optimum. With this in mind, the aim of HBE is to explain different patterns of human behaviour based on its costs and benefits to inclusive fitness. The main benefit of HBE is that it allows for a clear and simple way to understand human behaviour (Nettle et al., 2013), with its fundamental theories applicable across all populations.

1.3.2 Defining Investments into Children

Mothers and allomothers expend time, energy and resources in raising children. This can be conceptualised as *investments* into children, defined as any behaviour with the aim of increasing the quality of a child, with opportunity costs against any other behaviour. By quality, I mean any form of embodied capital (Kaplan, 1996; Kaplan, Lancaster & Robson, 2003) which links into the biological and cultural fitness of a child, including physical and mental health, human capital (see Sweetland, 1996) and cultural capital (see Throsby, 1999).

Investments have been categorised and defined in various ways within and between subject disciplines (e.g., Kaplan, 1996; Geary, 2000; Marlow, 2000). Here I categorise investments into two groups: direct and indirect. I define direct investments to be *any investments made from the investor straight to the child*, for example by providing physical care, feeding and teaching. Indirect investments are *investments which are transferred into direct investments*, for example when an investor provides financial assistance to an individual who then utilises those resources to invest directly into the child (Fig. 1.2). By this definition, maternal and allomaternal care is always a direct investment. Maternal and allomaternal provisioning, on the other hand, may be direct or indirect. It would be classed as direct if the resources are transferred directly to the child (e.g., providing food or wealth directly to the child). In contrast, the generation and acquisition of resources would be classed as indirect, along with and any resources which are transferred to an investor (e.g., monetary savings, later transferred to a different investor or the child). To summarise: 1) children always receive direct investments; 2) investors may invest directly or indirectly; 3) indirect investments may be transferred from one investor to another whereby the receiver converts it into direct investments; and 4) indirect investments may be generated by an investor who converts it into direct investments themselves.

In rural Ethiopia, maternal grandmothers frequently contributed to heavy domestic tasks, while paternal grandmothers contributed to agricultural labour (Gibson & Mace,

2005). Similarly, siblings are found across subsistence and developing populations to contribute to household and productive labour (e.g., Cain, 1977; Rosenzwig & Evenson, 1977; Turke, 1988; Lee & Kramer, 2002; Kramer, 2002). These could all be classified as indirect investments, where the investor raises resources or frees time for another investor who then directs investments towards the focal child. This effect has been found in the Hadza, where grandmothers generally had high foraging returns and shared their gathered foods with mothers, leading to the better nutritional status of children (Hawkes, O'Connell & Blurton Jones, 1989, 1997; Hawkes et al., 1998). On the other hand, the extensive holding and feeding of infants by allomothers in the Efe (Tronick, Morelli & Winn, 1987) would be classed as direct investments. In a contemporary developed context, for example, paying for education would be classed as an indirect investment, while the actual teaching would be classed as direct. Similarly, generating resources through employment would be classed as indirect, while the provisioning of toys and books by utilising these resources would be classed as direct.

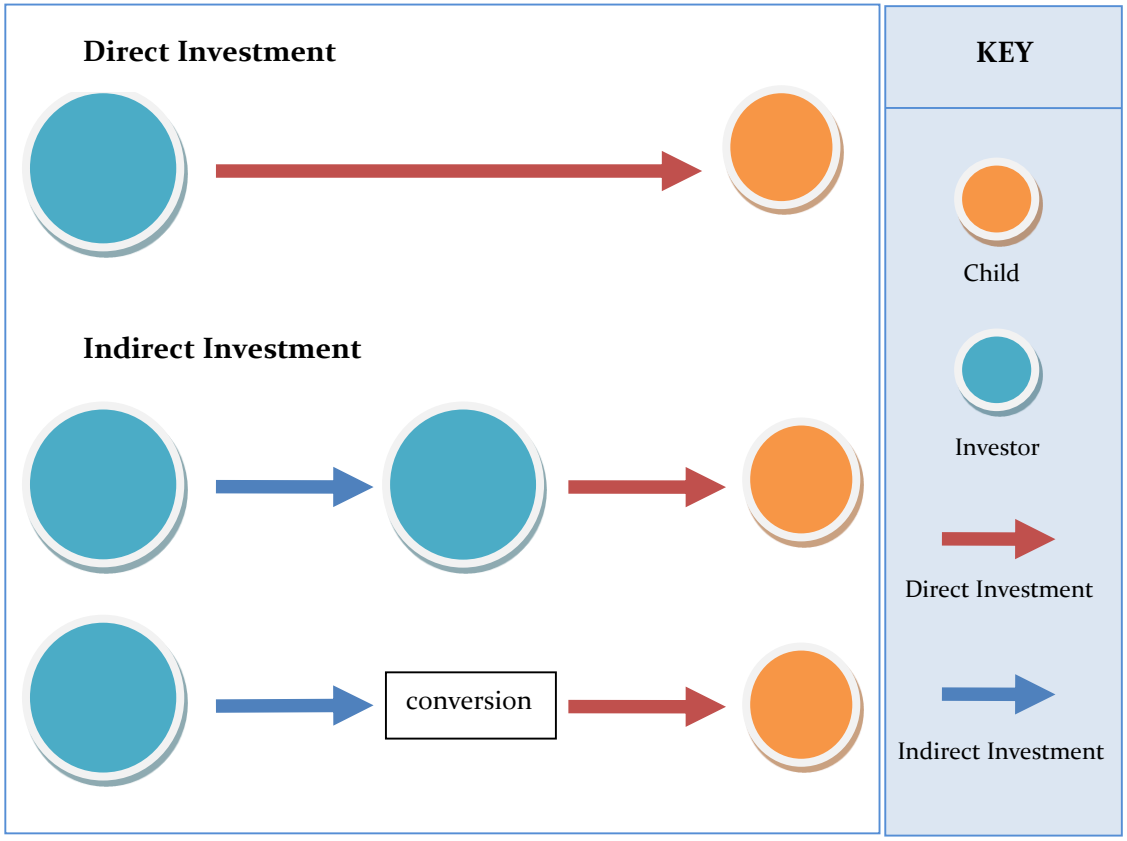

Fig 1.2: Pathways of direct and indirect investments from investors to children. Children always receive direct investments. Indirect investments can be transferred to another investor who utilises it to provide direct investments, or indirect investments may be converted within the investor into direct investments.

These direct and indirect investments may potentially affect the investment behaviours of others, affecting the amount of investments children receive. For example, if an individual observes the amount of direct investments provided by one investor to the focal child, that individual may adjust their own levels of direct investments (Fig. 1.3). Likewise, if an individual observes the amount of direct investments provided by one investor to the focal child, that individual may adjust their own levels of indirect investments (Fig. 1.4).

A similar process may also exist for indirect investments, where an individual observes the amount of indirect investments provided by one investor to the focal child, and that individual adjusts their own levels of direct investments (Fig. 1.5). Equally, if an individual observes the amount of indirect investments provided by one investor to the focal child, that individual may adjust their own levels of indirect investments (Fig. 1.6).

A handful of studies have investigated the effects of kin assistance on maternal investment, highlighting how investment from one source can affect the investment behaviour of others. Meehan (2009) conducted an observational study in the Aka foragers and the Ngandu farmers, measuring allomaternal direct care through holding, nursing, feeding, cleaning, soothing and other affectionate behaviours. She found that allomaternal direct investments mainly occurred when mothers were working, suggesting allomothers substitute direct care so mothers can engage in production activities. In a later, more detailed analysis, Meehan, Quinlan & Malcom (2012) investigated the effect of allomothers on maternal investments in the Aka. They found that direct care provided by grandmothers and fathers was associated with reduced maternal caregiving. However, while grandmaternal caregiving directly substituted for the reduced amount of maternal care, paternal caregiving was associated with a greater reduction of maternal care, leading to a net reduction in the total amount of caregiving those children received. In the Karo Batak farmers of Indonesia, help from matrilineal kin was associated with increases in direct maternal investments (carrying and breastfeeding) and a reduction in indirect maternal investments (farm work), while help from patrilineal kin was associated with reductions in direct maternal investments and an increase in indirect maternal investments (Kushnick, 2012).

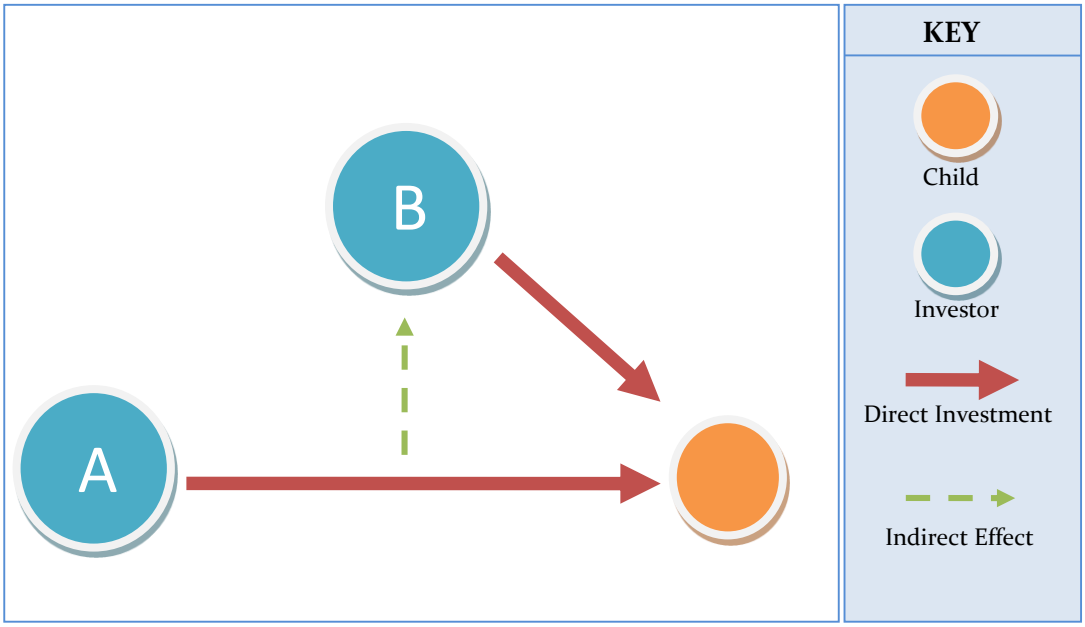

Fig. 1.3: Pathway of direct investment affecting the direct investment of others. The direct investment by A affects the direct investment by B.

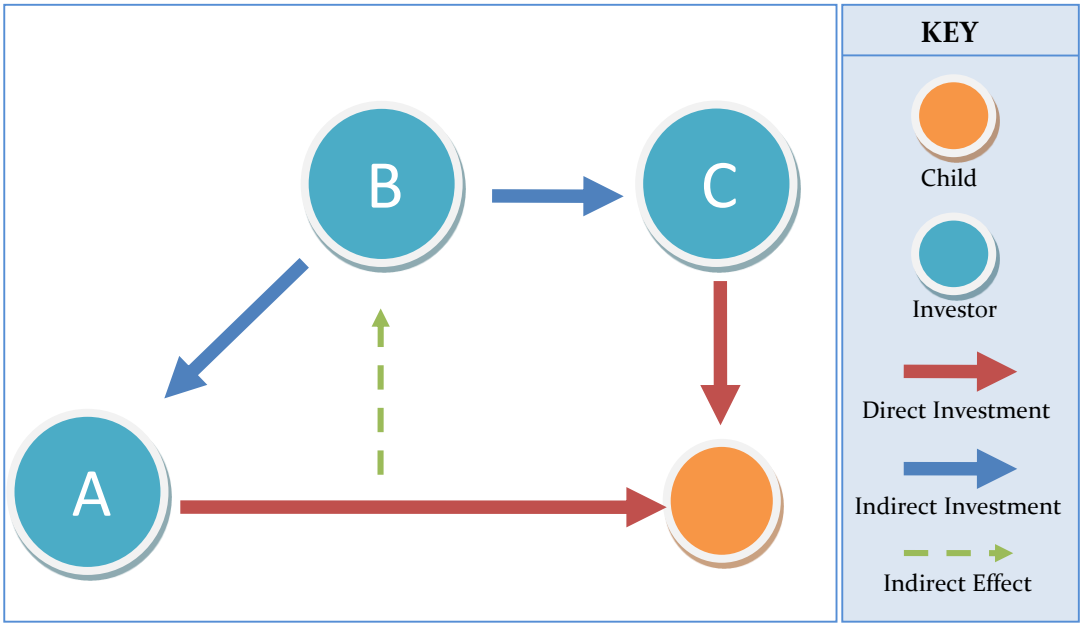

Fig. 1.4: Pathways of direct investment affecting the indirect investment of others. The direct investment by A affects the indirect investment from B to A, or from B to the unrelated C.

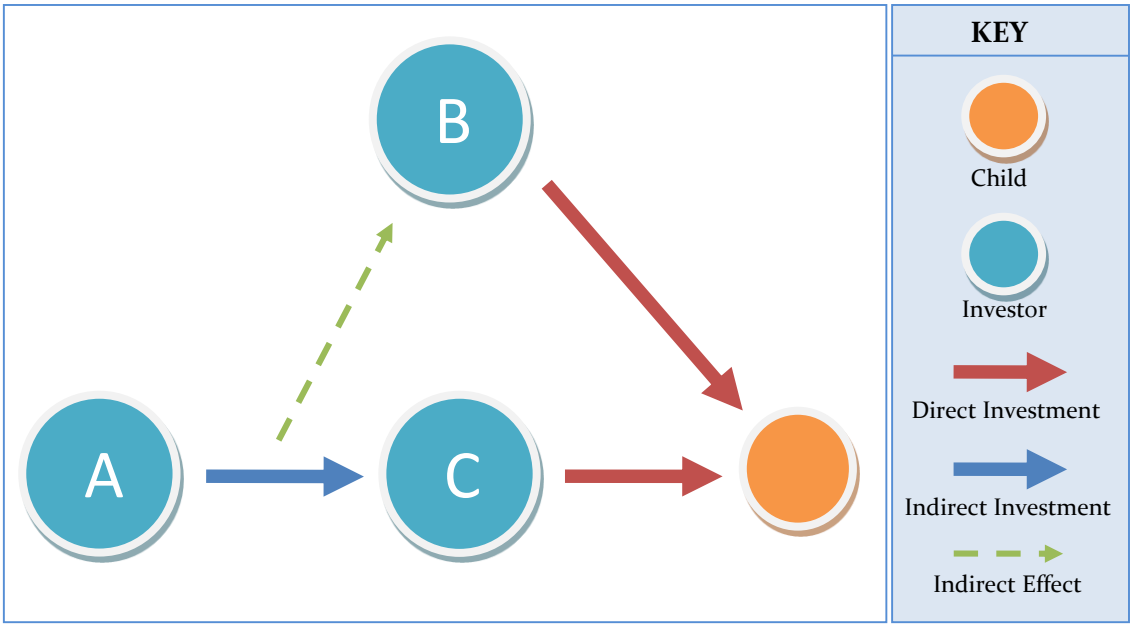

Fig. 1.5: Pathway of indirect investment affecting the direct investment of others. The indirect investment from A to C affects the direct investment by B.

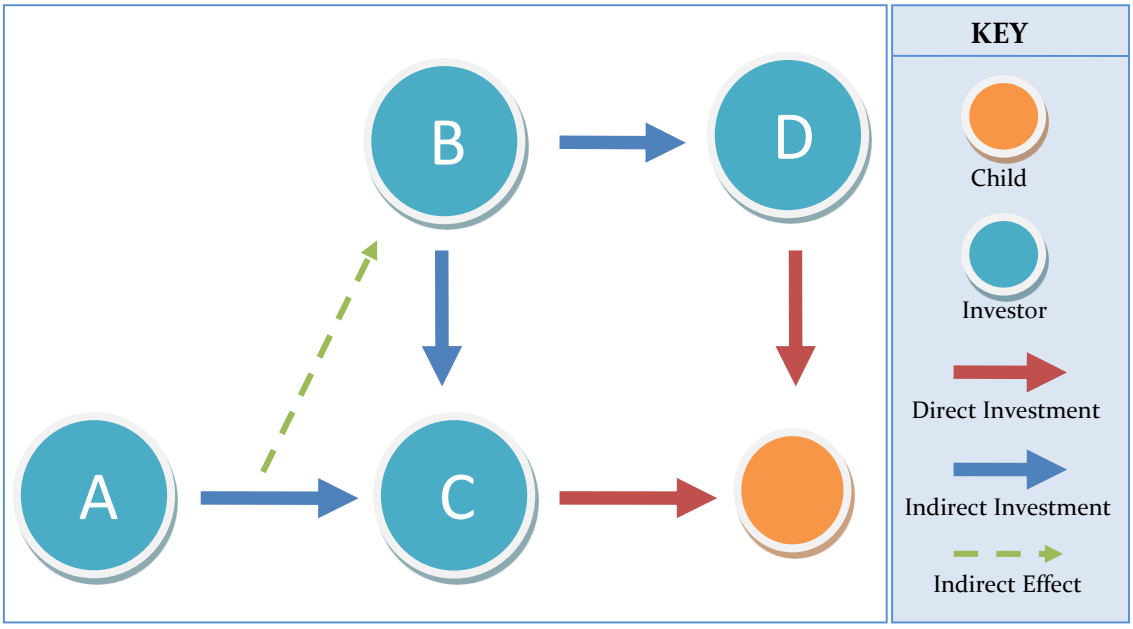

Fig. 1.6: Pathway of indirect investment affecting the indirect investment of others. The direct investment from A to C affects the indirect investments from B to C, or from B to the unrelated D.

Combining these pathways, children may experience a network of investors consisting of mothers and allomothers who provide direct and indirect investments, whereby the individual investments may or may not affect the investment levels of others (Fig. 1.7).

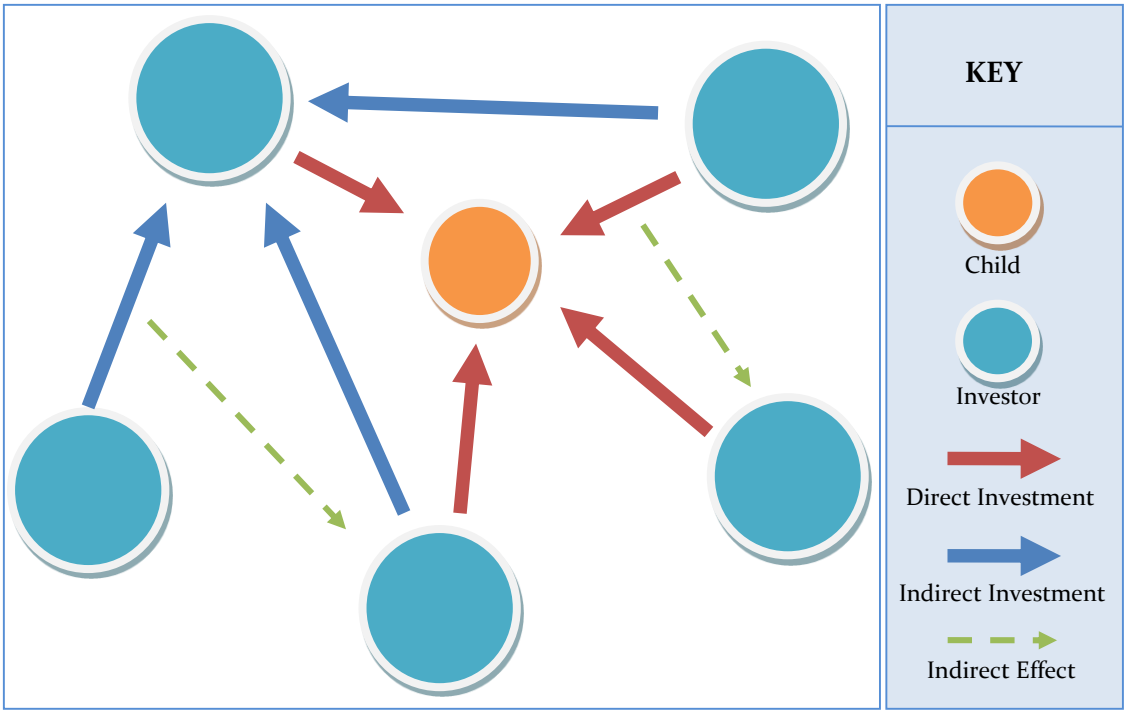

Fig. 1.7: An example of a network of direct and indirect investors, representing mothers and allomothers who care and provide for the focal child.

1.3.3 Why Invest in Children?

By definition, maternal and allomaternal investments are made for the purposes of increasing the quality of children. The reasons behind maternal investment, from an evolutionary perspective, are relatively straightforward. By increasing the quality of her offspring, her children are more likely to survive and reproduce, potentially leading to the greater quality or quantity of her grandchildren- and ultimately increasing the mother's inclusive fitness. However, there are other factors that need to be considered regarding the motivations behind allomaternal investments. Here, I concentrate on the HBE explanations behind the investments provided by family members, specifically siblings, fathers, stepfathers and grandparents. I concentrate on these allomothers as HBE directs our interests towards trade-offs in behaviours relating to inclusive fitness. As a result, HBE tends to focus on measuring how individuals within the family affect the survival and

reproduction of children and grandchildren. To explain investment behaviours by siblings, fathers, stepfather and grandparents, we must expand the concept of inclusive fitness and incorporate the ideas of kin selection, paternity certainty and mating effort.

Kin Selection

Kin selection is a mechanism that increases one's inclusive fitness. So far, I have touched upon the process of maximising inclusive fitness through increasing the fitness of one's offspring. However, you not only share genes with your offspring, but with other kin members who are blood relatives. To elaborate, you pass on half of your chromosomes to your offspring and share 50% of your genes. This is denoted as having a relatedness, or "r," of 0.5. Similarly, on average you share 50% of genes with your full siblings with an r of 0.5., and 25% of genes with your grandparents with an r of 0.25. As natural selection is based on the propagation of genes, in certain situations it may be beneficial to behave in a way that costs your own fitness but increases the fitness of your kin. Specifically, the theory of kin selection proposes that behaviours which benefit others should evolve so long as the benefit gained by the receiver, discounted by relatedness, exceeds the costs incurred by the actor (Hamilton, 1964). This is often represented as $rB>C$, where r is the relatedness between the recipient and the actor, B is the benefit gained by the recipient, and C is the cost incurred by the actor.

This theory can be used to explain investments from parents and other kin members into children. According to the equation, higher relatedness increases the likelihood of the net benefit outweighing the costs of investments. Therefore, mothers and fathers who share an r of 0.5 with their offspring should have the highest incentive to invest into the focal child. Similarly, full siblings with an r of 0.5 should also gain inclusive fitness benefits by providing investments for the focal child. However, the costs of investments between siblings and parents are likely to differ. Unlike the adult parents who are obviously reproducing, siblings are often still developing, needing to invest in their own growth and skills. Older siblings may need to expend their energy and resources into finding reproductive mates, so they themselves can reproduce. In short, siblings are likely to have a greater need to invest in their own fitness compared to their parents. As the relative costs of investments are greater for siblings, parents are expected to invest more than siblings, all other things being equal. The differences in costs may also affect the investment patterns of grandparents. Post-menopausal grandmothers, unable to reproduce, are expected to have a lower cost of investments compared to grandfathers

who are still able to reproduce. We would therefore expect grandmothers to invest more in children than grandfathers. Indeed, this is the pattern that emerges in the patterns of allomaternal care across cultures where kin, especially grandmothers, frequently serve as allomothers (see section 1.1.2).

Overall, the theory of kin selection is a useful tool to predict and explain patterns of investment behaviours, based on the relatedness between the focal child and the investor, the benefit they bring to the child, and the relative costs of the investments to the mother or allomother.

Paternity Certainty

Paternity certainty is the concept that captures the uncertainty fathers face regarding their relatedness to their children (Alexander, 1974; Kurland, 1979). The levels of paternity certainty can vary within and between populations. For instance, when mothers have multiple sexual relationships through extra-pair copulations or polyandrous mating systems, paternity certainty between the father and child is generally lower than mothers who have stable, monogamous relationships. Theoretically, this certainty should affect investment behaviours by affecting the potential benefits of investments. This can be expressed through the addition of the term *p* into the equation of kin selection, $prB>C$, where p represents the probability of relatedness. This means that the higher the paternity certainty, the higher the potential benefit to one's inclusive fitness, and the higher the likelihood of the net benefit to outweigh the costs of investments. At the same time, if p is low, potential fathers may be better off not investing into the focal child as the costs outweigh the net benefits.

In addition to fathers, paternity certainty can affect the investment levels of other kin members. Full siblings, for example, experience a level of uncertainty in whether they share the same father, potentially affecting their investment levels into each other. Interestingly, however, under very low paternity certainty, siblings may be more inclined to invest than fathers. This is because the probability of relatedness is higher for full siblings who share the same mother, meaning that the potential benefit of sibling investments may outweigh their relatively higher costs.

Similarly, the probability of relatedness differs between the types of grandparents. Maternal grandmothers have the greatest certainty, as their daughter's child is definitely related to her. Maternal grandfathers and paternal grandmothers both have 1 degree of

uncertainty, followed by paternal grandfathers who have 2 degrees. Therefore, based on the probability or relatedness and kin selection, we would expect maternal grandmothers to benefit most and provide the greatest levels of investments, followed by maternal grandfathers and paternal grandmothers, and finally paternal grandfathers. Indeed, maternal grandmothers have consistently been found to provide the greatest allomaternal investment, while paternal grandfathers are found to invest the least (Euler & Weitsel, 1996; Michalshi & Shackelford, 2005; Bishop et al., 2009; Pollet, Nelissen & Nettle, 2009; Danielsbacka et al., 2011).

Mating Effort

So far, I have outlined why people may invest in children based on kin selection and maximising inclusive fitness. However, males may have incentives to invest in children to maximise their own fitness. To put it simply, women incur large, unavoidable costs in reproduction due to expensive egg production, 9 month gestation and lactation. This means that female reproduction is biologically limited, and successful reproduction is predominantly dependent on the availability of resources and energy. Men, on the other hand, are able to reproduce by simply fertilising the egg, with fewer biological limits. Successful reproduction for males is therefore limited by the number of copulations with fertile females (Bateman, 1948; Trivers, 1972). These differences in the limits to reproduction create an opportunity for trade, where males may provide investments in exchange for reproductive opportunities with females. Furthermore, due to the greater costs and limitation of reproduction for females, it is more important for them to be "picky" in choosing who to reproduce with. Therefore, males may invest in children to show-off their quality as good allomothers.

In effect, males may invest in children to gain reproductive opportunities. Investments under such circumstances are made as a mating effort. Note that paternal investments could serve the purposes of both kin selection and mating effort, where fathers invest in their offspring to increase his or her quality, and at the same time encourage the mother for mating opportunities. Stepfathers, on the other hand, are not related to the children they invest in. Stepfather investments are therefore likely to be made in terms of mating effort, where a new partner invests his time and resources for the benefit of the mother and her child in order to gain matings (Anderson, Kaplan & Lancaster, 1999a, 199b; Lancaster & Kaplan, 2000). In support, resident stepfathers have been found to provide and care for stepchildren, though at a lower level than the average investments by resident

biological fathers (Flinn, 1988; Anderson, Kaplan & Lancaster, 1999a, 1999b; Lawson & Mace, 2009a; Lancaster & Kaplan, 2000; Hofferth & Anderson, 2004). Furthermore, while it is common for biological fathers to keep providing paternal investment even after the relationship with the mother is terminated, almost all stepfathers stop any investment into their stepchildren if they leave the household (Anderson, Kaplan & Lancaster, 1999a, 1999b; Lancaster & Kaplan, 2000). These investment patterns follow the expectations where stepfathers invest as mating effort, where they may have less of a motivation to invest compared to fathers who have the additional incentive to increase their inclusive fitness.

The Importance of Context regarding Trade-Offs

From an evolutionary perspective, allomaternal investments may be influenced by the costs and benefits to inclusive fitness following kin selection, paternity certainty and mating effort. In the preceding pages, I have presented the theoretical backbone regarding these three concepts, as well as highlighting that a combination of these factors may influence investments into children. From an HBE perspective, however, it is too simplistic to explore allomaternal behaviour without considering the local context. The social and ecological environment is should influence the trade-offs surrounding kin selection, paternity certainty and mating effort, feeding into the optimal levels of allomaternal investment.

Using one case as an example, the Mosu farmers of southwest China are traditionally a matrilineal population with duolocal residence, where husbands and wives live separately at their natal household (Wu et al., 2013). A typical traditional household is three generational, headed by the grandmother. The house is shared by the grandmother, her sisters and all their children. However, only the grandchildren from the female line reside in the household (i.e., only her daughter's children). Her son's children live with their mothers, as men visit their wives at night (Wu et al., 2013). While males generally contribute little in terms of household production, when they do, they tend to contribute to their natal household. In evolutionary terms, the Mosu system is a puzzle. Why would males contribute to their natal households, investing into their sisters' children instead of their own?

Models by Wu et al. (2013) predict that Mosu men are likely to gain greater inclusive fitness benefits by investing into their natal households rather than investing into their children. This is predicted when there are several closely related female kin (such as

sisters) breeding in one household. Under this system, men have higher relatedness with their natal households rather than to their wives' households where their offspring reside (Wu et al., 2013). Indeed, this shows how the local context influences the trade-offs surrounding kin selection which feed into the optimal levels of paternal investment.

In summary, HBE views any behaviour to have costs and benefits to inclusive fitness, and that individuals generally behave optimally to maximise their inclusive fitness. HBE and the related evolutionary theories provide a useful framework to predict and explain the patterns of allomaternal investments, such as the differences of investments between grandparents, fathers and stepfathers. The theoretical approach of the current thesis relies predominantly on HBE, where the causes and consequences of allomaternal investment are explored in the context of maximising inclusive fitness. These allomaternal investments are categorised into direct and indirect investments.

1.4 Allomothers and their Effects on Children within Subsistence and Developing Populations

1.4.1 Allomaternal Effects on Child Fitness

So far, I have presented the reasons on why allomothers may invest in children from an HBE perspective. In this section, I review the effects of these investments on children in subsistence, developing and historical populations. Traditionally, most HBE research has concentrated on such populations due to their higher fertility and mortality rates, where measuring fitness relatively straight forward. Studies within HBE have explored allomaternal effects on children by looking at proxies of offspring fitness, measured through offspring survival and reproduction. Furthermore, they have mainly concentrated on within-family allomothers due to the theoretical interest in kin selection along with the ease of comparability across cultures. Note that the presence of an allomother is often taken as a proxy of investment, though it is not always explored whether it stands for direct investment, indirect investment or both. Nevertheless, as the absence of an allomother equates to a definite absence of investment, it is arguably a useful proxy in exploring the effects of allomaternal investment on aspects of fitness.

Sear & Coall (2011) reviewed studies investigating the effects of allomothers (fathers, older siblings and grandparents) on child survival, covering 37 high fertility/mortality societies. In all studies, the presence of at least one relative increased child survival,

suggesting that allomaternal investments are important for successful childrearing across cultures. However, the importance of each allomother varied. Of the 26 studies investigating the effect of father presence on child survival, 38% found positive effects. Of the 6 studies investigating older siblings, 83% found positive effects. There were 13 studies on maternal grandmothers, 69% finding positive effects, 12 on maternal grandfathers, 17% finding positive effects, 18 on paternal grandmothers, 55% finding positive effects, and 13 on paternal grandfathers, 23% finding positive effects. Interestingly, 36% of studies looking at paternal grandfathers found that their presence had negative effects on child survival. This may be driven by the fact that paternal grandfathers typically have the least inclusive fitness incentives to invest in children.

Overall, older siblings and grandmothers frequently emerge as allomothers who have positive impacts on child fitness in subsistence and developing populations. For example, in the !Kung and the Ache hunter-gatherers, the number of older siblings positively predicted adult fertility of the focal child, especially for males (!Kung: Draper & Hames, 2000; Ache: Hill & Hurtado, 1996). Similarly, in a rural Moroccan population whose birth histories spanned the 1930s to 1980s, having an older sibling who was in a position to provide allomaternal investments increased child survival (Crogner, Baali & Hilali, 2001). In 18th and 19th century Cambridgeshire, the presence of maternal grandmothers directly reduced the risk of child mortality, as well as indirectly through reducing the risk of maternal mortality (Ragsdale, 2004), while in the Oromo agropastoralists of Ethiopia, grandmother presence was associated with better child survival (Gibson & Mace, 2005). These effects were not found for maternal and paternal grandfathers. Taken together, these results can be explained from an inclusive fitness perspective. Older siblings with high relatedness have one of the biggest incentives to maximise their inclusive fitness by investing in younger siblings. Furthermore, grandmothers who can no longer reproduce can maximise their inclusive fitness by investing in grandchildren.

Father presence did not increase child survival for the majority of cases. Why would this be the case? Firstly, one possibility is that fathers only influence child quality in certain times in the offspring's life, creating an analytical challenge in terms of capturing father effects on child survival. For instance, some researchers have argued that fathers are especially important in hunter-gatherer populations when mothers are breastfeeding (Marlowe, 2003; Quinlan & Quinlan, 2008), after which they may have minimal influence on child survival. Secondly, fathers may be important in transferring skills and resources to their children (Hewlett et al., 2011), which increases offspring quality but its effects may not manifest itself in terms of child mortality. Shenk & Scelza (2012) suggest that paternal

investments may be principally important for child quality in later life, and they find that adults whose fathers were alive between their birth and age 25 had higher levels of educational achievement and income in Bangalore, India. Similarly, amongst the Martu Aborigines of Australia, father presence was associated with greater reproductive success for adult male offspring (Scelza, 2010).

Finally, father effects may only appear if mothers and children are especially dependent on paternal investments. If other allomothers are available, the absence of fathers may be compensated by increased investments from these allomothers, masking the positive effects fathers may have on child survival. In fact, analysis on the Standard Cross Cultural Sample shows that prevalence of alloparental care in a population positively correlates with divorce prevalence (Quinlan & Quinlan, 2007). This suggests that fathers may have a greater incentive to stay and provide paternal investments when other allomothers are not available to compensate for their absence. Furthermore, there is evidence of other allomothers increasing investment when fathers are absent (van Poppel, 2000; Marlow, 2005; Winking, 2006), potentially masking any positive effects of fathers on child survival. Taken together, positive effects of father presence on children may appear if the focus is on a fine detailed measure of child quality rather than child survival, and in populations where other allomothers are not available to compensate for absent fathers.

Nevertheless, some researchers argue that fathers have minimal effects on child quality in high mortality, high fertility populations as fathers tend to optimise the quantity of children rather than the quality. Supporting evidence comes from a cross-cultural analysis on multiple hunter-gatherer groups by Marlowe (2001), which shows that greater male dietary contributions correlate with increased female fertility, but has minimal effects on child survival. A more comprehensive investigation of father effects in the Tsimane of Bolivia, looking at the effects of father death on multiple measures of adult fitness, found that fathers did not have any influence apart from on the BMI of daughters (Winking, Gurven & Kaplan, 2011). This result emerged despite the fact that fathers in this population provide relatively high levels of paternal investment, leading the authors to suspect that fathers in this population invest in their children as mating effort. Furthermore, Winking & Gurven (2011) modelled potential inclusive fitness costs of father desertion based on offspring mortality in 5 hunter-gatherer or horticulturalist populations. They found that the inclusive fitness benefit of father presence through offspring survival was minimal, and it was outweighed by the inclusive fitness benefit of father desertion accompanied by reproduction with a younger, more fertile female. In effect, in these populations, the

model suggested that fathers gain greater inclusive fitness payoffs by directing their energy into mating effort rather than parenting effort.

In terms of stepfathers, there is minimal literature on how they affect child survival in subsistence and developing populations. A few researchers have looked at the effect of remarriage in historical European populations, where they found that stepfather presence reduced child mortality compared to those in single-mother household in 19th century Sweden (Andersson, Högberg & *Åkerman, 1996) and 17th/18th century* Quebec (Willfür & Gagnon, 2013). However, no such positive effects of stepfathers were found in 18th/19th century Germany (Willfür & Gagnon, 2013). While these studies provide us with some evidence that stepfather presence is beneficial for child survival compared to single-mother households, stepfather presence may be less desirable than father presence. In a rural Gambian population, children whose younger siblings had a different father, most likely due to stepfather presence, had increased child mortality risks compared to those with the same fathers (Sear et al., 2002). Similarly, in rural Trinidad, children who grew up with stepfathers went on, as adults, to have lower numbers of children surviving infancy compared to those who grew up with fathers (Flinn, 1988). The causes of these "negative" stepfather effects are hard to determine. It may be that stepfathers are ineffective or lower investors compared to fathers, or there may be other detrimental factors linked to stepfather presence. Specifically in The Gambia, father absence was not associated with increased child mortality. Therefore, we could extrapolate that stepfather presence, or something inherently linked to stepfather presence, was having a detrimental effect on child survival.

1.4.2 Variations in Who Matters for Children

From the review of the effects of allomothers on child fitness, we see that various allomothers have positive effects on children across cultures. However, as with the patterns of allomothering, who affects child quality varies greatly across populations. This may be because the differences in the local ecology and context between populations lead to different costs and benefits surrounding allomaternal investments.

For instance, the presence of a maternal grandmother in a rural Malawian population was found to increase the risk of child mortality, though only for girls (Sear, 2008). This may come as a surprise, as maternal grandmothers are usually found to have positive effects on child survival in subsistence and developing populations. With the relatedness to their grandchildren certain, maternal grandmothers should gain inclusive fitness

benefits through increasing the fitness of their grandchildren. However, in this particular Malawian population, there may be a conflict of interest between maternal grandmothers and granddaughters due to matrilineal wealth inheritance and the scarcity of resources. Sear (2008) suggests that limited availability of land which needs to be distributed between female matrilineal kin creates competition between grandmothers and granddaughters. The consequence of this competition is the detrimental effect of maternal grandmothers on granddaughter survival.

Similarly, if and how siblings affect child quality may be depend on the context of the population. While sibling presence in some hunter-gatherer populations is associated with positive effects on children, introducing heritable wealth to the equation can increase the costs of sibling investment. In both the Gabbra of Ethiopia and the Kipsigis of Kenya, having older brothers were detrimental to the reproductive success of males (Gabbra: Mace, 1996; Kipsigis: Borgerhoff Mulder, 1998). This can be explained through the competition between brothers for resources due to the need for males to make brideprice payments in acquiring wives. Younger brothers are likely to be out-competed as older brothers use the family wealth to acquire wives. On the other hand, older sisters were found to have some positive effects on male fertility (Mace 1996; Borgerhoff Mulder, 1998), possibly as they bring in wealth to the family through brideprice payments.

Regarding fathers, their presence in the majority of subsistence and developing populations did not have positive effects on child fitness. Studies on hunter-gatherer populations suggest that paternal effects on children are determined by ecological and cultural factors: In the Hiwi of Venezuela, fathers invest relatively heavily in children through provisioning and direct caregiving. However, father absence did not have a significant effect on child mortality (Hurtado & Hill, 1992). In contrast, in the Ache of Paraguay where fathers were rarely seen to care for their children, father absence had a detrimental effect on child survival (Hurtado & Hill, 1992). While this seems rather counterintuitive, in hunter-gatherer contexts where childcare is shared and food resources frequently pooled, the lack of paternal direct investments is perhaps unlikely to have negative impacts on children. The finding that Ache fathers matter despite their lack of involvement in childcare may be driven by fathers serving as protectors, since infanticide of orphans is reported to be relatively common in this population. These examples show that the pathways in how fathers affect children may not be straightforward, and that paternal investments are not necessarily a requirement to optimise child fitness. In fact, the studies identified in Sear & Coall (2011) which found positive effects of fathers on child survival were predominantly in historical populations

which were agricultural and patrilineal. In these contexts, wealth is inherited through males and labour is relatively more intensive, which may lead to heavier reliance on men within households. Furthermore, unlike in hunter-gatherers, resources are rarely pooled within the community. Because of this, fathers may have been an important source of investments for women and their children.

Studies investigating stepfather effects in historical populations also hint at the possibility that the importance of stepfathers on children is mediated by the dependence of families on male household heads. Willfür & Gagnon (2013) suggests that the non-significant effect of stepfather presence on child survival in 18th/19th century Germany, unlike in *17th/18th century* Quebec, can be explained through mothers' dependence on their partners for resources. The authors suggest that the relatively greater prosperity of the German region meant that widowed mothers could rely on their kin for supplementation of resources, thus the benefit of remarriage was negligible. Stepfather presence may be beneficial for child quality when they serve as an important source of resources, but when males are not especially important investors who are essentially substitutable, stepfather presence may even have negative effects as found in rural Gambia (Sear et al., 2002).

Overall, allomothers are clearly important for child quality in subsistence and developing populations, as some kind of allomother is always found to have positive effects on child survival (Sear & Coall, 2011). However, who matters is dependent on the local ecology and societal context. The environment in which individuals find themselves in affects the costs and benefits of allomaternal help, influencing the levels of cooperation and competition between mothers, allomothers and the focal child. Furthermore, the lack of investment from specific allomothers may be substituted by others, buffering the potential negative impacts. These findings imply that the cooperative breeding system in humans cannot be generalised across cultures. Who helps in raising children varies between populations, and helping allomothers are not always found to be important if they are substitutable. To know if and why allomothers invest in children, a population specific approach may be more appropriate where allomaternal behaviours and its consequences on child quality can be studied within the local context.

1.5 Investigating Allomaternal Effects in Contemporary Developed Populations

1.5.1 Overview: Investigating Allomaternal Effects from an HBE Perspective

Traditionally, researchers working within HBE have focused on high fertility, high mortality populations. The overall aim of this thesis is to build on this foundation, extending the application of HBE into a contemporary developed population. On the premise that humans evolved as cooperative breeders, how do allomothers affect child development in contexts where kin networks are smaller, mortality is low, and institutional allomothering is available? As discussed, investments from mothers and allomothers can affect children directly and indirectly. With this in mind, how does allomaternal behaviour affect children, and how does allomaternal behaviour affect the investment behaviour of others? In this section, I discuss the theoretical and methodological issues faced when investigating allomaternal effects within an HBE framework in contemporary developed populations.

1.5.2 Application of HBE in Contemporary Developed Populations

In investigating allomaternal effects on children from an HBE perspective, research on subsistence and developing populations have measured child survival and fertility as a proxy to child fitness. In contemporary developed populations, using these measures may be problematic due to the low levels of mortality and fertility, where the lack of variation makes it difficult to investigate behavioural effects on such outcomes. Furthermore, considering the low fertility levels, we must question whether humans behave in ways to maximise fitness in contemporary developed contexts: The demographic transition, referring to a pattern of reduction in mortality and fertility rates, was first observed in Western Europe during the late 18th century and has spread across the globe. The second phase of the demographic transition, also called the fertility transition, resulted in a breakdown of the positive correlation between fertility and resource availability seen in pre-transition populations. In fact, the demographic transition resulted in the decline of fertility rates despite the increased availability of resources (Ostergren & Rice, 2004). From an evolutionary perspective, this is very puzzling. Why would people have fewer children than they could, when natural selection should have favoured behaviours which increase reproductive success? As HBE assumes that the motivation behind human behaviour is to maximise inclusive fitness, the low fertility levels despite high resource availability raises

an issue on whether such theoretical assumptions are appropriate in contemporary developed contexts.

Several ideas have been proposed to explain the low fertility levels seen in post-transition populations from an evolutionary perspective. For example, some have argued that the puzzling contemporary shift to lower fertility is an adaptive response to the increasing costs of parental investment: If parental investment is finite, and parents need to invest more to achieve adequate offspring fitness, parents should have fewer children to enable larger investments per child. Mace (2000) finds support for this idea in the Gabbra pastoralists of Northern Kenya, where she found that the best predictor of reduced fertility was the increased costs of parental investment. When children became more expensive, the optimal level of household wealth needed before having a child rose, and the optimal allocation of wealth to each offspring also increased. These effects were associated with reduced fertility, and interestingly, led to an increase in the average wealth of the population.

This idea that lower total fertility rates may be adaptive has been criticised on the account that we should still observe a positive association between resources and fertility within populations, as those with more resources should be able to afford more children (e.g. Borgerhoff Mulder, 1998; Kaplan et al., 1995). However, this is not the case in most post-transition populations where total fertility rates are similar across wealth groups (Borgerhoff Mulder, 1998; Kaplan & Lancaster, 2000). Still, the positive correlation between resources and fertility is only likely to exist within a homogeneous group (Mace, 2000; Low, 2000). If the population under question is comprised of several groups, where the costs of parental investment vary between groups, the correlation between resources and fertility could break down in the aggregate demographic data. In fact, a closer inspection shows that the wealthiest of specific groups within populations tend to have higher fertility: A study on Harvard graduates found that those earning in excess of $25 million a year had higher fertility than those earning $1 million (Weeden et al., 2006), and an analysis on the 400 wealthiest men in the U.S. born between 1901 and just after 1940 found their average number of children to be slightly higher than the population average (Vining, 1986).

Nevertheless, some researchers doubt that the observed low fertility levels are adaptive, as those who have the most children simply tend to have the most grandchildren irrespective of wealth (Kaplan et al., 1995; Goodman, Koupil & Lawson, 2012). It simply does not seem that people are maximising their inclusive fitness in contemporary developed populations. Low fertility has therefore been argued to be a maladaptive by-

product of the human cognitive biases to optimise the quality of offspring over the quantity (Kaplan et al., 1995; Kaplan & Lancaster, 2000). Specifically, Kaplan et al. (1995) proposes that humans are biased towards investing in children until investments make little difference to offspring quality. In subsistence and land-production economies, the limits to production means that, once a child reaches a certain quality, investments make minimal difference to their fitness in terms of acquiring resources and mates (Kaplan et al., 1995; Kaplan & Lancaster, 2000). In contrast, in contemporary developed populations, the market economy creates an increasing competitive system based on supply and demand where the quality of the offspring is dependent on the quality of others. As a simplified example, say the market demands those who have completed high school but those with such education levels are scarce. In this context, those who are educated to high school level are valued and deemed to be of high quality. However, to optimise the quality of children, mothers and allomothers increase their investments so more children finish high school. Ironically, with the increased supply, the relative value of high schooled children diminishes, and university education becomes necessary for children to be high quality. In essence, the market economy creates a shift in the important measure of child quality from absolute terms to relative terms, where competition between individuals means investments keep increasing child quality. Such environments could lead to 'runaway parental investment' (Mace, 2007) where parents increasingly invest in the quality of offspring to compete with others, consequently resulting in very low fertility levels. In fact, an analysis on fertility and wealth allocation suggests that Kipsigi men of Kenya tended to optimise allocation of resources per child rather than the quantity of children (Luttbeg et al., 2000). Furthermore, analyses using multigenerational Swedish data have shown that lower fertility increased the socioeconomic positions of descendants, especially for wealthier groups, suggesting that individuals in contemporary developed populations are behaving in a way to optimise their socioeconomic success rather than inclusive fitness (Goodman, Koupil & Lawson, 2012).

If humans are not optimising their reproductive success in contemporary developed populations, thus not maximising their inclusive fitness, can HBE be a valid framework to investigate allomaternal effects on children? As HBE generally focuses on evaluations of behaviours based on whether they are adaptive, it could be viewed as an inadequate theoretical tool in the contemporary developed context. However, even if the current fertility behaviours are maladaptive, human fertility is still theorised to be fundamentally driven by trade-offs in conjunction with the evolved bias to optimise child quality. HBE is not mutually exclusive from other schools of thought, and is a complimentary framework in investigating multidimensional motivations behind human behaviour (Medicus, 2005).

Working from an HBE perspective, utilising evolutionary principles such as kin selection, paternity certainty and mating effort, we are able to uncover the ultimate causes behind human behaviours (Medicus, 2005). On an analytical level, HBE assumes that there are differences in the costs of behaviours dependent on relatedness, and it is standard practice to separate fathers and stepfathers, and the four types of grandparents. This practice is not especially common in the other social sciences, where fathers and stepfathers can be categorised into one as "male role model" or "father figure," and grandparents as "grandparent" or "grandmother/grandfather." While the social role between fathers/stepfathers, grandmothers and grandfathers may be similar, the fact that their relatedness to the focal child differs, means we expect differences in their allomaternal behaviours and their effects.

Nevertheless, some adjustments in the HBE approach must be made in addressing contemporary developed populations. HBE has traditionally focused on subsistence and developing populations where the effects of behaviours on fertility and mortality have been the primary interest. In contemporary developed populations, focusing on fertility and mortality is not appropriate due to the lack of variation in these outcomes and the proposition that people are no longer behaving in a way to optimise fertility. Instead, it may be more suitable to concentrate on how behaviours influence aspects of individual quality.

1.5.3 The Measures of Interest in the Current Thesis

In investigating the effects of allomothers on child quality in contemporary developed populations, how should we measure quality? Given that child mortality rates are low in contemporary developed populations, measuring aspects of child development may be a better proxy. Child development is frequently conceptualised as being multidimensional, with the simplest categorisation of the dimensions involving physical development, cognitive development and socio-emotional development (Bredekamp & Copple, 1997; McDevitt & Ormrod, 2004). Physical development captures physical growth and maturation, including motor skill development and onset of puberty. Cognitive development captures the development of traits such as logic, reasoning skills, creativity and language. Socio-emotional development captures the development of traits relating to emotions and morals, as well as dealing with emotions and stress (Bredekamp & Copple, 1997; McDevitt & Ormrod, 2004).

Within this thesis, I conceptualise child development as a process relating to attaining greater individual quality/embodied capital. Ultimately, child development is an additive process whereby greater development is analogous to greater quality. However, we must also consider the *development trajectory* in relation to life history theory. Greater or faster development in the early years of childhood may reflect a faster life-history strategy, meaning comparatively greater development in childhood may not necessarily translate to greater quality in adulthood. This point, in relation to individual development outcomes, will be discuss in more detail under 2.3.2 ALSPAC Child Outcomes.

HBE has traditionally used allomother presence as a proxy of investment. However, this measure is not ideal as presence does not necessarily equate to investment, it is impossible to separate any effects between direct and indirect investments, and it is impossible to investigate the effects of allomothers on the investments if others. One possibility is to measure contact frequency which is likely to be a slightly more accurate measure of investments, especially with direct investments which require direct contact. Using contact frequency, we may also speculate on the effects of allomothers on the investment behaviour of others. However, like allomaternal presence, contact does not necessarily mean allomothers are providing investment. If possible, the best method of capturing allomaternal investments would be to measure actual behaviour. For direct investments, behaviours associated with direct caregiving should be measured such as holding, playing, feeding and teaching. For indirect investments, resource transfers or assistance to direct caregivers should be measured such as financial help and labour substitution.

Overall, in investigating the effects of allomothers on child quality in contemporary developed populations, the ideal measures would be multiple child development outcomes capturing its multidimensionality, and actual investment behaviours by allomothers. Given the different pathways in how allomothers affect child quality, it would be interesting to investigate how allomaternal direct and indirect investments affect different dimensions of child development, with attention on how allomaternal investments affect the investment behaviour of others.

1.6 Aims of the Thesis: Investigating Allomaternal Effects in the UK

1.6.1 Why Study Allomothering in the UK?

This thesis considers the effects of allomothers in a contemporary developed context, specifically in the UK. Due to the variation in the behaviours and the effects of allomothers across cultures, a population specific approach is preferable. I chose the UK due to my familiarity with the social context, as well as the availability of suitable datasets with information on maternal and allomaternal behaviour as well as multiple child outcomes.

In addition, there is scope for the current thesis to inform UK social policy. Some politicians and lobbyists have argued that nuclear, two-parent family structures create the most beneficial environments for children. See, for example, an article in The Telegraph insisting 'traditional nuclear family' has been proven to be best for children, calling for government policy to encourage two-parent family structures (Kirby, The Telegraph, 2009). Such opinions are partially reflected in the introduction of the married couple's allowance in 2000 where married couples in the UK get extra income tax allowances (Directgov, 2011), or the UK Conservative party's now-abandoned proposal of a tax break for married couples to discourage divorce in 2010 (Watt, The Guardian, 2010). At the same time, there has been a diversification of family structures in the UK over the last 50 years with greater levels of cohabitation, divorces and remarriages (Hunt, 2009). This thesis investigates the influence of allomothers on child development, in both the nuclear and extended family. In doing so, I hope to contribute to the discussion on whether two-parent nuclear family structures are indeed "the best" for children in the UK.

In the sections below, I elaborate on the allomaternal context in the UK today, followed by the approach I take in my research throughout this thesis.

1.6.2 The Allomaternal Context in the UK

To expand on the current societal context of the UK, first-time mothers and all low-income mothers are entitled to a £500 lump-sum maternity grant payment. Mothers are entitled to 52 weeks of statutory maternity leave, of which the first 39 weeks are paid (GOV.UK, 2014a). Fathers are entitled to 2 weeks of paid paternity leave, and can claim an additional 26 weeks provided that the mother returns to work and fathers are in a job where they earn at least £111 a week (GOV.UK, 2014b). Furthermore, child benefits are available for individuals with children up to the age of 16, or 20 if they are in education/training, which is £20.30 a week for the first child and £13.40 for each additional

child (GOV.UK, 2013a). If the parents are employed, tax credits are available at £122.50 a week for one child, and £250 a week if there are two children or more (HMRC, 2013). These benefits are aimed to assist parents with the costs of childcare. In addition to these payments, institutionalised childcare is available through free early education schemes, where all 3 and 4 year olds, and some 2 year olds, are entitled to 15 hours of childcare per week centred on play based learning for 38 weeks of the year (GOV.UK, 2013b). This is accompanied by state provisioning of compulsory schooling for 5 to 16 year olds, to be raised to 18 years in 2015 (Sullivan & Unwin, 2011).

In terms of demographics, the average UK life expectancy was 81 years in 2011, which has been steadily growing over several decades (World Bank, 2013). Infant mortality rates in 2011 were at 4.2 deaths per 100 live births, compared to 11.1 deaths per 100 live births in 1981, amounting to a 62% reduction in 30 years (ONS, 2013a). The UK seems to follow a nuclear family norm, where the majority of household units consist of married couples with or without children, with 12.3 million households out of the 18.2 households fitting into this category (ONS, 2013b). In 2012, the average household with dependent children had 1.7 children (ONS, 2013c). At the same time, lone parent households with dependent children have been steadily increasing over the last few decades. In 2011, there were 1.7 million lone-parent households, which has slowly risen to 2 million in 2011 (and increase of 2%) (ONS, 2012).

Compared to subsistence and developing populations, the societal context of the UK differs with its "institutionalised allomothering" through state provisioning of benefits and childcare, smaller kin networks, neolocal residence, longer lifespans, lower mortality and lower fertility. How do such contexts affect the impact of allomothers within the family? Are family members still important for children, and if so, who is important and how?

In general, the lower fertility and the consequent smaller family sizes should mean that children have smaller kin networks (Eberstadt, 1997). This could mean that kin support is less readily available and less replaceable, so that the few allomaternal kin who provide investments for children become increasingly important. On the other hand, the availability of institutionalised allomothering through childcare provisioning and financial assistance could mean allomothers are no longer essential in the UK, reducing their importance.

Specifically regarding fathers and stepfathers, the financial dependence of mothers on male partners is unlikely to be obligatory due to increased female labour participation and the availability of welfare. There has been an increase in rates of divorce/single

parenthood in the UK (ONS, 2011a; ONS, 2013b): 22% of marriages in 1970 ended in divorce by the 15th wedding anniversary, and this had increased to 33% for marriages in 1995 (ONS, 2011a). The increasing trends of unstable partnership may suggest that investments from male partners are not a necessity when it comes to childrearing. At the same time, the smaller kin networks may mean that partner assistance is less substitutable. While financially independent mothers may not be reliant on their partners for resources, they may be dependent on them for direct investments due to the incompatibility between labour force participation and childcare.

Regarding grandparents, the relatively longer life expectancies in the UK mean that many children are likely to have both paternal and maternal grandparents. Traditionally, the focus on nuclear families led to a common assumption that grandparents had minimal involvement in childrearing (McKenry & Price, 1984). Though studies on grandparental involvement in the family context have increased, research on this topic is sparse (Aldous, 1995; Arr*ánz Becker & Steinbach, 2012*). With neolocal residence of nuclear families being the norm, grandparental allomothering may not be readily available. Furthermore, grandparental investments may be substitutable with institutional allomothering. These factors could mean that grandparents have little importance on childrearing in the UK context. At the same time, the high costs associated with raising children (Viitanen, 2005; Hirsch, 2013) may mean that families rely on grandparental provisioning and care for childrearing support.

There are different possibilities on how important allomothers may be for children in the UK today. Evidence from subsistence and developing contexts suggest that humans are cooperative breeders where children receive investments from mothers and allomothers. The emerging question is whether this is still the case in a nuclear household culture where institutional allomothering is available for support.

1.6.3 The Research Approach of the Current Project

To answer questions surrounding allomothering in the UK, I use large, longitudinal cohort datasets. Specifically, I use the Avon Longitudinal Study of Parents and Children (ALSPAC) and the Millennium Cohort Study (MCS). These two datasets are particularly suited for this project, as they have information on maternal and allomaternal behaviour, as well as frequent and detailed measures on various child development outcomes. While several large cohort datasets are available with information on child development outcomes, ALSPAC and MCS are unique in that they have detailed information on

maternal and allomaternal investments. These datasets will be fully introduced in the coming chapters. Using large, cohort datasets mean that the research questions are partially constrained by the data they carry. However, the major benefit comes from the large sample size with its data gathered through many years, which is difficult to achieve through individual primary data collection. With these datasets, we are able to achieve greater statistical power (Yee & Niemeier, 1996; Singer & Willett, 2003) as well as take advantage of repeated measures. For instance, we can minimise reverse-causality issues by lagging the predictors of interest, so that a measurement or a predictor taken in the first sweep is used to predict the outcome in the second sweep (Singer & Willett, 2003). The specific methods and its advantages will be elaborated on in the following chapters. Overall, the benefits gained from using large, longitudinal datasets outweigh the costs from the restrictions it poses on the current thesis.

In terms of allomothers, I concentrate on fathers, stepfathers and grandparents. I concentrate on these particular allomothers, firstly, as HBE has traditionally focused on allomothers within the family. By investigating similar allomothers to previous HBE research, comparisons can be made on allomothering and its effects between subsistence/developing contexts and that of the UK. Secondly, these familial allomothers are likely to be the most common types of allomothers in contemporary developed populations. The prevalence of fathers, stepfathers and grandparents as allomothers not only makes it ideal in terms of empirical testing, but the findings from this thesis is likely to be applicable and of interest to a large audience.

Firstly, this thesis investigates the effects of allomaternal investments on child quality. I attempt to capture multiple dimensions of child quality by exploring the effects of allomaternal behaviour on height, educational achievement, and behavioural difficulties before age 10. Height as an outcome serves as a proxy of physical development, while educational achievement captures cognitive development, and behavioural difficulties capture socio-emotional development. I focus on these outcomes before age 10 to concentrate on development during childhood when children are most dependent on the care of others. The reasons behind focusing on these three outcomes, as well as what these outcomes represent, will be discussed in the next chapter.

Secondly, this thesis investigates the associations between grandparental investments and maternal and paternal investment behaviours. Previous research using data from the UK have focused on associations between maternal, paternal and stepfather investments (Lawson & Mace, 2009a). A handful of studies on some subsistence populations have looked at how grandparents and fathers affect maternal investments (Meehan, 2009;

Meehan, Quinlan & Malcom, 2012; Kushnick, 2012). I aim to build on previous research by investigating the effects of grandparents on the investment behaviour of mothers and father in the UK.

In summary, this thesis explores the effects of paternal, stepfather and grandparental investment behaviours on children's height, educational achievement, and behavioural difficulties. Furthermore, this thesis explores the effects of grandparental investment behaviours on maternal and paternal investments.

1.7 Outline of the Thesis

The remainder of this thesis is presented in two parts. Part 1 uses data from ALSPAC and concentrates on fathers and stepfathers, who are common allomothers within the nuclear family. Part 2 uses data from MCS and concentrates on grandparents, who are common allomothers in the extended family. Chapter 2 introduces Part 1 and the ALSPAC dataset. Chapter 3 explores how fathers affect multiple child outcomes, focusing on paternal direct investments. Chapter 4 explores how stepfathers affect multiple child outcomes, and whether stepfather direct investments differ in its effects from paternal direct investments. Chapter 5 introduces part 2 and the MCS dataset. Chapter 6 explores how grandparental direct and indirect investments affect maternal and paternal direct investments, including breastfeeding initiation and duration. Chapter 7 explores how grandparental direct and indirect investments affect multiple child outcomes. Finally, chapter 8 presents the conclusions and discussions surrounding how allomothers affect children in the UK today.

Part 1: Fathers and Stepfathers

Chapter 2: Introducing Part 1 and the ALSPAC Dataset

2.1 Aims of Part 1

In the previous chapter, we saw that fathers tend to have minimal effects on child survival in subsistence and developing populations, while the limited available literature on stepfathers makes it difficult to draw general conclusions. Simultaneously, the reviewed literature hints that father/stepfather presence may have positive effects on child survival in environments where mothers and children are particularly dependent on paternal or stepfather investments.

In the UK, the nuclear family norms mean that fathers and stepfathers are good candidates for allomothers. The high costs of childrearing, the bias towards optimising child quality, combined with the smaller allomaternal kin networks, could mean that mothers and children in the UK are dependent on paternal and stepfather investments. If so, allomaternal investments from fathers and stepfathers may have significant influences on child development. On the other hand, the increasing levels of female economic participation and self-sufficiency, increased longevity of grandparents, as well as institutionalised childcare and subsidies, may allow mothers to rear children successfully without input from fathers or stepfathers. If so, allomaternal investments from fathers and stepfathers may have minimal influences on child development.

Overall, the aim of Part 1 is to address the question, how important are fathers and stepfathers for childrearing in the UK? More specifically, I investigate the impact of paternal and stepfather direct investments on multiple child outcomes up to age 10. I focus on direct investments rather than provisioning, as there is already extensive literature on the effects of paternal employment and income on child development outcomes with consistent findings (see chapter 3). In contrast, there is minimal literature with conflicting findings on if and how paternal/stepfather direct investments influence child development in contemporary developed populations.

To address these questions, I use data from the Avon Longitudinal Study of Parents and Children (ALSPAC). Below, I introduce ALSPAC and the variables of interest, followed by a brief outline of the research questions for chapters 3 and 4.

2.2 ALSPAC Dataset Description

I use the Avon Longitudinal Study of Parents and Children (ALSPAC). This ongoing longitudinal cohort study began with the recruitment of pregnant women residing within the old county of Avon by the south-west coast of England, whose estimated delivery date fell between 1st April 1991 and 31st of December 1992. County Avon consisted of a mix of urban and rural areas, including the city of Bristol and city of Bath, with a total population size of 903,870 in 1991. 14,541 pregnant women were initially recruited into the study, which lead to 13,988 children being retained in the sample at age 1. This was followed with occasional further recruitment of the eligible sample. As with most longitudinal studies, comparisons at age 16 have shown that ALSPAC has experienced a higher drop-out rate for male children, those with lower than average educational attainment, and those who are eligible for free-school meals (i.e., lower income households). Furthermore, due to the regional characteristics, the children of ALSPAC are more likely to be ethnically White and slightly more affluent than the national average. However, permanent attrition in ALSPAC is relatively low, with 13,972 children eligible for follow-up at age 7 (note, 456 children were recruited at age 7). The full ALSPAC cohort profiles are available in Boyd et al. (2012) and Fraser et al. (2012).

The greatest benefit of ALSPAC is the frequent and extensive data collection on parental behaviour and multiple aspects of child development. In general, ALSPAC data have been gathered through repeated questionnaires administered to the mother, her partner, the focal child and the school teacher of the focal child. In addition, children were invited to attend ALSPAC child clinics where anthropometric measures were taken by clinical staff, and further information was collected through interviews and/or anonymised electronic questionnaires. In total, there were 50 separate occasions of data collection from the birth of the focal child up to age 10. Linkage with some external data sources means that some information such as exam performance is available for the majority of ALSPAC children. The unusually detailed data collection of parenting and step-parenting behaviour is especially useful for the current investigation regarding the effects of father and stepfather direct investments on child quality.

2.3 Key Variables of ALSPAC for Part 1

I focus on the same key variables from ALSPAC throughout Part 1. First, as proxies of direct investments from mothers, fathers or stepfathers, I use their parenting scores which measure their direct parenting activities. Second, as proxies of child development I use

children's height, test scores, and behavioural difficulty scores. Fig 2.1 represents the frequency of data collection for the key variables between the cohort children's birth and age 10.

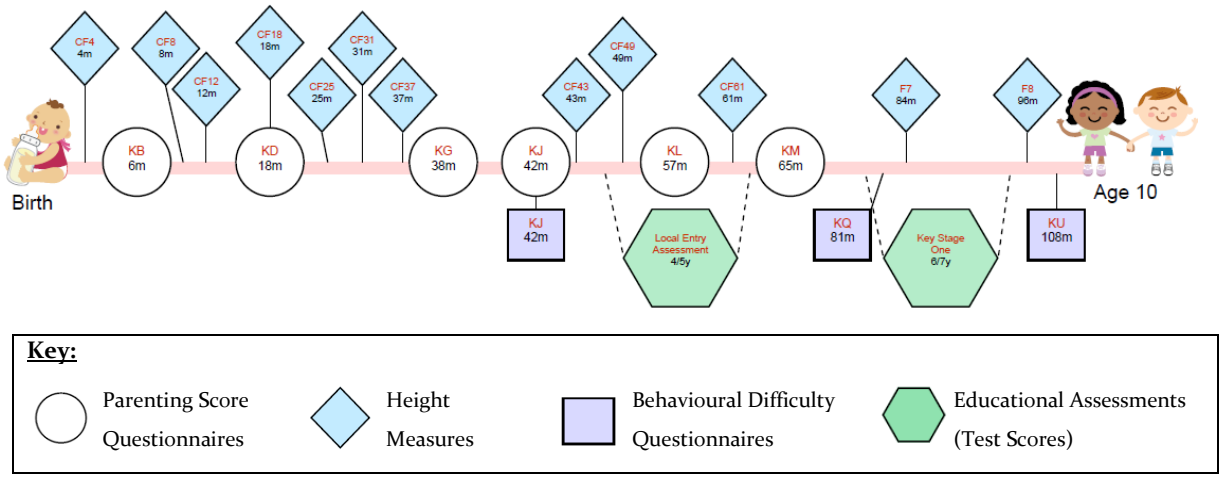

Fig. 2.1: Visual display of the frequency of data collection for key variables. The text within the shapes display the questionnaire code, followed by the measurement occasion based on the target age of the children.

2.3.1 ALSPAC Parenting Scores

ALSPAC collected information on the frequency of various parenting activities carried out by the mother and her partner at 6m, 18m, 38m, 42m, 57m and 65m (Table 2.1). At 6m, 38m, 57m and 65m, mothers were asked how often she and her partner took part in various activities with the child, based on a subjective scale of never, rarely, sometimes and often. At 18m and 42m, mothers were asked how often she and her partner took part in various activities with the child, based on an objective scale of never, <1 per week, 3-5 per week and nearly every day. Note that "partner" includes fathers and stepfathers, not necessarily married. Furthermore, the parenting activities measured by ALSPAC varied by each occasion.

From these, ALSPAC derived cumulative parenting scores for the mother and partner for each measurement occasion. As the ranges of the parenting scores varied between measurement occasions, they were standardised across sweeps to range from 0 to 10 (38m, 42m, 57m and 65m by David Lawson, 2009; 6m and 18m by myself). The descriptive statistics of the derived parenting scores are displayed in Table 2.2 (Note, due to the fact

that 5 different frequency categories available for each measured activity, I display the percentage of the most frequent category to facilitate comparison between activities).

Table 2.1: Parent-child activities measured by ALSPAC to create mother and partner parenting scores, by measurement occasion. The table displays the % of those who reported that the mother & her partner carry out these activities at the highest frequency (i.e., often or nearly every day). *At 6m, frequency of general play was measured objectively and the reported percentage represents % *nearly every day*. The other activities at 6m were measured subjectively.

Measurement Occasion (Average Age)	**6m**		**18m**		**38m**		**42m**		**57m**		**65m**	
N Survey Participation (Mothers)	11485		10750		10150		10083		9531		9013	
	Mothers	**Partners**	**Mothers**	**Partners**	**Mothers**	**Partners**	**Mothers**	**Partners**	**Mothers**	**Partners**	**Mothers**	**Partners**
Activities	% Often		% Nearly Every Day		% Often		% Nearly Every Day		% Often		% Often	
General Play	91.9*	74.7*	--	--	--	--	--	--	--	--	--	--
Play with toys	92.2	62.4	85.9	50.4	70.3	57.8	61.6	33.6	50.2	40.2	38.5	31.4
Physical play	88.0	64.1	63.7	63.5	68.5	71.3	30.7	47.0	25.7	41.9	21.1	36.2
Sing to/with child	74.3	30.0	66.8	19.3	69.5	25.5	47.6	11.7	46.6	16.2	36.1	11.9
Show/read (picture) books	40.0	17.2	70.2	32.0	84.4	56.4	63.5	28.9	80.2	49.5	78.0	45.9
Cuddle	98.7	84.9	99.2	89.1	97.7	87.6	97.6	82.5	96.3	83.5	96.1	80.5
Take for walk/to playground	78.3	22.1	66.3	9.1	71.8	38.3	50.8	8.1	32.0	23.7	26.8	19.3
Feed/Prepare food	NA	37.7	87.3	18.7	79.1	35.3	68.7	11.9	93.2	30.6	93.5	27.5
Bathe child	NA	29.0	48.9	12.9	87.3	42.0	39.3	10.2	83.4	34.6	82.2	28.3
Play imitation games	NA	NA	75.6	39.1	NA	NA	34.3	17.3	NA	NA	NA	NA
Put child to bed	NA	NA	NA	NA	84.0	53.0	NA	NA	83.5	51.3	84.0	47.0
Make things with child	NA	NA	NA	NA	NA	NA	NA	NA	41.9	22.9	34.5	16.6
Go swimming	NA	NA	NA	NA	NA	NA	NA	NA	30.5	17.5	30.1	15.0
Draw/paint	NA	NA	NA	NA	NA	NA	NA	NA	37.8	15.4	26.7	10.2

Overall, the standardised mother parenting scores (mother scores) are higher than partner parenting scores (partner scores) across all measurement occasions. Furthermore, there is slightly greater variation in partner scores than mother scores. Fig. 2.2 displays the distributions of mother scores for each measurement occasion, and fig. 2.3 displays the distributions of partner scores for each measurement occasion.

In both mother score and partner score, the mean is lower when the parenting activities were measured objectively, which is unsurprising as carrying out an activity "often" was given the same value as "nearly every day." The difference between objective and subjective scoring is especially prominent in the partner scores, which suggest that mothers reported partners to be taking part in activities "often" even when this did not occur "nearly every day." Because of the differences in the means between objective and subjective scoring, mother and partner scores are mean-centred by measurement occasion in all analyses. This turns the parenting scores into relative scores by measurement occasion, whereby a score of 1 would indicate 1 point above average, and a score of -1 would indicate 1 point below average.

Table 2.2: Descriptives of the standardised ALSPAC parenting scores for mothers and their partners.

Measurement Occasion	6m	1y6m	3y2m	3y6m	4y9m	5y5m
Questionnaire Style*	Sub	Ob	Sub	Ob	Sub	Sub
Mother Scores						
N	11318	10951	9416	9339	8759	8308
Mean	8.70	7.98	8.38	7.95	8.34	8.12
SE	1.29	0.91	1.04	1.34	1.01	1.01
Partner Scores						
N	10931	10471	8804	8723	8129	7545
Mean	7.82	5.98	7.08	5.98	6.82	6.58
SE	1.27	1.71	1.63	1.76	1.62	1.60

* Sub=Subjective Scoring, Ob=Objective Scoring

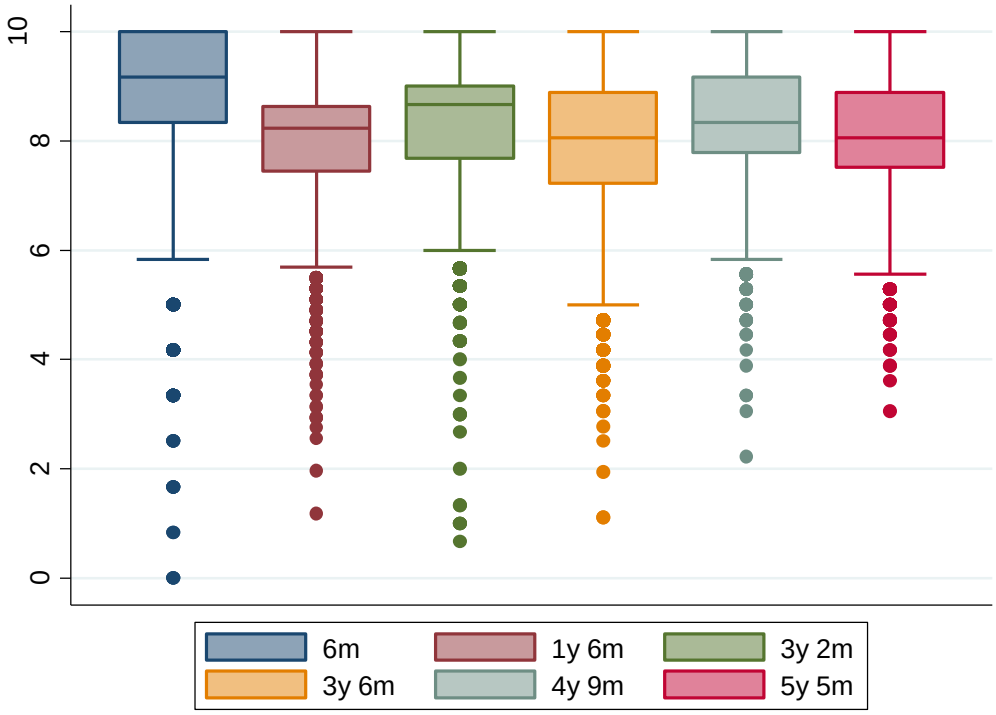

Fig 2.2: Box-plot of ALSPAC mother score by measurement occasion.

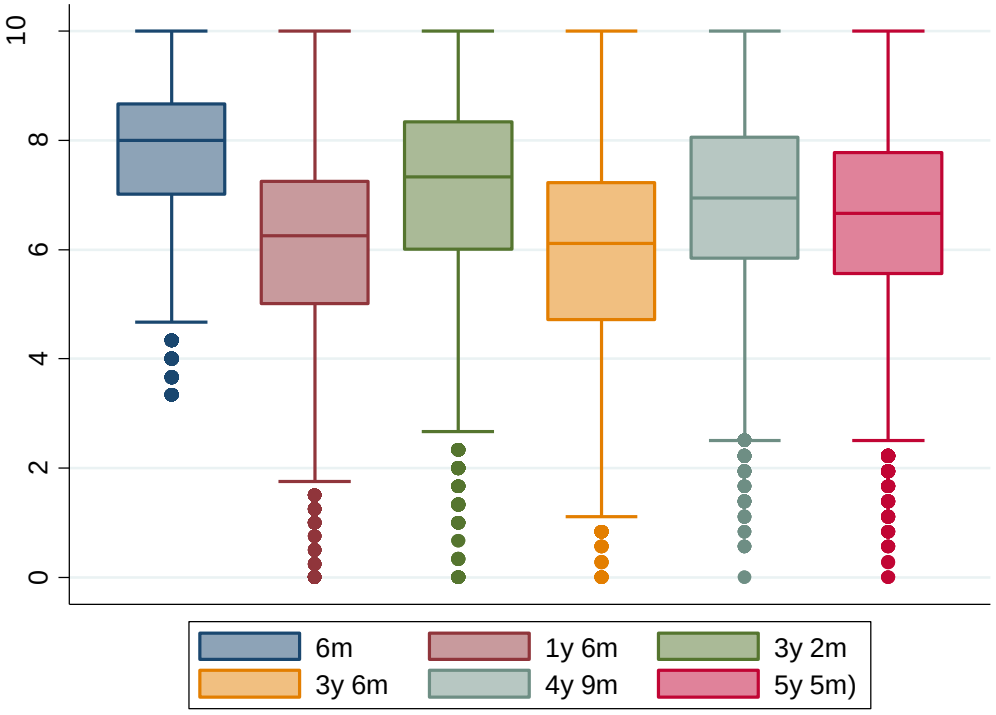

Fig 2.3: Box-plot of ALSPAC partner score by measurement occasion.

These parenting scores are comprised of various caretaking and play activities between the mother/partner and the focal child, involving direct contact. I take these scores to be a proxy of direct investments by the mother and her partner. In the previous chapter, I defined direct investments as any behaviour directed to the child with the aim of increasing the quality of a child, with opportunity costs against any other behaviour. Following this definition, the parenting scores are likely to be a good reflection of direct investments provided by mothers and her partners: Caretaking activities such as feeding and washing addresses the basic needs of young children. The absence of such caretaking is often presented as neglect which negatively affects child development (Hildyard & Wolfe, 2002). Similarly, childhood play, both supervised by and involving adults, has been argued to be a necessary component of childhood for optimal child development (Ginsburg, 2007).

Nevertheless, there are few potential issues in the scores that must be highlighted. Firstly, these composite scores are specific to ALSPAC, which may make comparisons of results difficult across different studies. Secondly, the frequency of activities may not accurately reflect quality of activities. For instance, reading a simple picture book to a child could be qualitatively different to reading a children's novel, and the "best" type of interaction may be age-dependent in that reading a picture book to a 1yr old child may be more appropriate than reading a children's novel. Similarly, there is a lack of detail regarding the types of interaction between the mother/partner and child for each activity. For instance, the activity of "reading a book to a child" could involve different types of engagement, where some adults could encourage children to comment on the story and ask questions, some may encourage children to listen quietly, some may include teaching how to read, and so on. Furthermore, it is unclear whether these parenting activities are provided exclusively to the focal child or whether these activities are shared with other children, particularly in households where there are siblings. As the specifics surrounding the activities are unknown, the quality of investment the child receives is also unknown. Thirdly, the frequency of activities does not reflect the length of activities. For instance, mothers and partners who read to their children every day for 5 mins would get the highest score, while those who read to their children for 45 mins once a week would get a low score, when in fact the total reading time is higher for the latter.

Finally, the scores are reported by the mother, thus the parenting scores may be biased by her perceptions. An element of bias is clearly evident in the differences between objective and subjective scoring, where subjective scores are higher than objective scores.

Note, the issue of bias is less problematic for objective scoring as the information is collected in frequency of activities and less dependent on mothers' perception of how much their partner contributes to parenting. Interestingly, the spread of the parenting scores are relatively similar between objective and subjective scoring, and the difference between these measurement methods are with the means (table 2.2, fig 2.2, fig 2.3). This suggests that the parenting scores are capturing something similar regardless of objective/subjective scoring, and mean-centring by measurement occasion should remove some subjective report bias. Still, we cannot discount the likelihood of a bias in the parenting activity reports given that mothers report her own activities and her partner's: Mothers could, for example, overestimate their investments and underestimate the partners' and vice versa. If such systematic biases exist, note that it is unlikely to be problematic in the current thesis. I do not compare absolute parent scores between mothers and partners, but the focus is on investigating the effects of investing more or less than other mothers and partners (i.e., if all partners are scored lower, then relative scores are unaffected). Finally, reporting biases may also exist whereby mothers' perception of parenting activities may vary by individual circumstances. I therefore control for individual and household factors such as mother and partner's education, income, employment and financial stress. Full control variables are outlined and described in the following chapters.

The current parenting scores are by no means a perfect measure of direct investment by mothers and partners into the focal child. However, there is great strength in the ALSPAC parenting scores in that they are based on a variety of direct parenting behaviours involving children. Most commonly used alternative measures of direct investments, outlined in more detail in chapter 3 and chapter 4, are proxies such as presence, proximity or emotional closeness. While these proxy measures may capture aspects of direct investment, they are indirect measures meaning there is greater uncertainty surrounding what exactly they are measuring and how accurate they may be. In fact, the current ALSPAC parenting scores are one of the most detailed repeated measures of direct parenting activities available in a cohort dataset (e.g., see chapter 10 for parenting measures in the MCS). Previous studies using similar ALSPAC parenting scores suggest that these scores do follow patterns expected with direct investments: Lawson & Mace (2011) found that ALSPAC parenting scores are lower in households with more children, which would be expected due to trade-offs in direct investments between offspring. The current parenting scores provide a finer measure of the *amount* of direct investments compared to other proxies, allowing for a more detailed and accurate investigation

surrounding the associations between direct investments and child development outcomes.

2.3.2 ALSPAC Child Outcomes

This thesis focuses on the effects of allomaternal investments on child development outcomes. In both Part 1 and Part 2, I focus on height, educational attainment and behavioural difficulties as proxies of physical development, cognitive development and socio-emotional development, respectively.

There are several reasons behind the decision to focus on these three outcomes. First, as discussed in the previous chapter, child development is often conceptualised as being multidimensional. The simplest categorisation of child development consists of three dimensions: physical, cognitive and socio-emotional (Bredekamp & Copple, 1997; McDevitt & Ormrod, 2004). The current child development outcomes reflect each of these categories. Second, these particular outcomes were chosen as these are the outcomes available as repeated measures in the ALSPAC dataset, and similar measures of height, educational attainment and behavioural difficulties are often collected in other cohort studies, including the MCS. The availability of these outcomes in both ALSPAC and the MCS mean there is some comparability in the results between Part 1 and Part 2 of this thesis. Third, these outcomes are highly studied. The availability of literature means other studies may be available for comparison, and information is generally available surrounding these measures. Finally, these three child outcomes have been found to predict adult quality, and it seems these outcome measures are good indicators of offspring quality. Below, I expand on this final point for height, educational attainment and behavioural difficulty. The descriptive statistics for each of the child outcomes are presented in each chapter.

Height Trajectory as a Proxy for Physical Growth

Physical growth in children is often tracked through weight and height (Cole, Freeman & Preece, 1995), with body-mass index (BMI) and height being the most commonly used proxy. In the current thesis, I use the available height measures to analyse children's *height trajectory*, which I treat as a proxy of children's physical growth trajectory. In ALSPAC, children's birth length was reported by hospital staff at birth, and children's height was repeatedly measured by ALSPAC clinical staff to the nearest millimetre. Originally, clinical

height measures by ALSPAC staff were only taken for a 10% subsample of ALSPAC children between the ages of 4 months and 61 months. This was expanded to include all ALSPAC children from age 7 onwards.

By controlling for variables such as birth length, gestation length and mother's height, children's height as an outcome represents whether a child is growing faster or slower than expected, reflecting their trajectory. In the following chapters, results indicating greater height are then taken to represent a faster growth trajectory, and less height is taken as a slower growth trajectory. Note, estimated coefficients indicating "smaller height" does not necessarily translate to shorter absolute height.

Fig 2.4 displays a scatter plot of height measures for 40 random ALSPAC children, giving an indication of the different growth trajectories observable in the ALSPAC data. Note, more plots are displayed in the later ages coinciding with the expansion of data collection from a 10% subsample to the full sample. Fig 2.5 displays an average growth curve of height of ALSPAC children, estimated through a random-intercept random-slope regression model (see Chapter 3). The trajectory of growth seems to vary between individuals (fig. 2.4), with the variation in absolute height increasing over time (fig. 2.4, fig. 2.5).

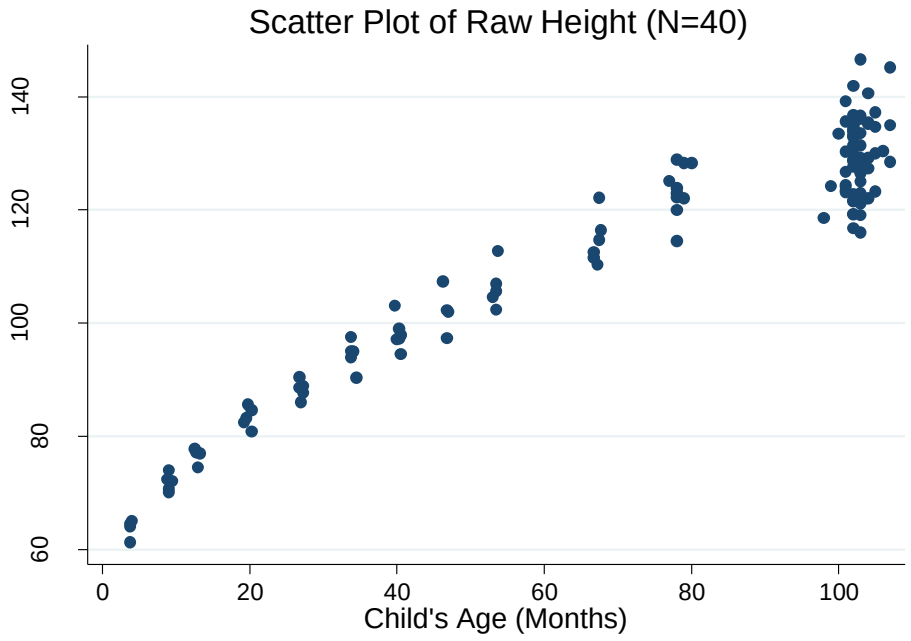

Fig. 2.4: Scatter plot of raw height in 40 random ALSPAC children from birth to 108 months.

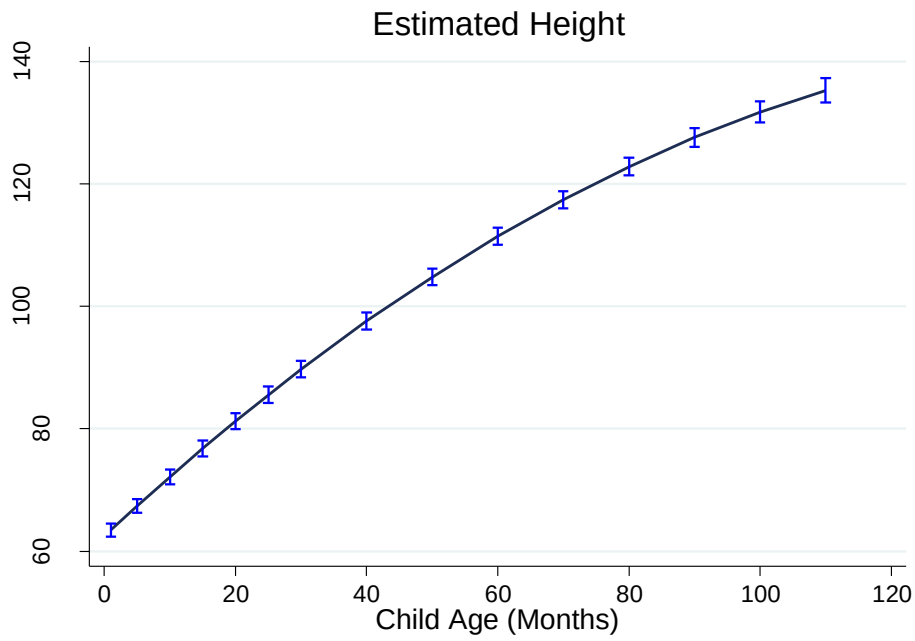

Fig. 2.5: Average growth trajectory of ALSPAC children, estimated through a random-intercept random-slope regression analysis.

There are several reasons why I focus on height rather than BMI to capture physical growth. At first, BMI may seem to be a more appropriate measure of physical growth given that it incorporates weight and height, the two components of physical development. However, the interpretation of BMI in terms of growth trajectory is very complex. BMI in infancy rises steeply, followed by a fall up to around 6 years, followed by a steady rise into adulthood (Cole, Freeman & Preece, 1995). This means that a faster *reduction* in BMI could be an indication of faster growth trajectory, though only in a specific window of time during early childhood. Furthermore, in contrast to adults, "healthy" BMI in childhood is age and sex-dependent, and the assessment of "healthy" BMI is often carried out through percentiles in relation to the BMI of other children rather than absolute BMI (Cole, Freeman & Preece, 1995). This introduces an issue in that the appropriate interpretation of BMI is dependent on percentiles, relative to others in the population. However, growth trajectory is an absolute measure relating to the individual, and it cannot be tracked through percentiles. Finally, there is a theoretical issue with BMI if we are to treat physical development as additive, due to the fact that a BMI can fall, and a typical BMI trajectory through childhood includes a reduction in BMI. When the BMI of children or adults fall, it's unreasonable to treat this as "negative development" or a regression in development. Overall, despite the fact that BMI incorporates both weight and height, it may be a more

appropriate measure for adiposity (Cole, Freeman & Preece, 1995) rather than growth trajectory.

Height, on the other hand, avoids the outlined issues with BMI. Height can be modelled through individual trajectory, where its interpretation is not dependent on the height of others. Height is an additive child development outcome, which fits with the concept of physical growth and building up one's embodied capital. A criticism of using height over BMI may be that it does not incorporate weight; an important component of growth. However, note that height trajectory as a proxy of physical growth theoretically incorporates weight. Height and weight is highly correlated (Cole, Freeman & Preece, 1995), meaning greater height also captures greater weight, reflecting greater growth overall. In other words, height itself is a product of weight. Using height trajectory as an outcome, *without controlling for weight*, should capture children's growth trajectory effectively. Nonetheless, as a point of interest, additional analyses on BMI as a child outcome have been carried out. These results are available in the appendix, highlighted in the relevant sections in the following chapters.

If height reflects the overall growth trajectory, how should height be interpreted? Note, there is some disagreement in the literature regarding the interpretation of height. Childhood height has been found to correlate strongly with adult height (Tanner & Whitehouse, 1976; Tanner et al., 1983), which in turn has been found to positively predict adult health (Davey Smith et al., 2000; Lawlor et al., 2004), economic success (Strauss & Thomas, 1998; Thomas & Frankenberg, 2002) and male reproductive success (Pawlowski, Dubar & Lipowicz, 2000). Therefore, some studies have taken greater height in childhood to be a positive developmental outcome reflecting higher child quality (e.g., Lawson & Mace, 2008), which is a common position in developing populations where resource stress can lead to stunting (Grantham-McGregor et al., 2007). However, there is clear consensus in the medical and child development literature that faster growth trajectory is a negative child outcome in resource-rich developed populations. Rapid childhood growth in Western populations has been associated with greater adult morbidity such as obesity (Wells, Chomtho & Fewtrell, 2007; Brisbois, Farmer & McCargar, 2011), type 2 diabetes (Eriksson et al., 2003) and coronary heart disease (Forsén et al., 1999).

From a life history perspective, faster growth is likely to reflect a faster life history strategy in developed population where children are generally unlikely to be nutritionally stressed. Faster growth and the consequent greater height in childhood may be indicative of poor conditions in Western populations such as the UK. In fact, faster growth is a common occurrence in low birth weight children who are usually stressed in-utero or born

prematurely, linked to greater height and obesity in childhood (Ong et al., 2000). Furthermore, various indicators of lower socioeconomic status in western populations have been associated with faster childhood growth in terms of BMI (Eriksson et al., 2003; Wijlaars et al., 2011; O'Dea, Dibley & Rankin, 2012) and height (Herngreen et al., 1994; Silva et al., 2012). Thus, if we take fast life history strategies to be linked with lower quality offspring, faster growth in childhood is likely to be an indicator of lower quality. This is how I interpret children's height in the current thesis, where greater height reflects lower quality.

Educational Attainment as a Proxy for Cognitive Development

Educational attainment is measured through school test scores. These scores are based on the Local Entry Assessments (LEA), taken by children upon entering the British school system at age 4 or 5, and Key Stage 1 Standard Assessments (KS1), taken by children between the ages of 6 and 7. Both assessments are administered by teachers at school, and test the children on their Mathematics and English skills. As the maximum total test scores (compiled by ALSPAC) differed between LEA and KS1, the school test scores were standardised to range from 0 to 15 (child's score/max score x 15).

Higher test scores are assumed to equate to higher educational achievement, which is taken as an indicator of greater cognitive development. Educational achievement in childhood, specifically relating to reading and maths abilities, has been positively associated with school completion, later educational achievement and adult economic success (Gregg & Machin, 2001; Bynner & Joshi, 2002). This supports the idea that greater cognitive development, reflected through educational achievement, feeds into greater quality/embodied capital. In terms of life history theory, one key trade-off is *somatic effort vs. reproductive effort*, where greater investment in somatic effort is expected following a slower life history strategy in stable environments. Greater educational achievement, indicating greater cognitive development, may be expected under slower life history strategies. However, life history theory concerns the timing of events, and it is difficult to ascertain trade-offs between somatic effort vs. reproductive effort in childhood given that children do not reproduce. Furthermore, we must also consider environmental constraints, whereby children may not be able to attain optimal developmental outcomes. These two processes (i.e., life-history scheduling and environmental constraints) may not be mutually exclusive, and constraints are likely to feed into life-history trajectory. With

this in mind, the interpretation of educational attainment in the current thesis is primarily on how allomother investments relate to cognitive development as an indicator of quality.

The main benefit of the ALSPAC test scores in measuring educational achievement is that the assessments are standard tests which are administered widely. Given the standard nature of the test, the interpretation of the results is facilitated with many researchers using these measures to assess educational achievement levels in the UK. The tests are carried out nationally across all schools, meaning missing scores are relatively rare for ALSPAC children. However, note that the tests were developed to assess educational achievement in the UK school system, meaning the assessments have a Western, academic focus. The assessments in the early years focus on Maths and English, which may fail at capturing non-academic aspects of cognitive development such as social intelligence or creativity. Nonetheless, studies suggest that cognitive development in the broader sense may lead to better learning and educational outcomes (Campbell et al., 2001; Shunk, 2012), as information processing improves with overall cognitive development (Shunk, 2012). While these ALSPAC test scores may not be in-depth measure of cognitive development, it is likely to reflect at least specific aspects of development linked to learning, which may be linked with cognitive development as a whole.

Behavioural Difficulty as a Proxy for Socio-Emotional Development

Behavioural difficulty is measured through behavioural difficulty scores derived from the Strength and Difficulties Questionnaire (Goodman, 1997). This questionnaire is based on the Revised Rutter Parent Scale for Preschool Children, devised specifically to measure children's socio-emotional development (Elander & Rutter, 1996). The Strength and Difficulties Questionnaire measures hyperactivity, emotional symptoms, conduct problems and peer problems. This questionnaire was completed by the focal child's mother on three occasions, at 41 months, 81 months and 108 months, where she was asked to rate "how true" various statements were relating to her child's behaviour. For instance, mothers were given statements such as "often has temper tantrums," and were asked to rate whether these statements were not true, somewhat true or certainly true. Children were scored higher on behavioural difficulties if mothers answered "true" to a problematic behaviour such as temper tantrums. Each child could score a maximum of 40 points.

Lower behavioural difficulty scores are assumed to indicate better socio-emotional development. Specifically regarding the Strength and Difficulties Questionnaire, children who scored highly in behavioural difficulties were more likely to have psychiatric

disorders such as anxiety and conduct problems (Goodman et al., 2000; Stone et al., 2010). Behavioural difficulties in childhood have been linked to psychiatric disorders as well as economic, health and social issues in later life (Champion, Goodall & Rutter, 1995; Goodman, 1997). This supports the idea that greater socio-emotional development, reflected by the behavioural difficulty scores, feeds into greater quality/embodied capital of individuals. From a life history perspective, greater socio-emotional development and lower behavioural difficulty scores could be something we expect in a stable environment following the somatic effort vs. reproductive effort trade-off. Like with educational attainment, note that it is difficult to assess the trade-off in investment in between socio-emotional development and reproductive effort, and that it is difficult to tease apart strategy from constraint. Therefore, the interpretation of behavioural difficulty score in the current thesis is primarily on how allomother investments relate to socio-emotional development as an indicator of quality.

The main benefit of this measure is the wide use to assess children's socio-emotional development in Western populations. Consequently, there have been many validation studies testing whether the behavioural difficulty scores reliably reflect children's socio-emotional development (e.g., Goodman, 1997; Goodman & Scott, 1999; Mellor, 2005; Bourdon et al., 2005). These studies suggest that the behavioural difficulty scores are consistent across developed populations, and is a robust measure of children's socio-emotional development. Nonetheless, the current behavioural difficulty scores are reported by mothers, and the perceptions of their children's behaviour may be shaped by her biases. Furthermore, children may behave differently in front of mothers compared to other individuals, meaning mothers could have an incomplete understanding of children's socio-emotional development. However, note that the Strength and Difficulty questionnaire was originally developed with mothers as the respondents in mind, and there is high correlation between mother-reported and teacher-reported behavioural difficulty scores (Goodman, 1997). This suggests that maternal reports on children's behaviour are trustworthy. Furthermore, the issue of individual biases due to household and personal differences can be addressed, at least in part, through controlling for factors such as socioeconomic status, education level, maternal age and so on. The full list of control variables used in each analysis is presented in the following chapters.

2.4 Overview of the Research Questions in Part 1

In Chapter 3 and Chapter 4, I explore the effects of the parenting scores on multiple child development outcomes. Chapter 3 focuses on the effects of paternal direct investments on child outcomes, while Chapter 4 focuses on the effects of stepfather direct investments on child outcomes.

In more detail, Chapter 3 investigates the effects of paternal direct investments on children's height, school test score and behavioural difficulties. Previous findings in the available literature have been inconsistent, and I address several methodological issues prevalent in previous studies. Furthermore, I test whether the effects of paternal direct investments differ depending on the individual context. Fathers have been found to invest more when they have higher embodied capital and when they have sons. From a behavioural ecological perspective, one potential reason behind the higher investments is that fathers with higher embodied capital and fathers with sons gain higher returns in child quality from their investments.

In Chapter 4, I investigate the effects of stepfathers on children's height, school test score and behavioural difficulties. Previous findings in the literature consistently show negative effects of stepfather presence on multiple child outcomes. However, the proximate mechanisms behind such effects are yet to be fully explored. From a behavioural ecological perspective, the negative effects associated with stepfathers may be due to the reduced quantity and quality of investments children receive within stepfather households. I investigate whether the effects of stepfather presence on child outcomes are driven by the differences in the quantity of mother and partner direct investments between father-present and stepfather-present households. I also explore whether the effects of direct investments differ between fathers and stepfathers.

Chapter 3: Father Effects on Multiple Child Outcomes

3.1 Introduction to Chapter 3

3.1.1 Fathers as Allomothers in Contemporary Developed Populations

Fathers are often identified as potential allomothers within the human cooperative breeding system (e.g., Hrdy, 2007). However, as outlined in Chapter 1, father presence is rarely associated with positive effects on child survival in high fertility/mortality populations. From an evolutionary perspective, this apparent lack of inclusive fitness benefits is puzzling given that pair-bonding is widely seen across populations (Quinlan & Quinlan, 2007). It may be that the inclusive fitness benefits of paternal investments on child outcomes only appear if the focus is on a finer measure of child quality (rather than simply child survival), mothers and children are not dependent on fathers for investments, and/or the reproductive strategy is to optimise offspring quantity rather than quality.

In contemporary developed populations such as the UK, father effects on child quality may be more apparent due to the general trend of reducing fertility and optimising child quality. Fathers may invest more in parenting effort over mating effort, whereby paternal investments lead to greater child quality. Nevertheless, there are competing predictions which can be made from an HBE perspective regarding the importance of fathers for child development. On the one hand, fathers may be especially important for children. The smaller family sizes, a shift to nuclear family structures and neolocal residence has potentially reduced the availability of alloparents. As a result, children may be especially dependent on fathers for direct and indirect investments. With this dependence, paternal investments may have greater impact on child quality compared to the general trends in traditional populations. On the other hand, paternal investment may have become nonessential. First, state welfare has arguably removed the "necessity" of fathers in terms of provisioning. Furthermore, the smaller family sizes coupled with the increased life expectancy of grandparents may have reduced the competition for, and increased the availability of, grandparental support for childrearing. Thus, children may receive greater levels of alloparental investments, diminishing the need and influence of fathers. If so, we would expect paternal investments to have minimal effects on child quality despite the lower fertility. What does the available literature suggest regarding how fathers affect child development in contemporary developed populations?

3.1.2 Father Effects on Child Development in Contemporary Developed Populations

Previous studies on the effects of paternal indirect investments on child outcomes, which can be explored through paternal socioeconomic-positions and income, have consistently found positive effects on numerous child outcomes associated with physical, cognitive and socio-emotional development (Duncan & Brooks-Gunn, 1997; Jefferis, Power & Hertzman, 2002; Bradler & Corwyn, 2002). This suggests that resource provisioning by fathers is important for successful childrearing regarding optimising child quality in contemporary developed populations. However, the effect of direct paternal investments on child outcomes is less clear. Here, I review the available literature which investigates father effects on various child or adolescent outcomes. As the focus is on paternal direct investments, I only include studies where the effects of socioeconomic status or income have been controlled for.

There are many studies across disciplines which find positive effects of fathers on child outcomes. Though it is not an explicit measure of paternal direct investments, some researchers have investigated father effects by comparing child outcomes between father present and father absent households. Using data from a US household survey, Dawson (1991) found that children in father absent households had an increased risk of asthma, were more likely to repeat a school year, and were more likely to be expelled or suspended compared to children in father present households. Similarly, in a cross-sectional survey of secondary school children in England and Wales (Attar-Schwartz et al., 2009) and in a longitudinal study of children from Bristol (Lawson & Mace, 2010), children living with both biological parents were less likely to have behavioural problems compared to those children from single mother households. Though a slightly different measure of father presence, Dobowitz et al. (2001) found that US children whose father figures were biological fathers had fewer externalising behavioural problems. A similar pattern was found in the UK, where children whose father figures were biological fathers had less emotional and behavioural problems (Flouri & Buchanan, 2003).

Other studies have explored the effects of paternal involvement on child outcomes, usually measured through father-child relationship quality, parental attitudes and/or parenting style. In the US, greater paternal involvement with young adolescents were found to have beneficial effects on educational and economic attainment (Harris, Furstenberg & Marmer, 1998; Nord & West, 2001), as well as protective effects against delinquency (Harris, Furstenberg & Marmer, 1998; Nord & West, 2001), behavioural

problems (Carlson, 2006), and smoking (Menning, 2006). A handful of studies have measured involvement through measuring paternal behaviour and contact frequency. In the US, the frequency of activities between fathers and children were found to have a positive association with children's educational attainment (Cooksey & Fondell, 1996), while paternal parenting activities were associated with positive effects on the cognitive development of 24 month old children (Cabrera et al., 2011). In an Irish sample, paternal involvement in infant caretaking at three months was associated with a positive effect on infant cognitive development at age one. Finally, in an Israeli sample of hospitalised preterm infants, children had better physical and cognitive outcomes at 18 months if their fathers visited them regularly at hospital (Levy-Shiff et al., 1990).

These positive effects of father presence/involvement on child outcomes suggest that, unlike the majority of traditional populations, fathers may be an important allomother regarding child quality within the childrearing system of contemporary developed populations. However, the positive effects of fathers on various child outcomes are not always consistent. For instance, a study by Flouri & Buchanan (2003) found that father presence during childhood had no effect on their offspring's psychological problems at age 16 in the UK. In a longitudinal study from Bristol, children's physical development was unaffected by father absence, where no significant difference in height was found between children from father present and single mother households (Lawson & Mace, 2008). In the same sample, O'Connor et al. (2000) found that, in general, there were no significant differences in children's health measured by different types of accidental injury and medical prescriptions between father present and single mother families. Although the authors did find that children from single mother households were more likely to be referred to a specialist, this could be due to how single mothers tend to perceive the health of their child to be worse (e.g., see Dawson, 1991). In a longitudinal study of children in low SES households, father presence had no effect on cognitive and socio-emotional development as measured by vocabulary and behavioural difficulties scores (Crockett, 1993). Similarly, Walker & Zhu (2011) found that father absence itself had no negative effects on children's educational outcomes in the UK. Rather, the negative effects associated with single-mother families were due to reduced household income upon divorce. A similar conclusion was reached by Blakely et al. (2003) who found that the increased risk of child mortality in father absent families in the UK disappeared once SES was controlled for.

While the outlined studies finding non-significant effects focus on father presence, a handful of studies investigating aspects of paternal involvement in the US also find non-

significant effects. Harris, Furstenberg & Marmer (1998) found that paternal involvement had no effect on psychological distress and teenage childbearing in later adolescence, while Cabrera et al. (2011) found that paternal parenting activities had no effect on children's socio-emotional development at 24 months. In a sample of 11 to 16 olds with divorced parents, neither the frequency of contact nor the reported closeness between fathers and children had any effects on behavioural or academic outcomes (Furstenberf, Morgan & Allison, 1987). Finally, in a sample of children with non-resident fathers, frequency of contact between fathers and children had no effect on children's cognitive development. In fact, what was found to be important was the payment of child support from non-resident fathers (King, 1994).

These non-significant results have led some researchers to argue that the importance of fathers are down to socioeconomic factors and paternal provisioning (Lang & Zargosky, 2001; Blakely et al., 2003; Walker & Zhu, 2011), where paternal direct investments are assumed to make little difference to children's development outcomes. From an HBE perspective, this may suggest that despite the low fertility and smaller allomothering networks, the role of fathers in contemporary developed contexts may be similar to high-fertility high-mortality populations.

Overall, there is a divide in the current literature regarding the importance of paternal direct investments on child development. Some studies suggest that paternal direct investments have positive implications for child development, while others suggest that the benefit is purely due to indirect effects, and fathers have negligible effects on children after controlling for wealth and SES. Consequently, if and how paternal direct investments affect child outcomes in contemporary developed populations such as the UK are still unclear. In order to ascertain the role of fathers within the childrearing system of contemporary developed populations, and to infer whether a shift to low fertility in associated with a shift in the importance of fathers regarding child quality, further studies are required.

Methodologically, there are several possible reasons behind the inconsistent findings in father effects. Firstly, many use household father presence as a proxy for paternal direct investment. While it is found that household-absent fathers to tend to invest less than household-present fathers (Anderson et al. 1999a,b; Gibson-Davis, 2008), the levels of investments provided by fathers in the household still vary greatly (e.g., Lawson & Mace, 2009a; see Chapter 2). Thus, father presence is unlikely to be an accurate reflection of paternal direct investment, potentially leading to "false negatives." There is an added issue with father absence in that interpretation of the results is difficult. It is often unclear

whether the observed effects on child outcomes are down to family disruption, or whether it is specifically associated with the reduction in paternal investments. Secondly, direct maternal investments are often not controlled for. As maternal investment levels correlate with paternal investment levels (Lawson & Mace, 2009a), its inclusion is necessary to uncover the true effects of fathers (Amato, 1994). Otherwise, any observed father effects may in fact be confounded by mother effects, potentially resulting in "false positives." Thirdly, fathers could have different effects on different outcomes. Consequently, with the current literature, it is difficult to accurately ascertain if and how fathers are important for child development in contemporary developed contexts. For a wider picture of how fathers influence child outcomes in the UK, we must investigate how *paternal direct investments* affect *multiple child development outcomes* while controlling for *direct maternal investments*.

3.1.3 Variations in the Effects of Paternal Investment

One underexplored aspect of paternal investment is, if and how its effects on child outcomes differ depending on individual circumstances. HBE posits that that trade-offs in behaviours vary depending on one's situation, and assumes that individuals behave in ways to maximise their inclusive fitness benefits. There should be differences in the indirect fitness benefits of paternal investments between individuals, and fathers in situations where they receive the greatest returns (relative to opportunity costs) should provide the greatest investments. Previous studies from HBE and other fields have identified that fathers in developed countries tend to invest more if fathers have high embodied capital, often measured through socio-economic status or education level (Marsiglio, 1991; Kaplan, Lancaster & Anderson, 1998; Lancaster & Kaplan, 2000; Lawson & Mace, 2009a; Neill, 2010), and if investments are directed towards sons (Harris & Morgan, 1991; Harris, Furstenberg & Marmer, 1998; Anderson, Kaplan & Lancaster, 2001; Lundberg, 2005; Raley & Bianchi, 2006). Thus, we can hypothesise that fathers in these contexts may be investing more because their pay-offs are higher, in that they "gain more" in terms of child quality.

To elaborate, firstly, fathers with higher embodied capital may have greater incentives to invest in their children if their investments are more effective in improving child quality compared to fathers with lower embodied capital (Kaplan, Lancaster & Anderson, 1998; Lancaster & Kaplan, 2000). If fathers with high embodied capital could generate larger benefits in their children's quality, they may opt to invest maximally into their child. In

contrast, if fathers with low embodied capital make less effective investments with minimal difference to child quality, those fathers may divert their paternal investment efforts into other behaviours. To date, one study has specifically tested and found support for this idea, where paternal involvement from high SES fathers had a greater positive effect on child's IQ at age 11 compared to investment from low SES fathers (Nettle, 2008).

Secondly, fathers may be inclined to invest more in sons over daughters if their investments have a greater positive impact on the development of boys than girls. These sex-dependent returns to investments may be driven by a greater outcome potential in boys, or a greater investment need in boys. For example, in terms of greater outcome potential, returns to paternal investment may be higher for sons due to the greater economic potential in males than females. In many countries across the world, men achieve higher pay than women, though the severity of the gap varies between countries (Blau & Kahn, 1992; Alderman & King, 1998; Arulampalam, Booth & Bryan, 2007). In the UK, the gender pay gap for fulltime workers in 2010 was 10.2%, with the average male hourly earnings being £13.01, and average female hourly earnings being £11.68 (Pike, 2011). As Arulampalam and colleagues (2007) note, the gender pay gap tends to follow a "glass ceiling" effect, where women are less likely to be in high-earning positions. In short, if there are limits in increasing female quality, fathers could be discouraged from investing in girls.

In terms of greater investment needs, boys may simply need more investments to achieve a certain quality than girls. For instance, boys are thought to be physiologically more costly than girls during gestation due to the faster intrauterine growth resulting in heavier birth weights (Maršál et al., 1996; Hindmarsh et al., 2002), meaning boys require more investment in-utero. In contemporary developed populations, boys have a greater risk of infant mortality (Drevenstedt et al., 2008), and some studies suggest that socio-emotional development in boys are more vulnerable to stressful family environments (Amato & Keith, 1991). Furthermore, it has long been suggested that fathers have a special role in the development of boys (Morgan et al., 1988), where boys especially benefit from interacting with fathers. If so, fathers may have a greater incentive to invest in boys as their investments may be more beneficial to the quality of boys than girls. In support, a few studies have found that father absence or paternal neglect was more detrimental for boys than girls (Levy-svhiff, 1982,; Hoeve et al., 2011), though results have not been consistent (e.g., see Amato & Gilbreth, 1999; King, Harris & Heard, 2004).

3.1.3 Objectives of Chapter 3

The aim of this chapter is to extend the investigation into the effects of paternal direct investments on child development in the context of contemporary developed populations, focusing on the UK. This will aid us in the assessment of whether the societal shift from high fertility to low fertility was accompanied by a shift in the childrearing system. In traditional contexts, we have seen that mothers and children are not particularly dependent on fathers, meaning fathers tend to have minimal effects on child quality. Paternal investment may be directed as investments in child quantity over quality, and perhaps as mating effort over parenting effort, which are trade-off decisions associated with faster life history strategies.

In low fertility, low mortality environments found in contemporary developed populations such as the UK, paternal investments may follow a slower life history strategy, geared towards optimising child quality and parenting effort. Consequently, paternal direct investments may have positive associations with children's developmental outcomes. Alternatively, paternal investment strategies in developed contexts could follow a similar pattern to traditional populations, given that mothers may have greater opportunities to be financially independent with a greater likelihood of having grandparents as allomothers (and consequently less reliant on fathers). Finally, whatever the overall trend, following an HBE perspective we can expect variations in the paternal investment strategy within populations following individual, context specific trade-offs.

Previous studies by Lawson & Mace using ALSPAC explored the effects of household structure on multiple child outcomes. They found that father presence predicted greater height for children compared to those with stepfathers (Lawson & Mace, 2008) and reduced behavioural difficulties compared to those with single mothers or stepfathers (Lawson & Mace, 2010). However, no significant effect was found between father presence and children's educational achievement or IQ (Lawson & Mace, 2009b). I build on these studies by focusing on paternal behaviour rather than father presence. I investigate the effects of paternal direct investments on multiple child outcomes (height, educational attainment and behavioural difficulty) while controlling for direct maternal investment levels. Furthermore, I investigate whether the effects of paternal direct investments differ based on the individual context of the father. Specifically, I test whether father effects differ by paternal education levels and the sex of the focal child.

3.2. Analysis Methods of Chapter 3

3.2.1 Sample Selection

As discussed, I use data from ALSPAC for the following series of analyses. I select a subsample of ALSPAC households where biological mothers and biological fathers were present in the household from the birth of the focal child to age 10. This is because, firstly, parenting scores were only collected for the mothers' current partners, meaning all parents in the following series of analyses must in a relationship (i.e., no single mothers). Secondly, stepfathers are removed as I focus on the direct investment effects of biological fathers in the current study. By choosing stable, biparental households, I am able to minimise issues of household disruption as well as maximise information on direct parental investments. Finally, I remove households where the focal children are of multiple births (i.e., twins, triplets, etc.) due to uncertainty with the interpretation of investment levels between the siblings.

3.2.2 Variables

Outcomes

As discussed in the previous chapter, the child outcomes of interest are height (cm), school test score and behavioural difficulty score (BDS). With this, I hope to capture multiple dimensions of child development (physical growth, cognitive development and socio-emotional development, respectively).

I use all available measures of these three outcomes from birth up to age 10. For height, I have 12 available measures, with the first 10 measures taken from a 10% subsample of ALSPAC children. For test score, I have two available measures taken at Local Entry Assessments and Key Stage 1. For behavioural difficulty score, I have three available measures taken between 42 months and 108 months. The descriptive statistics of all measures at each measurement occasion are available in table 3.1.

Main Predictors

The main predictors of interest are mother score and father score, representing direct investment levels by the mother and the father, respectively. This is derived from the frequency of various play and caretaking activities carried out with the child (see Chapter 2). These two scores were reported separately by the mother on 6 occasions between the

child's ages of 6 months and 65 months. The scores were standardised to range from 0 to 10, then mean-centred for each measurement occasion. The descriptive statistics of mother score and father score at each measurement occasion is available in table 3.1.

Controls

Across all analyses, the time-varying controls with multiple measurement occasions are child's age at the measurement of the outcome (months), number of siblings in the household, weekly income (3 categories: <£200 p/wk., £200 to £399 p/wk., >£400 p/wk.), home ownership (2 categories: renting, own home), reported financial difficulty (range = 0-15; higher scores = higher difficulties), mother's employment (2 categories: employed, unemployed), and father's employment (2 categories: employed, unemployed).

The time-static controls are mother's education at time of birth (3 categories: O-Level and equivalent, A-Levels, degree), father's education at time of birth (3 categories: O-Level and equivalent, A-Levels, degree), mother's age at time of birth (years), child's sex, and child's ethnicity (2 categories: white, other). For the analyses on height, additional time-static controls are included, which are focal child's birth length (cm), focal child's gestation length (weeks) and mother's height (cm). The descriptive statistics of all controls are available in table 3.1.

Table 3.1: Descriptive statistics of variables used in the analyses of Chapter 3.

Descriptives for variables specific to each analysis.

Growth Since Birth													
Time-Varying Variables / Measurement Occasion		**4m**	**9m**	**13m**	**20m**	**27m**	**34m**	**40m**	**47m**	**53m**	**67m**	**93m**	**104m**
	N	479	647	630	670	629	637	595	556	559	498	3058	1483
Child's Age	mean	3.9	9.05	12.90	19.97	27.05	33.96	40.11	46.85	53.07	67.10	91.69	103.01
(months)	(sd)	(0.20)	(0.25)	(0.27)	(0.38)	(0.25)	(0.24)	(0.26)	(0.30)	(0.40)	(0.77)	(11.77)	(2.49)
	range	3.5-5	8.5-10.75	12.25-15	19-21.75	26.5-28.75	33.25-35.25	38.75-41.25	46-48.75	51.75-55	65-71	75-117	89-124
Height (cm)	mean	62.72	70.28	75.70	81.79	86.99	91.67	95.66	99.48	103.34	110.74	125.64	132.50
	(sd)	(2.10)	(2.33)	(2.53)	(2.78)	(2.99)	(3.26)	(3.45)	(3.61)	(3.78)	(4.26)	(5.23)	(5.54)
	range	57.4-71	61-78.1	68.4-85	72.1-91	77.4-99.6	81-102.4	82.5-106.7	88.9-110.2	93-115.6	100.3-126.3	104.4-147.3	116.5-157.4
Time-Static Variables													
Birth Length (cm)	mean	50.57											
	(sd)	(2.56)											
	range	20.5-62											
Gestation Length	mean	39.39											
(weeks)	(sd)	(1.93)											
	range	24-47											
Mother's Height	mean	163.98											
(cm)	(sd)	(6.73)											
	range	124.46-200.66											
Test Score													
Time-Varying Variables / Measurement Occasion		**55m (LEA)**	**88m (KS1)**										
	N	9224	10904										
Child's Age	mean	54.54	88.36										
(months)	(sd)	(3.76)	(3.75)										
	range	44-69	78-101										
School Test Score	mean	9.68	9.14										
	(sd)	(0.03)	(0.04)										
	range	0-15	0-15										
Behavioural Difficulty Score													
Time-Varying Variables / Measurement Occasion		**42m**	**81m**	**108m**									
	N	9312	8215	7545									
Child's Age	mean	42.30	81.44	115.80									
(months))	(sd)	(0.85)	(1.35)	(1.56)									
	range	41-57	80-101	114-132									
Behavioural	mean	8.89	7.48	6.84									
Difficulty Score	(sd)	(4.56)	(4.77)	(4.94)									
	range	0-33	0-33	0-35									

Table 3.1: Descriptive statistics, continued.

Descriptives for variables used across all analyses.									
Time-Varying Variables									
Number of Siblings	**Measurement Occasion**	**21m**	**33m**	**47m**	**85m**				
	mean	0.89	1.09	1.23	1.37				
	(sd)	(0.96)	(0.95)	(0.92)	(0.88)				
	range	0-12	0-12	0-11	0-11				
Weekly Income	**Measurement Occasion**	**33m**	**47m**	**85m**	**97m**				
	<£200 p/wk. (%)	26.4	23.4	18.4	11.4				
	£200 to £399 p/wk. (%)	49.6	48.3	29	37.6				
	>£400 p/wk. (%)	24	28.2	52.7	50.9				
Home Ownership	**Measurement Occasion**	**0m**	**8m**	**21m**	**85m**				
	Renting (%)	24.2	21	19.9	14.6				
	Own Home (%)	75.8	79	80.1	85.4				
Financial Difficulty	**Measurement Occasion**	**8m**	**21m**	**33m**	**85m**				
	mean	3.20	3.13	3.12	2.09				
	(sd)	(3.61)	(3.63)	(3.67)	(3.02)				
	range	0-15	0-15	0-15	0-15				
Mother's Employment	**Measurement Occasion**	**0m**	**2m**	**21m**	**33m**	**47m**	**85m**	**120m**	
	Employed (%)	40.5	40.5	47.1	49.9	55.2	66.9	71.8	
	Unemployed (%)	59.5	59.5	52.9	50.1	44.8	33.1	28.2	
Father's Employment	**Child's age at measurement**	**0m**	**2m**	**8m**	**21m**	**33m**	**73m**	**97m**	**108m**
	Employed (%)	65.8	88.8	86.8	88.9	89.7	90.7	92.7	95.8
	Unemployed (%)	34.2	11.2	13.2	11.1	10.3	9.3	7.3	4.2
Mother Score	**Measurement Occasion**	**6m**	**18m**	**38m**	**42m**	**57m**	**65m**		
	mean	8.70	7.98	8.38	7.95	8.34	8.12		
	(sd)	(1.29)	(0.91)	(1.04)	(1.34)	(1.01)	(1.01)		
	range	0-10	1.18-10	0.67-10	1.11-10	2.22-10	3.06-10		
Father Score	**Measurement Occasion**	**6m**	**18m**	**38m**	**42m**	**57m**	**65m**		
	mean	7.82	5.98	7.08	5.98	6.83	6.58		
	(sd)	(1.27)	(1.71)	(1.64)	(1.76)	(1.62)	(1.60)		
	range	3.06-10	0-10	0-10	0-10	0-10	0-10		

Table 3.1: Descriptive statistics, continued.

Descriptives for variables used across all analyses.		
Time-Static Variables		
Mother's Education	O-Level/Equiv.(%)	70.7
	A-Level (%)	22.5
	Degree (%)	12.9
Father's Education	O-Level/Equiv.(%)	55.8
	A-Level (%)	26
	Degree (%)	18.2
Mother's Age at Birth of Child (yrs.)	mean(sd)	28(4.96)
	range	15-44
Child's Sex	Male (%)	51.7
	Female (%)	48.3
Child's Ethnicity	White (%)	95
	Other (%)	5

3.2.3 Analyses

As ALSPAC is a longitudinal cohort study, many variables are available as repeated measures. To take advantage of these repeated measures through time, I carry out multilevel models for all outcomes with measurement occasion as level 1 and child ID as level 2 (fig 3.1). Multilevel modelling allows us to control for the similarities between variables and/or measurements which arise from "nested" structures (Singer & Willett, 2003). In short, multilevel models take into account of the fact that the measurements from one person are going to be similar to one another. The added benefit of multilevel modelling is that, even if individuals have missed measurements, they are still included in the overall analysis. This increases analytical power and reduces biases (Singer & Willett, 2003). Below, I elaborate on multilevel linear regressions and multilevel Poisson regressions based on Rabe-Hesketh & Skrondal (2008).

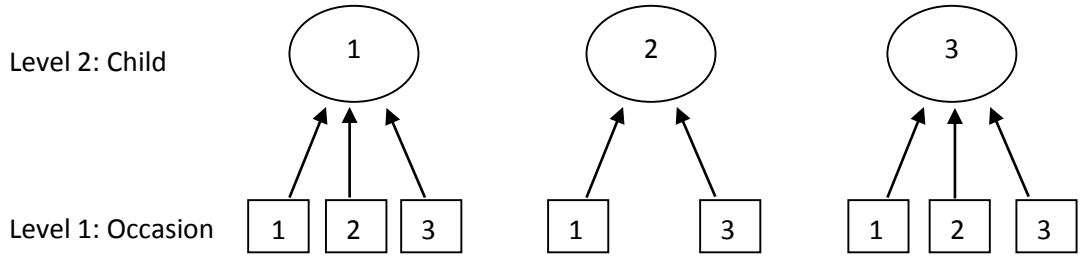

Fig 3.1: Representation of simple 2-level structure multilevel model for repeated measurements.

Multilevel Linear Regression

A normal linear regression model is expressed by the equation:

$$y_i = \beta_1 + \beta_2 x_{2i} + \cdots + \beta_p x_{pi} + \epsilon_i$$

where β represents the parameters, and i represents the measurements. β_1 represents the intercept, $\beta_p x_{pi}$ represents the i^{th} measurement of the p^{th} independent variable, and ϵ_i represents the residual of the i^{th} measurement.

In a normal linear regression, one of the assumptions is that the residuals between points are independent. However, this is not the case with repeated measures, as the residuals of measures are usually correlated within one individual. One way to address this issue is to allow each individual to have their own intercept, creating a random-intercept regression model. For random-intercept regression models, we simply add a random-intercept term ζ_{ij} to the regression equation:

$$y_{ij} = (\beta_1 + \zeta_{1j}) + \beta_2 x_{2ij} + \cdots + \beta_p x_{pij} + \epsilon_{ij}$$

where i represents the measurement occasion and j represents the individual. ζ_{ij} is the level-2 residual, representing individual j's deviation in the intercept from the mean value β_1. ϵ_{ij} is the level-1 residual specific to individual j at occasion i. Therefore, $(\beta_1 + \zeta_j)$ represents the individual-specific intercept, while ϵ_{ij} accounts for the residuals around the individual-specific regression line.

We can further add a random slope term to capture the different development trajectories of each individual. For a random-intercept random-slope regression, we add an additional random-slope term, ζ_{2j}:

$$y_{ij} = (\beta_1 + \zeta_{1j}) + (\beta_2 + \zeta_{2j})x_{2ij} + \cdots + \beta_p x_{pij} + \epsilon_{ij}$$

where ζ_{1j} represents the deviation of individual j's intercept from the mean of β_1, and ζ_{2j} represents the deviation of individual j's slope from the mean of β_2. $(\beta_2 + \zeta_{2j})x_{ij}$ represents the interaction between the individuals and the covariate x_{2ij}. This allows for the effect of x_{2ij} to differ between individuals, resulting in an individual-specific slope.

To express this visually in simplified form, a normal linear regression is represented in fig. 3.2, where a hypothetical regression line is plotted through fictional data points. Fig. 3.3 represents a random-intercept multilevel regression model, where each individual (represented by different colours) has a different intercept, taking into account of the nested structure. Fig 3.4 represents a random-intercept random-slope multilevel regression model, where each individual has a different intercept and a different slope, taking into account of the different trajectories.

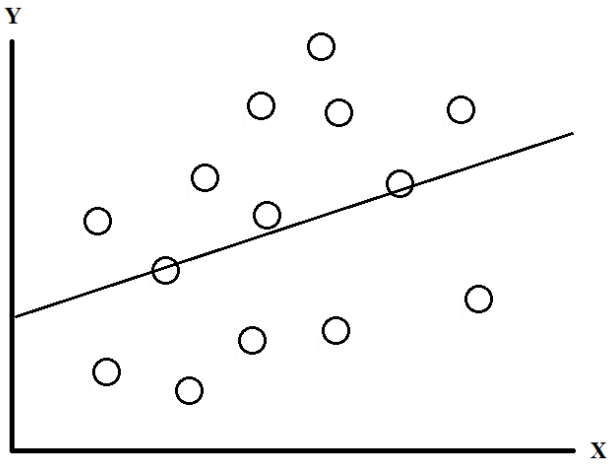

Fig. 3.2: Visualisation of a normal linear regression model.

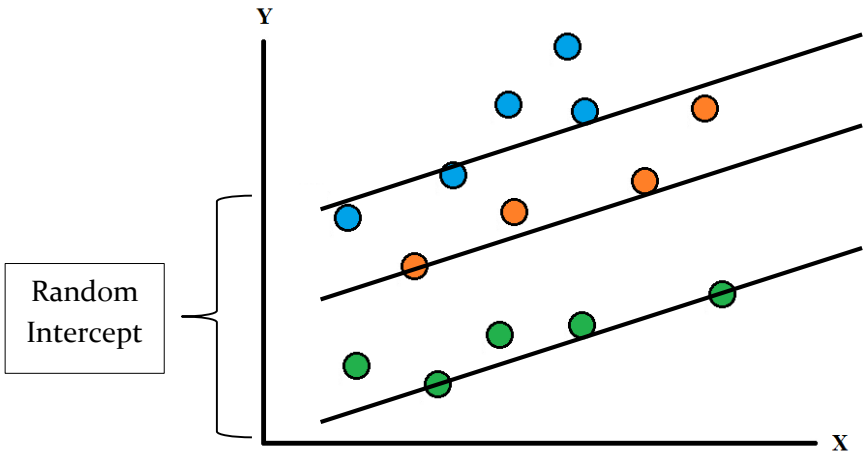

Fig. 3.3: Visualisation of a random-intercept regression model.

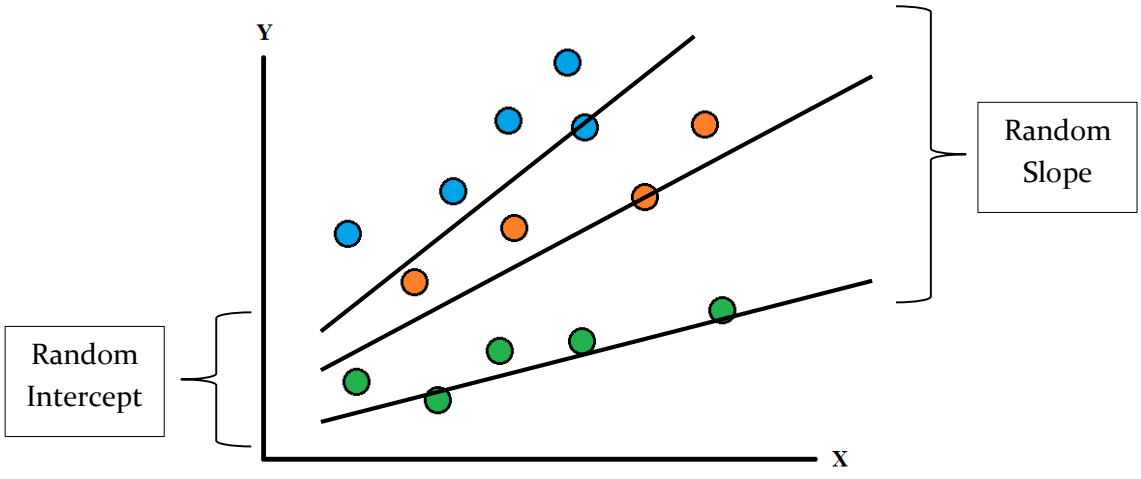

Fig. 3.4: Visualisation of a random-intercept random-slope regression model.

Multilevel Poisson Regression

Like linear regression, we can allow individuals to have their own intercept in a Poisson regression by the inclusion of a random intercept term, ζ_{ij}:

$$\mu_{ij} \equiv E(y_{ij}|x_{2ij}, \zeta_{1j})$$

$$\ln(\mu_{ij}) = (\beta_1 + \zeta_{1j}) + \beta_2 x_{2ij} + \cdots + \beta_p x_{pij} + \epsilon_{ij}$$

where i represents the measurement occasion and j represents the individual. ζ_j is the level-2 residual specific to individual j, and $(\beta_1 + \zeta_j)$ represents the individual-specific intercept.

Similarly, between-individual differences can be further addressed by a random-slope term ζ_{2j}:

$$\mu_{ij} \equiv E(y_{ij}|x_{2ij}, \zeta_{1j}, \zeta_{2j})$$

$$\ln(\mu_{ij}) = \left(\beta_1 + \zeta_{1j}\right) + \left(\beta_2 + \zeta_{2j}\right)x_{2ij} + \cdots + \beta_p x_{pij} + \epsilon_{ij}$$

where $\left(\beta_2 + \zeta_{2j}\right)x_{ij}$ represents the interaction between the individuals and the covariate x_{2ij}, resulting in an individual-specific slope.

To minimise the effects of reverse causality, I lag the mother and father scores in all analyses so that the outcome at a particular occasion is predicted by mother and father scores from the previous available occasion. For all outcomes, I began by identifying whether model fit was improved by an addition of a random-slope term to a random-intercept model, based on Akaike's information criterion (AIC) and Bayesian information criterion (BIC). AIC and BIC are both model selection criteria which penalises model fit based on the complexity of the model (Kuha, 2004). The issue with assessing the importance of added parameters using likelihood ratio tests and *P* values is that goodness-of-fit is usually improved with increasing parameters, which may lead to overly complex models and overestimation of the importance of parameters. To address this issue, AIC penalises the model fit based on the number of parameters, while BIC also incorporates penalties on sample size. For both criteria, smaller values suggest better model fit. The consequences of the differences in these penalty terms is that AIC tends to suggest larger models as best fitting, while BIC tends to suggest smaller models (Kuna, 2004). Though the philosophy behind AIC and BIC differ greatly (see Burnham & Anderson, 2004), Kuna (2004) recommends using both AIC and BIC. If AIC and BIC both agree in terms of model

fit, one can be relatively confident in the model fit values. If there are differences, caution and informed qualitative judgement may be necessary when assessing model fit. In general, a reduction in AIC and BIC score by 2 or more points is taken to be evidence for better model fit, though the bigger the reductions in scores the stronger the evidence for the better fit model (Kass & Raftery, 1993; Burnham, Anderson & Huyvaert, 2011).

Based on the distribution of the three outcomes and best model fit, I run the following models: 1) random-intercept random-slope linear regression models for height, 2) random-intercept linear regression models for school test score, and 3) random-intercept random-slope Poisson models for behavioural difficulty score. For school test score, note that there are only two measurement occasions for this outcome, thus a random-slope term was never added or it would be overparameterised. For behavioural difficulty score, note that I carried out a three-level random-intercept Poisson regression to check for uncontrolled overdispersion at level 1, which showed little variation between measurement occasions suggesting overdispersion was unlikely (see Rabe-Hesketh & Skrondal, 2008). All models are estimated using maximum likelihood estimations in Stata SE12.

The analytical approach I take is to assess the importance of the predictors of interest using penalised model fit values. I use AIC and BIC to identify whether mother score, father score and the interactions improve model fit. Improved model fit would suggest that these parameters are important predictors for the particular child outcome.

A maximum of five models were fit for each outcome. The *Base Model* is of the controls, and all other models were built on this base: Base + mother score (*Mother Model*), base + father score (*Father Model*), base + mother score + father score (*Parental Model*), and base + mother score + father score + interactions (*Interaction Model*). To test for the context-dependent effects of father score, I carried out interactions between father score and father's education and sex of child. However, as the interpretation of mother and partner scores become difficult with multiple interactions within one model, only the interactions which improve model fit based on AIC and/or BIC were included in the final interaction model. Out of interest, I also test for the same interactions with mother score.

Note, only for height, I include child's age^2 and child's age^3 due to the curvilinear trends of children's height by their age. The appropriate power terms of child's age were determined by improvement of model fit upon their inclusion to the base model.

3.3 Results of Chapter 3

Table 3.2 displays the key results for all three outcomes. The full results of the best fit models based on AIC are available in table 3.3.

For height, I find that inclusion of mother score does not improve AIC or BIC scores in the mother model. Focusing on AIC, the father model improves AIC by 6 points compared to the base model. The parental model including both mother score and father score is suggested to be the best fit model, which improved AIC by 10 points compared to base model, and 4 points compared to the father model. Focusing on BIC, there is very little difference in model fit between the base model and the father model, with a BIC difference of only 1 point. Inclusion of mother score does not improve BIC scores. While the base and father models are suggested to be similar in model fit, the father model and the parental model have smaller BIC scores than the mother model (-6 and -3, respectively). No interactions improved model fit. Taken together, the results suggest that father score is an important predictor for children's height. Overall, a 1 point increase in father score is associated with around 0.1cm (father model) or 0.13cm (parental model) reduction in children's height. Note, the exact same pattern is found for BMI, where a greater father score is associated with lower BMI (results not shown in chapter; see Appendix Table A1).

For school test score, the addition of mother score in the mother model reduced AIC by 11 points and BIC by 3 points compared to the base model. The addition of father score in the father model reduced AIC by 47 points and BIC by 40 points compared to the base model. Compared to the father model, the addition of mother score in the parental model had minimal influence on AIC with a reduction of 1 point, and increased BIC by 7 points. This suggests mother score may not be an important predictor for children's school test score despite the mother model being better fit than the base model. It is likely that the significance of mother score in the mother model is driven by its correlation with father score. This also explains why the significance of mother score is lost in the parental model.

An addition of an interaction term between father score and child's sex in the interaction model reduced AIC by 7 points and BIC by 1 point compared to the parental model, suggesting that the effects of father score may be dependent on sex. A visualisation of the interaction effect is presented in fig 3.5. Overall, there is a positive association between fathers score and school test score for both sexes. However, this association is steeper for boys, in that high father scores are associated with a relatively larger positive effect on boys than girls (fig. 3.5). Such effects were not found for mother score, and no other interactions improved model fit. Overall, a 1 point increase in father score is

associated with around 0.29 point increase in the test score for boys, and a 0.12 point increase in the test score for girls (interaction model).

For behavioural difficulty score, the addition of mother score in the mother model reduced AIC by 114 points and BIC by 106 points compared to the base model. The addition of father score in the father model reduced AIC by 118 points and BIC by 110 points compared to the base model. Both AIC and BIC agree that the best fit model is the parental model, with a reduction of 183 and 167 points compared to the base model, respectively. No interactions improved model fit. There is strong evidence that mother and father scores are good predictors of children's behavioural difficulty score. Overall, a 1 point increase in mother score is associated with a 5.5% decrease in BDS, while a 1 point increase in father score is associated with a 4.7% decrease in BDS (parental model).

Table 3.2: Key results for multilevel models: parent scores on height, school test score and behavioural difficulty score.

	Base		Mother		Father		Parental		Interactions	
	B	**se**	**B**	**se**	**B**	**se**	**B**	**se**	**B**	**se**
Height (cm)										
Mother Score	-	-	0.065	0.045	-	-	0.112*	0.047	NA	NA
Father Score	-	-	-	-	0.104**	0.037	0.130***	0.038	NA	NA
AIC	52180		52180		52174		52170		NA	
BIC	52352		52359		52353		52356		NA	
N Children=3299, N Obs.=9518										
School Test Score										
Child's Sex: Female	0.913***	0.073	0.907***	0.073	0.921***	0.076	0.917***	0.073	0.973***	0.075
Mother Score	-	-	0.139***	0.039	-	-	0.066	0.040	0.068	0.040
Father Score	-	-	-	-	0.218***	0.031	0.202***	0.033	0.288***	0.043
Father Score*Female	-	-	-	-	-	-	-	-	-0.171**	0.057
AIC	32626		32615		32579		32578		32571	
BIC	32755		32752		32715		32722		32721	
N Children=4711, N Obs.=6893										
	IRR	**95%CI**	**IRR**	**95%CI**	**IRR**	**95%CI**	**IRR**	**95%CI**	**IRR**	**95%CI**
Behavioural Difficulty Score										
Mother Score	-	-	0.930***	0.918, 0.942	-	-	0.945***	0.932, 0.958	NA	NA
Father Score	-	-	-	-	0.940***	0.930, 0.950	0.953***	0.942, 0.963	NA	NA
AIC	70377		70263		70259		70194		NA	
BIC	70519		70413		70409		70352		NA	
N Children=5908, N Obs.=13119										

*$P \leq 0.05$ ** $P \leq 0.01$ *** $P \leq 0.001$

Table 3.3: Full results of the best fit models of parent scores on child outcomes, based on AIC.

	Height (cm)		School Test Score		Behavioural Difficulty Score	
	Random Intercept Random Slope Regression		Random Intercept Regression		Random Intercept Poisson Regression	
	B	**SE**	**B**	**SE**	**IRR**	**95% CI**
¥Assessment:						
Local Entry (ref)	-	-	-	-	-	-
Key Stage 1	-	-	-6.558***	0.333	-	-
†Birth Length (MC)	0.534***	0.035	-	-	-	-
†Gestation Length (MC)	-0.256***	0.050	-	-	-	-
†Mother's Height (MC)	0.127***	0.011	-	-	-	-
†Child's Age^2 (Months)	-0.003***	0.000	-	-	-	-
†Child's Age^3 (Months)	$-1.82_{x10^{-12}}$***	0.000	-	-	-	-
Child's Age	1.000***	0.007	0.191***	0.010	0.995***	0.995,0.996
Child's Sex:						
Male (ref)	-	-	-	-	-	-
Female	-0.889***	0.140	0.973***	0.075	0.894***	0.872,0.918
Child's Ethnicity:						
White (ref)	-	-	-	-	-	-
Other	0.730	0.464	0.089	0.243	1.063	0.948,0.974
Number of Siblings	-0.185**	0.068	-0.181***	0.041	0.961***	0.948,0.974
Weekly Income:						
<£200 p/wk. (ref)	-	-	-	-	-	-
£200 to £399 p/wk.	-0.704***	0.153	0.436***	0.129	0.959*	0.929,0.991
>£400 p/wk.	-0.627***	0.166	0.762***	0.145	0.949**	0.913,0.987
Home Ownership:						
Renting (ref)	-	-	-	-	-	-
Own Home	0.080	0.206	0.828***	0.135	0.998	0.957,1.039
Financial Difficulty	-0.013	0.017	-0.009	0.012	1.011***	1.008,1.015
Mother's Age (MC)	0.023	0.018	0.010	0.010	0.994**	0.991,0.998
Mother's Employment Status:						
Unemployed (ref)	-	-	-	-	-	
Employed	-0.016	0.095	0.023	0.070	0.981	0.962,1.000
Mother's Education:						
O-Level/Equiv.(ref)	-	-	-	-	-	-
A-Level	0.275	0.169	0.451***	0.091	0.942***	0.912,0.974
Degree	-0.127	0.230	0.985***	0.135	0.925***	0.884,0.968
Father's Employment Status:						
Unemployed (ref)	-	-	-	-	-	-
Employed	0.185	0.145	0.364*	0.148	0.988	0.949,1.028
Father's Education:						
O-Level/Equiv.(ref)	-	-	-	-	-	-
A-Level	-0.328	0.168	0.322***	0.087	0.972	0.941,1.003
Degree	-0.246	0.216	1.028***	0.125	0.978	0.938,1.021
Mother Score (MCO)	0.112*	0.047	0.068	0.040	0.945***	0.932,0.958
Father Score (MCO)	-0.130***	0.038	0.287***	0.043	0.953***	0.942,0.963
Father Score x Sex:						
x Male (ref)	-	-	-	-	-	-
x Female	-	-	-0.171**	0.057	-	-
Constant	62.410***	0.552	-2.653***	0.625	10.711***	9.656,11.882
ψ_1 (intercept)	1.630		1.874		0.349	
ψ_2 (slope: Child's Age)	0.051		-		0.005	
θ	2.580		1.909		-	
N Observations	9518		6893		13119	
N Children	3299		4711		5901	
AIC	52170		32572		70195	
BIC	52356		32722		70352	

*$P \leq 0.05$ **$P \leq 0.01$ ***$P \leq 0.001$

† Variables only included for height analysis. ¥ Variables only included for test score analysis. Note, for BDS, the constant displays the coefficient rather than IRR.

(MC)=Mean Centred, (MCO)=Mean Centred at each measurement occasion.

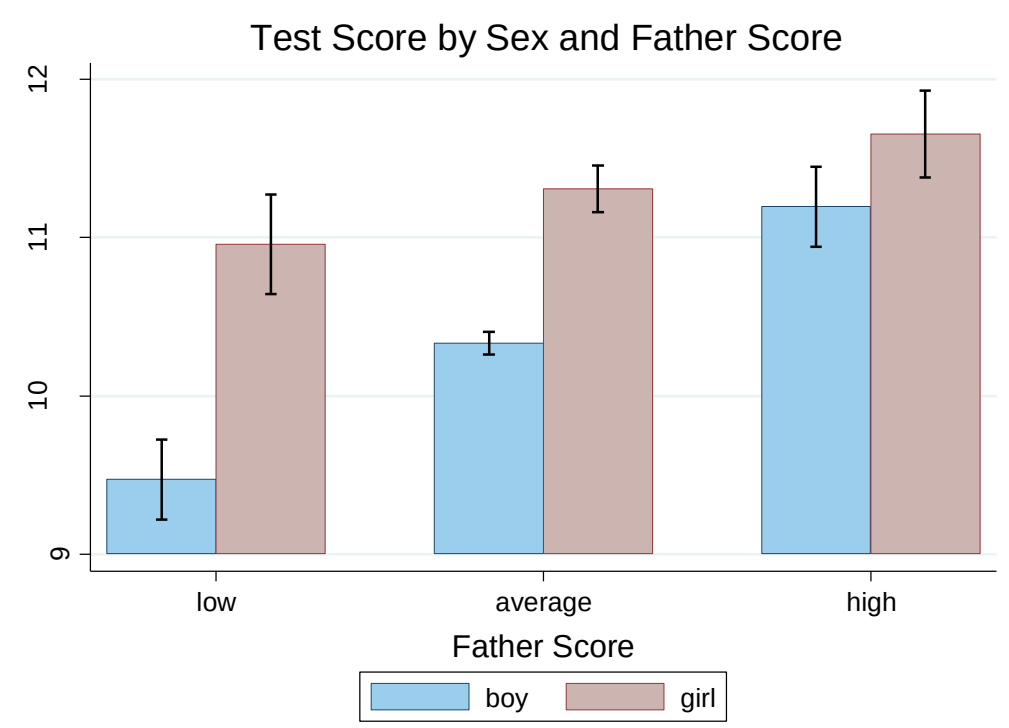

Fig 3.5: Predicted School Test Score by Father Score and Sex of Child. The bar chart depicts the predicted test score for boys and girls that had low (-3), average (0) and high (3) father score, based on the interaction model. The error bars are confidence intervals based on child's sex and father score.

3.4 Discussion of Chapter 3

3.4.1 Main Findings of Chapter 3

In this chapter, I investigated the effects of paternal direct investment on multiple child outcomes while taking account of maternal investment levels. Furthermore, I explored whether the effect of paternal direct investments depended on father's education level and sex of child. This was carried out as part of the investigations into the childrearing system in the UK, specifically regarding the role of fathers as allomothers.

Firstly, paternal direct investments were associated with beneficial effects on all three outcomes considered, where higher father scores were associated with shorter height, higher academic attainment and lower behavioural difficulty. Furthermore, paternal direct investments were associated with greater positive effects on the academic attainment of boys than girls. Under low father scores, boys seemed to do much worse in

their academic attainment than girls. Under high father scores, however, this gap was reduced to the extent that boys did almost as well as girls.

Overall, these results indicate that paternal direct investments are associated with beneficial effects on multiple aspects of child development in stable, two-parent households in the UK. This could be a reflection of how fathers in the UK follow a slower life history strategy compared to fathers in more traditional contexts, optimising child quality over quantity. Furthermore, male and female sensitivities to paternal direct investments may differ on some developmental outcomes, especially those associated with cognitive development. The results suggest that boys are more sensitive to paternal investments in terms of educational attainment, and low investments are more detrimental to boys than girls. These sex differences in the benefits to child quality may provide some explanation for the observed trend where fathers tend to invest more in sons, and supports the HBE idea that trade-offs in investments can be context specific.

Contrary to my expectation, there was no evidence of paternal direct investments having different effects on child outcomes depending on the education levels of the fathers. This suggests that the quality/efficacy of paternal direct investments do not differ by paternal education levels, and highly educated fathers are not encouraged to invest more through higher returns to child quality. Why, then, do fathers tend to invest more if they are of "higher quality"? One possibility is that their higher quality equips these fathers with an ability to invest more: Compared to lower quality fathers, higher quality fathers may simply have more time and/or skill to be able to provide direct investments. As indirect support, education level has been found to have a positive association with economic productivity (Chevalier et al., 2004), and a similar process may be present in terms of parenting where highly educated parents are more "productive" with their parenting.

The greater importance of paternal direct investments over maternal direct investments on height and school test score is rather surprising, highlighting a possibility that studies finding significant effects of maternal investments on child development could be picking up on the confounding paternal effect. However, the current results do not necessarily suggest mothers are unimportant: In general, the levels of maternal investment do not vary as much as paternal investment in the current dataset, and most mothers tend to invest relatively highly (see Chapter 2). Therefore, what may end up making the biggest difference between these children is the level of additional paternal investment they receive.

Overall, these findings suggest that fathers may be important allomothers within contemporary developed populations. Unlike the general trends seen in traditional contexts, paternal direct investments are associated with greater child quality in the UK (controlling for other household factors). This hints at the possibility that the childrearing system in developed populations such as the UK is different from high-fertility high-mortality populations: In line with the societal shift to lower fertility and optimising child quality (see Chapter 2), fathers may be following a relatively slower life history strategy by focusing on optimising child quality and parenting effort over child quantity and mating effort.

3.4.2 Limitations of the Current Analyses

There are several limitations which must be highlighted. Firstly, the current analyses focused on stable, biparental households where biological fathers and biological mothers were present. This was driven by the need to focus on biological fathers, where information on parenting scores was required for both parents. Furthermore, I wanted to minimise the confounding effects of family disruption often associated with father absence. It is important to note that the importance of paternal direct investments on child development could differ in households generally associated with greater family disruption, such as single-parent households. For instance, following life history theory, slower life history strategies are expected in more stable environmental conditions. Consequently, the role of fathers as allomothers in less stable households may be more similar to traditional populations, where paternal investments have minimal effects on child quality.

In addition, the assumption of the current study is that paternal direct investments increase child quality. However, the fine details of the proximate mechanism and the process in which this occurs have not been explored. It is not clear, for example, whether paternal direct investments increase educational attainment because it increases knowledge (e.g., knowledge of numbers and words), or whether it equips children with a greater ability to learn at school.

3.4.3 Conclusions: The Importance of Fathers as Allomothers in the UK

Despite limitations, the results presented within this chapter suggest that paternal direct investments are beneficial for multiple aspects of child development in the UK,

though these effects may vary depending on the sex of child for cognitive development. The current methodology disentangled the effects of paternal direct investments from maternal direct investments and family disruptions, suggesting that paternal care is indeed important for offspring quality in the UK. We find that the benefits of fathers for child development do not solely stem from socioeconomic factors, as argued by some researchers. Furthermore, I find that fathers are not inferior caregivers compared to mothers in terms of the efficacy of direct investments. Finally, the results hint that the observed son-biases in paternal direct investments may, at least in part, be driven by the sex-differences in its effect on cognitive development. However, the greater levels of paternal investments by fathers with higher levels of education cannot be explained through differences in their effects on child quality.

To conclude, fathers are often presented as potential allomothers in the human cooperative breeding system. The current results suggest that fathers are indeed important allomothers in the UK childrearing system. This is in contrast to the general finding in high mortality, high fertility populations, where father presence is rarely associated with positive effects on child survival. As discussed in Chapter 1, when father presence is associated with positive effects in high fertility/mortality populations, it tends to be in environments where mothers and children are dependent on fathers. This dependency may emerge due to factors such as the economic reliance on males and/or lack of other allomothers. From this, we could infer that, mothers and children in stable, two-parent families in the UK may be relying on fathers as allomothers. Paternal input may be especially important due to the high costs of childrearing and the lack of other allomaternal kin.

Chapter 4 : Stepfather Effects on Multiple Child Outcomes

4.1 Introduction to Chapter 4

4.1.1 Stepfathers as Allomothers in Contemporary Developed Populations

In the previous chapter, I presented evidence suggesting that fathers in biparental households are important allomothers in the UK, where paternal direct investments positively influence multiple aspects of child development. However, a significant number of children in contemporary developed populations do not reside with their father, but their stepfather. In 2011, there were 544,000 stepfamilies with dependent children in England and Wales, which includes both married and cohabiting couples. This equates to 11% of all two-parent families with dependent children (ONS, 2014a). The majority of these families are stepfather households: In 2011, 85% of stepfamilies were composed of the mother, her children and the stepfather (ONS, 2014a). With so many children having stepfathers as potential allomothers, how do stepfathers affect child development in the UK?

In high fertility, high mortality populations, there are only a handful of studies which investigates the effect of stepfathers on child quality (see Chapter 1). Within this limited literature, some studies suggest that stepfather presence is associated with positive effects on child survival when mothers and their children are dependent on stepfathers for resources. At the same time, several studies suggest that stepfathers are detrimental for children, with stepfather presence associated with increased child mortality. The small amounts of available literature makes it difficult to draw conclusions regarding the importance of stepfathers as allomothers in high fertility, high mortality populations. Nonetheless, we can speculate that stepfather effects on child quality may be influenced by how much mothers and children depend on stepfathers for allomaternal support.

Findings from the previous chapter suggest that, in contemporary developed populations such as the UK, mothers may be dependent on allomothers within the nuclear family. If so, stepfathers could be an important type of allomother just like fathers, potentially having positive effects on child development. However, stepfathers are sure of their "unrelatedness" to the children. The previous chapter indicated that paternal direct investments in the UK may be geared to optimise child quality, with investments made primarily as parenting effort over mating effort. As an unrelated male, stepfather

investments into focal children are theorised to be made as mating effort, for future reproduction. Consequently, the costs and benefits surrounding direct investments into children are expected to be different between fathers and stepfathers, meaning the association between direct investments and child outcomes may also differ between fathers and stepfathers. If stepfather investments serve primarily as mating effort, the direct investments could be channelled into future reproduction rather than child quality. For instance, stepfather direct investments could substitute maternal direct investments, allowing mothers to invest in reproductive effort (and a similar process may occur with biological fathers). In relation to this, stepfathers may induce greater parent-offspring competition between the focal child and mothers/stepfathers, where conflict arises as investments are directed away from child quality/parenting effort (i.e., what is optimal for child fitness) into child quantity/mating effort (what is optimal for maternal/stepfather fitness). This could mean that stepfather investments are associated with no benefit to child quality, or even lower levels of child quality in comparison to non-stepfather households.

In this chapter, I investigate how stepfather direct investments affect multiple child outcomes in the UK. At the same time, I investigate if and how stepfather direct investments differ between fathers and stepfathers. This should shed light on the role of stepfathers as allomothers in contemporary developed contexts. Compared to high mortality, high fertility populations, there has been greater academic interest in stepfathers in developed populations. In the following section, I review the available literature on stepfather effects on child development outcomes in developed populations.

4.1.2 Stepfather Effects on Child Development in Contemporary Developed Populations

In contemporary developed populations, decades of research has identified stepfather presence to have negative effects on multiple child outcomes. Perhaps the most well-known example is the Cinderella Effect, where stepfather presence, compared to fathers, has been associated with significant increases in child mortality risk through homicide and accidental death (Wilson, Daly & Weghorst, 1980; Daly & Wilson, 1980, 1994, 1998, 2001, 2005; Tooley et al. 2006). This is clearly an extreme example regarding the negative effects of stepfathers, and stepfather-related child deaths in contemporary developed populations are rare in absolute terms. It is reasonable to assume that the majority of stepfathers do not intentionally harm or neglect their stepchildren. Nevertheless, the negative effects of stepfathers have been found for less extreme child outcomes. Children

with stepfathers, compared to those with biological fathers, have been associated with lower levels of educational achievement (Dawson, 1991; Thomson, Handon & McLanahan, 1994; Manning & Lamb, 2004), and greater levels of behavioural difficulties (Dawson, 1991; Thomson, Handon & McLanahan, 1994; Dunn et al., 1998; Amato & Rivera, 1999; Manning & Lamb, 2004; Carlson, 2006; Lawson & Mace; 2010). This trend continues even when compared against children with single mothers, where children with stepfathers do worse in terms of accidental death (Tooley et al., 2006) educational achievement (Thomson, Handon & McLanahan, 1994), and behavioural difficulties (Carlson, 2006; Lawson & Mace, 2010), though results are less consistent (e.g., see Lancaster & Kaplan, 2000; Gennetian, 2005).

These findings are generally in line with expectations from an evolutionary perspective: Stepfathers are not related to their stepchildren, and do not gain any inclusive fitness benefits from investing in those children. Stepfather-child interactions are assumed to be driven purely by mating effort while father-child interactions are driven by a combination of mating and parenting effort (Anderson, Kaplan & Lancaster, 1999a). Though some studies have found that married stepfathers invest in children as much as biological fathers (Hofferth & Anderson, 2004; Berger et al., 2008), stepfathers have generally been found to invest less than fathers (Thomson, McLanahan & Curtin, 1992; Bronstein et al., 1994; Amato & Rivera, 1999; Anderson, Kaplan & Lancaster, 1999a, 1999b; Zvoch, 1999; Lancaster & Kaplan, 2000; Case & Paxson, 2001; Hofferth & Anderson, 2004; Lawson & Mace, 2009a), perhaps reflecting the lack of parenting effort within stepfather-child interactions. These lower levels of investment by stepfathers could, at least in part, explain why children with stepfathers do worse in developmental terms compared to children with fathers.

Nonetheless, it is also true that stepfathers are generally found to provide and care for their stepchildren (Bronstein et al., 1994; Anderson, Kaplan & Lancaster, 1999a, 1999b; Zvoch, 1999; Lancaster & Kaplan, 2000; Case & Paxson, 2001; Hofferth & Anderson, 2004). If stepfather effects are driven through lower levels of investments by stepfathers, we would expect children's developmental outcomes to be better in stepfather households compared to single-mother households. As discussed, this is not always the case. These findings suggest there may be other factors associated with stepfather presence which are detrimental to aspects of child development, which may be directly or indirectly related to stepfather presence. Stepfather presence is undoubtedly linked to multiple confounding factors which are often difficult to disentangle, leading us to question whether stepfather effects are simply down to stepfathers. This is an inherent problem in

the numerous cross-sectional studies that have explored this topic. Below, I elaborate on several confounding factors associated with stepfather presence which may influence child development: *reduction in investment levels*, *differences in quality of investments*, and *household instability*.

One possible confounder associated with stepfather presence is the differences in the overall levels of investments children receive. First, as discussed above, stepfathers are found to invest less than fathers. While non-resident fathers may continue to provide investments into their children, the levels of investments have been found to be significantly lower compared to resident fathers (Anderson, Kaplan & Lancaster, 1999a, 1999b; Gibson-Davis, 2008). In addition, stepfather presence has been associated with a further reduction in the involvement by non-resident fathers (Furstenberg, Morgan & Allison, 1987; Christensen & Rettig, 1996; Juby et al., 2007). Therefore, children living with stepfathers may receive lower levels of investments from "male figures" overall compared to children living with biological fathers or single mothers. Secondly, maternal investment levels have been found to be lower in stepfather households compared to father-present or single-mother households (Amato & Rivera, 1999; Lawson & Mace 2009a). Mothers within stepfather households may be diverting attention away from their children and redirecting it to their new partners as mating effort. Children may not only receive lower levels of investment from "male figures," but also from their mothers, meaning the overall investments they receive may be reduced in stepfather households.

Another possible confounder associated with stepfather presence is the differences in the quality or the efficacy of investments children receive. Parenting is often viewed to be less of a responsibility for stepfathers than fathers, with less involvement, less warmth and fewer disciplinary interactions (Fine, 1996). Stepfathers are more likely to have a disengaged parenting style (Fine, 1996), and stepfather presence may be associated with greater negligence (Tooley et al. 2006). It is therefore possible that the quality of investments children receive from stepfathers are lower: For instance, an hour under the care of a father has more benefit to a child than an hour under the care of a stepfather.

Thus the negative effects of stepfathers could, at least in part, be driven by the differences in the quantity and quality of investments children receive, which may or may not be directly related to stepfathers. However, only a small number of studies control for various aspects of investments while exploring the effects of stepfather presence. Of these, most have found that stepfather presence is still associated with negative effects on children's behaviour and/or educational achievement (Thomson, McLanahan & Curtin, 1994; Amato & Rivera, 1999; Carlson, 2006; Flouri, 2008), suggesting that lower levels of

investments do not drive all of the negative stepfather effects. However, the investment controls used within these studies vary, from controlling for within-household investments by mothers and their partners (fathers or stepfathers) (Thomson et al., 1994; Amato & Rivera, 1999), investments by mothers and biological fathers (present or absent in household) (Carlson, 2006), and investments by father figures (fathers, absent fathers or stepfathers) (Flouri, 2008). Maternal, paternal and stepfather investments are not explored separately, leaving the possibility that some other aspect of investment may be driving the stepfather effect. This concern is strongest for studies which do not fully control for within-household investments by mothers and their partners, as investment levels are known to differ significantly between father and stepfather households.

Rather than focus on stepfather presence, a handful of studies have explored the effect of stepfather investments on child outcomes. For instance, a retrospective study of university students found that perceived involvement from stepfathers had a weak but positive association with adolescent wellbeing (Schwartz & Finley, 2006). Another study found that, though children in stepfather households had lower levels of educational achievement in general, stepfathers' educational involvement had a positive effect on children's educational achievement (Nord & West, 2001). In contrast, Vogt Yuan & Hamilton (2006) found that direct investment activities by stepfathers did not have a significant effect on behavioural problems and depression in adolescents after controlling for maternal and paternal (non-resident) investment, though emotional closeness between stepfathers and stepchildren did predict higher levels of adolescent wellbeing. Similarly, Bronstein et al. (1994) found that, while controlling for non-resident father involvement, direct stepfather investment was not associated with any effects on child outcomes. However, supportive parenting behaviour provided by stepfathers was associated with reduced behavioural difficulties. Within this limited literature on stepfather investment, there is conflicting evidence on whether direct investments by stepfathers have positive effects on child outcomes, though the quality of stepfather-child relationships seems to have positive associations with emotional and behavioural outcomes. However, the majority of these studies concentrated solely on the effect of stepfathers without comparison to fathers. It is still unclear whether investments from stepfathers are as beneficial for children as investments from fathers, and whether the ineffectiveness of stepfather investments could be contributing to the negative effects of stepfather presence.

Finally, Belsky, Steinberg & Draper (1991) propose that father absence/stepfather presence may provide cues of "unstable environments" to children, especially important

during the first 7 years of life, prompting children to develop taking a faster life history strategy. This may mean children develop in a way to optimise reproductive effort over somatic effort, resulting in the "detrimental effect" on child development outcomes. In support, stressful family environment such as father absence and stepfather presence has been associated with earlier reproductive maturation in girls (Ellis & Garber, 2003; Ellis, 2004) and boys (Sheppard & Sear, 2011) in developed populations. If so, the negative effects of stepfather presence on child development may not be directly linked to the actions/direct investments of the stepfather, but indirectly caused through the signalling of environmental instability to children. Even if stepfathers provide investments to children, this could mean that stepfather presence is associated with detrimental effects on child development.

4.1.3 Objectives of Chapter 4

While stepfather presence is generally found to have negative implications on child development in contemporary developed populations, the proximate mechanisms behind such effects are yet to be fully explored. From an HBE perspective, the negative effects of stepfather presence on child outcomes may be due to the reduced quantity of direct investments, differences in the quality of direct investments, or some other factor associated with stepfather presence (such as household instability) which could signal environmental instability to children and consequently prompt them to develop following a faster life history strategy.

The overall aim of this chapter is to explore how stepfather direct investments affect multiple child development outcomes in the UK. Following previous studies which have found associations between stepfather presence and child development outcomes, I focus on disentangling the "stepfather effect" by focusing on the impact of stepfather direct investments. Controlling for stepfather direct investment levels, and comparing it to father direct investment levels, should highlight whether stepfather effects are driven by differences in the quantity and quality of investments children receive in stepfather households. If "stepfather effects" still exist after controlling for investment differences, it would suggest that stepfather effects may be caused by other factors associated with stepfather presence, potentially relating to the signalling of environmental instability to children.

Previous work on ALSPAC by Lawson & Mace (2009b, 2010), focusing on sibling competition, simultaneously explored the effects of household structure on multiple child

outcomes. They found that stepfather presence did not have a significant effect on children's educational achievement or IQ (Lawson & Mace, 2009b). In contrast, stepfather presence was associated with detrimental effects on children's behavioural difficulty, where children in stepfather households scored higher in behavioural difficulties compared to children in single-mother or father-present households. Further analysis suggested that children in stepfather households were more likely to score highly on hyperactivity (Lawson & Mace, 2010). I build on previous studies on stepfather presence, particularly on Lawson & Mace (2010), by including measures of direct investments children receive from the mother and her partner (i.e., father or stepfather) within the household. Furthermore, I explore whether the effects of stepfather investments differ from paternal investments. First, I minimise the confounding effect of family disruption and single motherhood which are inevitably linked to stepfather presence by selecting a subsample of ALSPAC families who have experienced relatively stable household structures. Second, I address missing responses to increase power and achieve more accurate estimates. Third, I include measures of maternal and father/stepfather direct investment levels within the household.

In the following analyses, I investigate whether: 1) stepfather presence effects are removed if direct maternal investment levels within the household are controlled for; 2) stepfather presence effects are removed if direct father/stepfather investment levels within the household are controlled for; and 3) direct investments from stepfathers have a less positive effect on child outcomes compared to direct investments from fathers. This will help us determine whether the negative effects of stepfather presence is driven, at least in part, by the differences in the quantity and the quality of direct investments associated with stepfather households. Overall, disentangling stepfather direct investments from other confounders will help reveal the "true" effects of stepfather direct investments on child development in the UK.

4.2 Analysis Methods of Chapter 4

4.2.1 Sample Selection

As the focus of my investigation is with the effects of direct investments rather than household disruptions, the final sample is restricted to children who had the same father or stepfather present in the household between the ages of 3 years 11 months and 7 years. The importance here is that the same father or stepfather was reported by the mother to be present at all time points between 3 years 11 months and 7 years, so that children in both groups experienced stability in male presence.

To minimise the potential effects of family disruption and single motherhood associated with stepfather households, I aimed to select the earliest time-point for stepfathers entering the household. At the same time, I aimed to maximise the number of stepfather households within the sample. 3 years 11 months was the earliest time-point with a substantial number of stepfather households, where 289 mothers reported cohabitation with a stepfather. Note that many children in stepfather households are likely to have encountered stepfathers before the age of 3 years 11 months. Regarding cohabitation, data available from previous waves indicate that 36.3% of children in stepfather households lived with their stepfather by age 2 years 9 months, and 15.6% by age 1 year 9 months. I expect that these values would be higher for frequent contact between stepfathers and children.

The cut-off point of 7 years was chosen, as the last available measures of investments were at 5 years 5 months. I therefore required child outcomes reported after 5 years 5 months, and for father and stepfather presence to be stable up to that interval. 7 years was the measurement occasion which maximised the sample size due to loss of stepfather households at older ages, with the biggest issue being non-response and drop-outs.

Finally, children from multiple births (i.e., twins, triplets etc.) were removed from the sample due to uncertainty with the interpretation of investment levels between the siblings. This left us with 246 stepfather households identified within 12895 households.

4.2.2 Variables

Outcomes

As with the previous chapter, I investigate the effects of stepfathers on height, school test score and behavioural difficulty score. However, I focus on outcome measures taken at around age 7 years. For height, I use clinical height measurements taken at around age 7 where the whole ALSPAC sample was eligible (rather than 10% subsample). For school test scores, I use scores based on the Key Stage 1 Standard Assessments taken between ages 6 and 7, standardised to range from 0 to 15. For behavioural difficulty score, I use scores from the Strength and Difficulties Questionnaire administered to mothers to report on their behaviour at around 7 years.

Main Predictors

The main predictors of interest are 1) *stepfather presence*, which indicates whether the mother's partner in the household is the father or the stepfather, 2) *mother's investment score* (mother score), which is a combined score based on the self-reported frequencies of various play & caretaking activities with the focal child, and 3) *partner's investment score* (partner score), which is a combined score based on the mother-reported frequencies of various play and caretaking activities by the mother's partner (i.e., father or stepfather). Specifically, I use mother and partner scores collected when children were around 4 years 9 months and 5 years 5 months (see Chapter 2). Table 4.1 displays the descriptive statistics of the measured parenting activities, with additional separation between the father and stepfather. These scores were standardised into a scale ranging from 0 to 10, and an average score for the mother and partner was calculated based on the two measurements.

Controls

In all analyses, I include controls of children's age at the time of measurement (in months), number of siblings in the household (including half-siblings related to stepfathers), home ownership (2 categories: renting, own home), reported financial difficulty (range = 0-15; higher scores = higher difficulties) and household income (3 categories: <£200 p/wk., £200 to £399 p/wk., >£400 p/wk.), which was measured at or around age 7. I also include mother's age at birth (in years), child's sex, child's ethnicity (2 categories: white, other) and mother's level of education (3 categories: O-Level and

equivalent, A-Levels, degree), which was measured at birth of the cohort child. Finally, I include maternal employment and partner employment which is based on employment status between 3 years 11 months and 7 years, where employment was categorised into never, some and constant. The descriptive statistics of all measures are available in table 4.2.

Table 4.1: Descriptive statistics of parenting activities for mothers, fathers and stepfathers. The sample criteria consist of mothers who reported having the same partner between 3y11m and 7yrs, who completed the parenting questionnaires fully. Columns show the % of mothers, fathers and stepfathers reported to take part in the specific activity *often*. The last row displays the mean parenting score for mothers, fathers and stepfathers.

	4 years 9 months *% reported "Often"*			**5 years 5 months** *% reported "Often"*		
Activities:	**Mother (N=8759)**	**Father (N=6856)**	**Stepfather (N=182)**	**Mother (N=8308)**	**Partner (N=6531)**	**Stepfather (N=167)**
Bathe/shower child	83.78	38.90	31.32	82.50	32.00	27.54
Make things with child	41.90	23.60	21.43	34.50	17.06	14.97
Sing to child	46.66	16.67	9.34	36.22	12.31	8.38
Read to child	80.45	52.26	34.07	78.35	47.82	31.14
Play with toys	50.41	41.47	36.81	38.43	33.10	27.54
Cuddle	96.40	85.84	72.53	96.20	82.82	66.47
Active play with child	25.63	43.74	38.46	20.62	37.45	33.53
Take to park/ playground	31.96	23.98	22.53	25.47	19.55	20.36
Put child to bed	83.65	53.59	45.60	84.16	48.95	44.31
Take swimming	31.16	18.39	13.19	30.15	15.82	8.98
Draw/paint with child	38.00	15.24	13.74	26.73	10.38	13.77
Prepare food for child	93.34	30.12	37.91	93.60	27.21	32.93
	Mean(sd)	**Mean(sd)**	**Mean(sd)**	**Mean(sd)**	**Mean(sd)**	**Mean(sd)**
Parenting Score (Range: 0-10)	8.34 (1.01)	6.93 (1.54)	6.62 (1.61)	8.12 (1.01)	6.66 (1.54)	6.36 (1.69)

Table 4.2: Descriptive statistics of all variables included in analyses of Chapter 4. Analysis-specific variables are those specific to models for each child outcome. Analysis-general variables were used in all models.

N = 12895	Range	Mean	SD	N	%
Analysis-Specific Variables					
Height					
Height (cm)	104.4 - 147.5	125.65	5.38	7210	-
Age (months)	80 - 110	90.33	2.36	7269	-
Mother's Height (cm)	124.46 - 200.66	163.96	6.74	11370	-
Gestation Length (weeks)	24 - 46	39.40	1.93	12406	-
Birth Length (cm)	32.5 - 62	50.68	2.45	9742	
School Test Score					
Test Score	0 - 15	9.16	3.75	10426	-
Age (months)	78 - 101	88.38	3.75	10476	-
Behavioural Difficulty Score					
Behavioural Difficulty Score	0 - 31	7.48	4.76	7832	-
Age (months)	80 - 101	81.44	3.74	7844	-
Analysis-General Variables					
Sex of Child	-	-	-	12892	-
Male (ref)	-	-	-	6652	51.60
Female	-	-	-	6240	48.40
Ethnicity of Child	-	-	-	11286	
White (ref)	-	-	-	10712	94.91
Other	-	-	-	574	5.09
Number of Siblings in Household	0 - 11	1.37	0.88	7735	-
Mother's Age at Birth of Child	15 - 44	27.99	4.97	12894	-

Table 4.2, continued: Descriptive statistics of all variables included in analyses. Analysis-specific variables are those specific to models for each child outcome. Analysis-general variables were used in all models.

	Range	Mean	SD	N	%
Mother's Education Level	-	-	-	11617	-
O-Level/Equiv. (ref)	-	-	-	7489	64.47
A-Level	-	-	-	2625	22.60
Degree	-	-	-	1503	12.94
Mother's Employment	-	-	-	9509	-
Never	-	-	-	2341	24.62
Some	-	-	-	2561	26.93
Constant	-	-	-	4607	48.45
Partner's Employment	-	-	-	9192	-
Never	-	-	-	457	4.97
Some	-	-	-	687	7.47
Constant	-	-	-	8048	87.55
Home Ownership	-	-	-	7635	-
Renting (ref)	-	-	-	1093	14.32
Owned	-	-	-	6542	85.68
Financial Difficulty	0 - 15	2.08	3.03	7708	-
Average Weekly Income	-	-	-	8906	-
<£200 p/wk. (ref)	-	-	-	1559	17.51
£200 to £399 p/wk.	-			4064	45.63
>£400 p/wk.	-	-	-	3283	36.86
Stepfather	-	-	-	7729	-
Father (ref)	-	-	-	7483	96.82
Stepfather	-	-	-	246	3.18
Mother Score	2.22 - 10	8.24	0.96	8906	-
Partner Score	0 - 10	6.68	1.56	8300	-

4.2.3 Analyses

First, as found previously in the full ALSPAC sample (Lawson & Mace, 2009a), I carried out checks in this particular subsample to see if partner scores were lower for stepfathers than fathers, and mother scores were lower if her partner was the child's stepfather rather than father. I then carried out multiple imputations of missing values with chained equations using the -mi impute chained- command in STATA SE 12. Multiple imputations using chained equations generate multiple datasets with statistical estimates of missing values based on available data. Once imputations are complete, each generated dataset is analysed separately. The outputs from these datasets are combined to produce the most plausible results with the estimated missing values (Sterne et al., 2009; White, Royston & Wood, 2011; Schafer & Graham, 2002).

Multiple imputations assume that missing information is missing at random based on the predictors entered into the model. This assumption is likely to hold in the current dataset and methods: In ALSPAC, the risk of non-response has been identified to be higher for households with male cohort children and lower socio-economic status (Boyd et al., 2012). In the current analyses, I include information on sex of child and multiple predictors of socio-economic status. The appropriate number of imputations was determined using methods outlined in White, Royston & Wood (2011), where 1) the Monte Carlo error of the estimated parameters are approximately 10% of their standard errors, 2) the Monte Carlo error of the test statistics (parameter estimate / standard error) are approximately 0.1, and 3) the Monte Carlo error of the *P* value is approximately 0.01 when *P*=0.05. This resulted in carrying out 100 imputations. While this number of imputations may seem large especially as some recommend as little as 5 (Allison, 2000), others have argued that more imputations are necessary for accuracy and consistency, and 100 imputations have been noted as acceptable (White, Royston & Wood, 2011). The main benefits of imputations are that it permits use of all available information in the final sample, increasing efficiency, as well as reducing bias in estimations and standard errors (Sterne et al., 2009; Schafer & Graham, 2002). This is particularly important in the current analyses due to the relatively small number of stepfather households in the sample. Note that, with multiple imputations, postestimation procedures of the final results, such as model fit comparisons, are not applicable due to pooling of the results.

For school test score, I ran normal linear regressions due to the normal distribution of the outcomes. For behavioural difficulty score, I ran Poisson regressions due to the Poisson distribution with no overdispersion of the outcome. For each of the three outcomes, I ran 5 models: The first, along with the controls, only included stepfather

presence (*Presence Model*). This is analogous to most other papers exploring stepfather effects on child outcomes. To this base model, I added mother score (*Mother Model)*, partner score (*Partner Model)*, and mother and partner score (*Mother & Partner Model*). This controls for the associated differences in within-household direct investment levels between father and stepfather presence. Finally, I added an interaction term between stepfather presence and partner score (*Interaction Model)*. This allows us to investigate whether direct investments from stepfathers differ in its effect on child outcomes from fathers. Note that mother score, partner score, children's age, and mother's age at birth were mean centred to ease interpretation of the results, where the intercept is modelled at the average point of these values rather than the improbable or unlikely "0" value.

4.3 Results of Chapter 4

4.3.1 Mother and Partner's Investment Scores

A two-sample t-test with unequal variances showed that there is a significant difference in partner scores between fathers (Mean±SD=6.79±1.48, N=6874) and stepfathers (Mean±SD=6.45±1.54, N=193) (t_{202}=3.04, P=0.003), where the mean of fathers is significantly larger than the mean of stepfathers (P=0.001) (fig. 4.1). Furthermore, a two-sample t-test with unequal variances showed that there is a significant difference in the mother scores between father presence (Mean±SD=8.25±0.94, N=6891) and stepfather presence (Mean±SD=8.07±1.08, N=202) (t_{202}=2.29, P=0.023), where the mean is significantly larger if fathers are present in the household rather than stepfathers (P=0.012) (fig. 4.2). These results confirmed that, as in the full ALSPAC sample, stepfathers in our subsample invest less than fathers, and that mothers in our subsample invest less when stepfathers are present in the household.

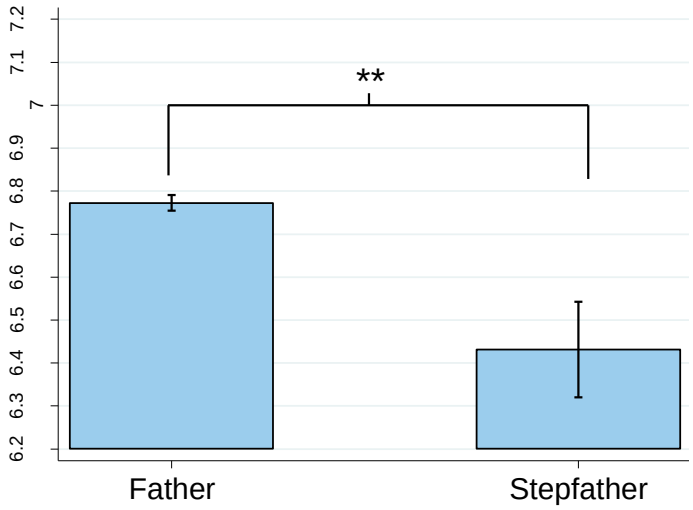

Fig 4.1: Partner score by father and stepfather. ***P*=0.003.

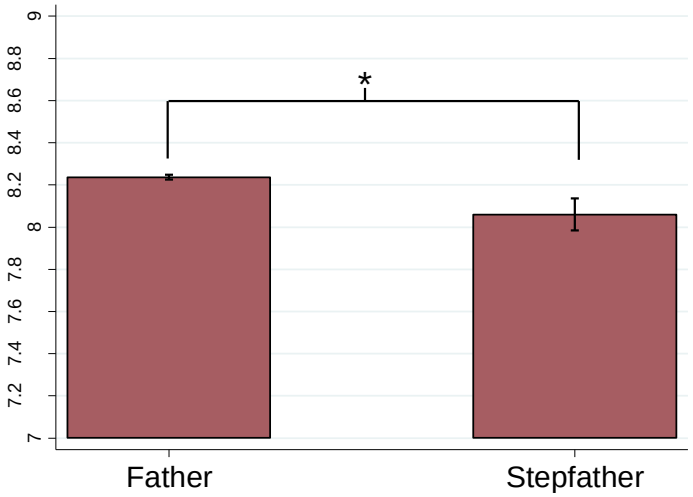

Fig. 4.2: Mother score by father and stepfather. **P*=0.012.

4.3.2 Main Analyses

Table 4.3 displays the key results for all three outcomes. The full results of the interaction models with information on all control variables are available in table 4.4.

For height, I did not find a stepfather effect in that there was no statistically significant difference in children's height whether there was a father or a stepfather present in the household. This did not change whether mother score or partner score was added into the

model. The interaction between stepfather presence and partner score was also not significant. Note, the exact same pattern was found for BMI (results not shown in chapter; see Appendix Table A2 and A3).

For school test score, stepfather presence was initially a significant predictor, where stepfathers in the household predicted a lower test score by -0.5 points. This fell to -0.479 in the mother model, though it retained significance at the $P \leq 0.05$ level. In the partner model, the inclusion of partner score dropped the negative stepfather presence effect to a greater degree to -0.476, and stepfather presence was no longer a significant predictor of children's test scores. The inclusion of both mother score and partner score in the same model further dropped the coefficient of stepfather presence to -0.469, and partner score was the only significant predictor of children's test score. The interaction between stepfather presence and partner score was not significant. Overall, this suggests that the negative effect associated with stepfather presence on children's educational achievement is primarily driven by the lower direct investment levels provided by stepfathers compared to fathers; the effects of direct investments do not differ whether it comes from the father or the stepfather.

For behavioural difficulty score, stepfather presence was associated with a 10.9% increase in the behavioural difficulty scores of children in the presence model. Controlling for mother score did not alter this negative effect, where stepfather presence was still associated with an 11% increase in behavioural difficulty score. An inclusion of partner score reduced the negative effects of stepfather presence to a 10.1% increase in behavioural difficulty score, though stepfather presence still retained significance at the $P \leq 0.01$ level. Including both mother score and partner score lowered the negative effects further to 9.3%, but again it remained significant at the $P \leq 0.01$ level. An interaction between stepfather presence and partner score was significant, where the positive effect of partner score associated with lower behavioural difficulties was not seen if the direct investments were provided by the stepfather (fig. 4.3). Interestingly, there is no significant difference between low father score and stepfather presence (regardless of partner score), where both predict higher levels of BDS compared to higher levels of partner score (fig. 4.3).

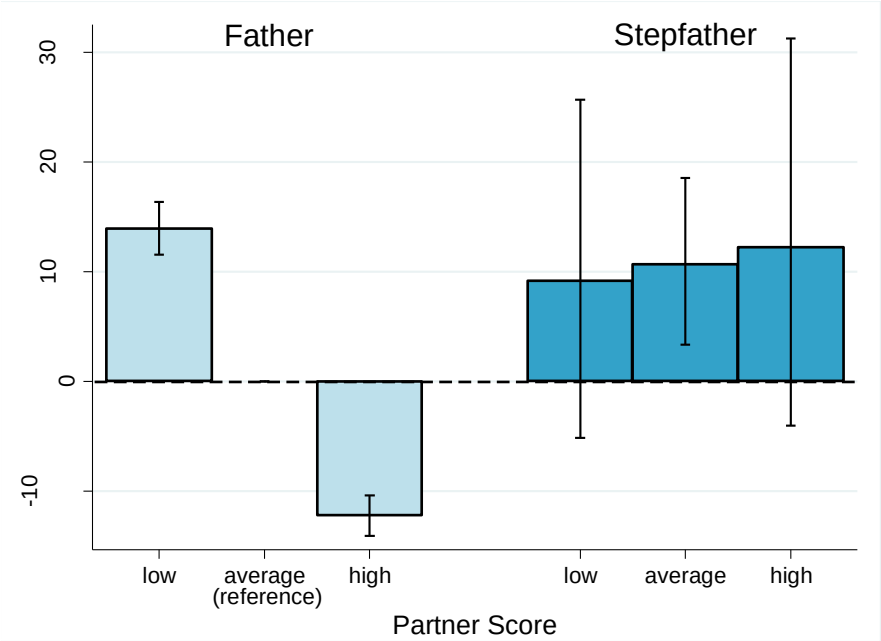

Fig. 4.3: Predicted difference in behavioural difficulty score (%) by father and stepfather partner score.

Specifically, compared to children with fathers who invest at the mean level, children with high investing fathers (+3 partner score) had 12% lower BDS (IRR= 0.878, 95% CI= 0.869-0.896, *P*≤0.001) while children with low investing fathers (-3 father score) had 14% higher BDS (IRR= 1.139, 95% CI= 1.115-1.163, *P*≤0.001). In contrast, compared to children with stepfathers who invest at the mean level, there was no significant differences in BDS between children with high investing stepfathers (+3 partner score) (IRR= 1.014, 95% CI= 0.889-1.157, *P*=0.836) or low investing stepfathers (-3 partner score) (IRR= 0.986, 95% CI= 0.864-1.125, *P*=0.836). Overall, this suggests that the negative effect associated with stepfather presence on children's socio-emotional development is partly driven by the ineffectiveness of direct investments from stepfathers. Furthermore, stepfather presence continued to be associated with detrimental effects on children's behavioural difficulties after controlling for within-household direct investments. This suggests that there are additional factors associated with stepfather presence which negatively impacts children's socio-emotional development.

Table 4.3: Key results for multiply imputed regression models: father and stepfathers on height, school test score and behavioural difficulty score.

N = 12895	Presence		Mother Score		Partner Score		Mother & Partner Score		Interactions	
	B	**se**	**B**	**se**	**B**	**se**	**B**	**se**	**B**	**se**
Height (cm)										
Stepfather (ref: Father)	0.369	0.415	0.374	0.416	0.378	0.416	0.379	0.416	0.272	0.421
Mother Score	-	-	0.033	0.058	-	-	0.008	0.062	0.008	0.062
Partner Score	-	-	-	-	0.059	0.043	0.058	0.045	0.071	0.045
Stepfather * Partner Score	-	-	-	-	-	-	-	-	-0.437	0.263
School Test Score										
Stepfather (ref: Father)	-0.500*	0.243	-0.479*	0.243	-0.476†	0.244	-0.469†	0.244	-0.458†	0.251
Mother Score	-	-	0.114**	0.044	-	-	0.067	0.046	0.067	0.047
Partner Score	-	-	-	-	0.119***	0.029	0.107***	0.031	0.106***	0.031
Stepfather * Partner Score	-	-	-	-	-	-	-	-	0.046	0.195
	IRR	**95%CI**	**IRR**	**95%CI**	**IRR**	**95%CI**	**IRR**	**95%CI**	**IRR**	**95%CI**
Behavioural Difficulty Score										
Stepfather (ref: Father)	1.109**	1.037, 1.187	1.110**	1.025, 1.173	1.101**	1.029, 1.178	1.093**	1.021, 1.169	1.107**	1.034, 1.184
Mother Score	-	-	0.923***	0.914, 0.931	-	-	0.939***	0.930, 0.948	0.939***	0.930, 0.948
Partner Score	-	-	-	-	0.950***	0.943, 0.956	0.959***	0.952, 0.965	0.957***	0.951, 0.964
Stepfather * Partner Score	-	-	-	-	-	-	-	-	1.049*	1.003, 1.097

†$P \leq 0.10$ *$P \leq 0.05$, **$P \leq 0.01$, ***$P \leq 0.001$

Table 4.4: Full results for the interaction models: fathers and stepfathers on height, school test score and behavioural difficulty score.

	Height (cm)		School Test Score		BDS	
	B	**se**	**B**	**se**	**IRR**	**95%CI**
Mother's Height (cm)	0.273***	0.009	-	-	-	-
Birth length (cm)	0.505***	0.026	-	-	-	-
Gestation length (weeks)	0.027	0.030	-	-	-	-
Child's age (months)	0.460***	0.023	0.236***	0.009	1.013***	1.007, 1.019
Child's sex (ref: Male)						
Female	-0.549***	0.111	1.023***	0.066	0.869***	0.855, 0.884
Child's ethnicity (ref: White)						
Other	1.426***	0.292	0.089	0.202	0.947*	0.900, 0.995
Number of siblings in household	-0.469***	0.070	-0.156***	0.047	0.971***	0.961, 0.980
Mother's age at birth (yrs.)	0.045***	0.014	0.041***	0.010	0.993***	0.991, 0.994
Mother's education (ref: O-Level/Equiv.)						
A-Level	0.124	0.136	0.996***	0.089	0.966***	0.946, 0.986
Degree	-0.185	0.183	2.075***	0.125	0.941***	0.914, 0.968
Mother's employment (ref: Never)						
Some	-0.390*	0.165	0.341**	0.107	0.986	0.962, 1.011
Constant	-0.025	0.163	0.256*	0.101	0.972*	0.949, 0.996
Partner's employment (ref: Never)						
Some	0.128	0.378	0.333	0.237	1.002	0.947, 1.061
Constant	0.066	0.332	0.570**	0.203	0.970	0.923, 1.018
Home Ownership (ref: Renting)						
Owned	0.151	0.240	1.079***	0.168	0.952***	0.924, 0.981
Financial Difficulty	-0.018	0.024	-0.028	0.018	1.027***	1.024, 1.031
Average Weekly Income (ref: <£200p/wk.)						
£200 to £399p/wk.	0.207	0.240	0.508**	0.183	1.031	0.998, 1.064
>£400p/wk.	0.176	0.252	1.024***	0.263	0.977	0.941, 1.014
Stepfather (ref: Father)						
Stepfather	0.272	0.421	-0.458	0.251	1.107**	1.034, 1.184
Mother Score	0.008	0.062	0.067	0.047	0.939***	0.930, 0.948
Partner Score	0.071	0.045	0.106***	0.031	0.957***	0.951, 0.964
Stepfather*Partner Score	-0.437	0.263	0.046	0.195	1.049*	1.003, 1.097
Constant	126.137***	0.359	6.660***	0.276	8.593***	8.155, 9.054

*$P \leq 0.5$, **$P \leq 0.01$, ***$P \leq 0.001$ Note, for BDS, the constant displays the coefficient rather than IRR.

4.4 Discussion of Chapter 4

4.4.1 Main Findings of Chapter 4

In this chapter, I investigated whether the negative effects associated with stepfather presence were driven by the reduced quantity and quality of direct investments children receive within the household, or whether stepfather presence led to detrimental effects on child development regardless of direct investments. I specifically explored if stepfather presence effects were driven by 1) levels of maternal direct investments in the household, 2) differences in the levels of stepfather/father direct investments in the household, and 3) differences in the effectiveness of stepfather/father direct investments. Ultimately, this would highlight the role of stepfathers as allomothers in the UK childrearing system. Given the importance of fathers on child development highlighted in Chapter 3, how does an unrelated male as a carer influence child quality in contemporary developed contexts?

Firstly, I found no stepfather presence effects on height. It may be that stepfather presence does not affect the physical development of children, but it could be that stepfather effects were not found due to lack of analytical power. The latter scenario is more likely considering our significant findings of father score on children's height in the previous chapter, which was not replicated in the current series of analyses. Investment effects on height are generally small. In Chapter 3, we saw that a 1 point increase in father score was associated with a 10 to 13 mm reduction in height. In a longitudinal analysis of children from birth to age 10 using ALSPAC, stepfather presence was associated with a change of 8.7mm to 9.9mm in children's height (Lawson & Mace, 2008). In both cases, a longitudinal approach was taken which allowed for larger sample sizes and more cases, increasing power. Unfortunately, this was not possible in the current study due to household changes which follow longitudinal formats. The problem is in that we cannot simultaneously include information on single mother households, direct investment levels and change in family structure: As there is no information on absent-father investments for single-mother households, there are issues of perfect collinearilty between lack of partner score and single mothers. Without including single mother households, however, we are unable to track change in family structure. Overall, it is likely that the number of stepfathers in our current study was too small to pick up any stepfather effects on height with our cross-sectional approach.

In addition, it is likely that our sample of stepfather households may be slightly different from other studies, in that stepfathers had entered the household at a relatively young age and household structures were stable. Therefore, the negative effect of

stepfather presence on child outcomes in this study may be smaller compared to other studies. Combining these two points, it is likely that I was simply unable to capture stepfather effects on height.

In contrast, for school test score and behavioural difficulty score, there was a significant negative effect of stepfather presence in the household. For school test score, the negative effects of stepfather presence was reduced when mother score was added to the model, and the negative effect of stepfather presence was reduced to a greater extent and lost its significance when partner score was added to the model. However, the positive effect of direct investment on children's educational achievement was the same whether it was provided by the father or stepfather.

This suggests that the negative effect of stepfather presence on children's educational achievement is primarily due to the lower levels of direct investments children receive within stepfather households. Furthermore, stepfather investment itself has a positive effect, and the negative stepfather effect on educational achievement may be overcome if stepfathers are encouraged to interact more with their stepchildren. This is in contrast to previous literature in developed populations exploring stepfather presence which suggest stepfathers are "bad" for child development. It seems that stepfather presence, independent of investment levels, does not trigger the children to achieve lower levels of cognitive development as would be expected following the ideas proposed by Belsky, Steinberg & Draper (1991). In fact, the current results suggest that stepfather direct investments can lead to greater child quality regarding cognitive development. These findings in ALSPAC differ from that of Lawson & Mace (2009b), where they found that stepfather presence had no significant effect on educational achievement at age 4/5 yrs. and 6/7 yrs. However, I believe this difference is driven by sample size. Lawson & Mace (2009b) took a cross-sectional approach as I have here, but did not impute missing values. This left their analyses with a comparatively smaller sample size (N=3762 for 4/5 yrs., N=4638 for 6/7yrs), potentially leading to lack of power through small numbers of stepfathers and less accurate estimates.

Secondly, for behavioural difficulty score, the negative effect of stepfather presence was not affected when mother score was added to the model. However, the negative effect of stepfather presence was reduced when partner score was added to the model, suggesting differences in investments between fathers and stepfathers partly drive the stepfather effect. Furthermore, direct investments provided by stepfathers had no beneficial effect on children's behavioural difficulty score. Overall, this suggests that the negative effect of stepfather presence on children's socio-emotional development is due to multiple factors:

First, unlike paternal direct investments, children's behaviour is unlikely to improve however much stepfathers invest in children. This could suggest that paternal direct investments may not be substitutable with stepfather investments for children's socio-emotional development. Reduced paternal investments, combined with the ineffectiveness of stepfather investments, are both likely to contribute to the higher levels of behavioural difficulties for children in stepfather households. Unlike with school test score, this suggests that the negative effect of stepfather presence on children's socio-emotional development is unlikely to be overcome even if stepfathers are encouraged to interact more with their stepchildren.

Second, stepfather presence was associated with detrimental effects on children's behavioural difficulties irrespective of within-household direct investment levels. Note that this does not necessarily mean stepfathers directly cause negative effects on children's socio-emotional development. While I took steps to minimise unobserved heterogeneity, stepfather households are inherently associated with greater family disruption which could be contributing to the detrimental effects. Overall, what these results suggest is that stepfather presence is associated with detrimental effects on children's behaviour, independent of the quality and quantity of direct investments within the household. This result is in line with Belskey, Steinberg & Draper (1991), where stepfather presence and the associated household instability may serve as a cue of environmental instability for children, prompting them to take a faster life history approach in terms of socio-emotional development.

The aim of the chapter was to disentangle the mechanism behind stepfather effects on child development. Previous studies have shown that stepfather presence is detrimental to child quality, while at the same time studies shows stepfathers do provide investments to their unrelated children. This lead to the question, why are stepfathers having negative effects even when children are receiving investments from an extra adult? Overall, the current results suggest that the mechanism behind the "negative stepfather effects" on child development may be outcome specific: Children's cognitive development is influenced by the reduced direct investments in stepfather households, while children's socio-emotional development is influenced by the lack of paternal investments as well as factors related to stepfather presence itself. While this chapter does not address why these differences exist, it may be that children's socio-emotional development is more susceptible to cues of environmental instability (e.g., stepfather presence) compared to cognitive development. This could be an adaptive mechanism if lower levels of socio-emotional development encourages faster life history strategies such as earlier age at

reproductive maturation and greater risk-taking. Ellis et al. (2003) has found that father absence in the U.S. and New Zealand is associated with internalising and externalising problems as well as early sexual activity and pregnancy in girls, though the causality between behavioural difficulties and sexual risk-taking is unclear in this particular study. However, another study from New Zealand suggests that conduct problems leads to adolescents engaging in risk-taking behaviours such as risky sexual behaviour and substance use (Fergusson & Woodward, 2000), suggesting that lower socio-emotional development may indeed encourage faster life history strategies.

The findings from the chapter suggests that stepfathers could have a positive impact for some aspects of child quality through their direct investments. However, given that stepfather investments are thought to predominantly serve as mating effort, it would be unusual for stepfathers to invest as much as fathers who have the added incentive of parenting effort. Furthermore, stepfather investments for some aspects of child quality may have negligible effects. From the child's perspective, this suggests that having a stepfather as an allomother may not necessarily be beneficial regarding child quality/embodied capital. However, stepfathers may be an important addition for mothers regarding their future reproductive output. Stepfather households may be a case where mothers "win" in the parent-offspring conflict, where an allomother enters the household not to improve investments into current offspring, but as investments towards future offspring.

4.4.2 Limitations of the Current Analyses

In the current study, I tried to minimise confounds related to stepfather presence with the sample selection criteria which required that households were stable, and that stepfathers entered the household at a very young age. Furthermore, I included a wide range of controls in attempt to minimise such problems. Nonetheless, there is the possibility that our findings could be driven by other unexplored characteristics specifically associated with stepfather households. In particular, one aspect I was unable to explore was the effect of absent fathers on child development, which may influence or interact with stepfather presence.

Unfortunately, detailed information on investments by absent fathers is unavailable in ALSPAC. Furthermore, there are methodological issues with perfect correlation between stepfather presence and father absence, meaning the effect of absent fathers cannot be analysed within the current framework where stepfather effects are compared against

father-present households. Stepfather presence is usually met with the reduction in the involvement by non-resident fathers (Furstenberg, Morgan & Allison, 1987; Christensen & Rettig, 1996; Juby et al., 2007), whose investment levels are already significantly lower than live-in fathers (Anderson, Kaplan & Lancaster. 1999a, 1999b; Gibson-Davis, 2008). It may be that the negative effect of stepfather presence on behavioural difficulties (controlling for maternal and stepfather direct investments) is driven by the lack of investments by absent fathers. If so, this would complement my suggestion that paternal direct investments may not be substitutable for children's socio-emotional development.

There is also a possibility that the effects attributed to the levels of stepfather investments may in fact be due to correlated levels of paternal investment from non-resident fathers. Recent studies suggest that there is no correlation between stepfather involvement and absent-father involvement within stepfather households (e.g., Jensen & Shafer, 2013; King, Thorsen & Amato, 2014), while others have found that contact with non-resident fathers negatively correlate with the quality of stepfather-child relationships (e.g., MacDonald & Demaris, 2002). If the effects of stepfather investments are driven by the negative correlation with absent-father investments, we would expect high stepfather investments to have no, or even a negative, effect on child outcomes. In fact, I found the opposite result on educational achievement where stepfather investments were associated with a positive effect on test scores. Thus, it is unlikely that the effect of stepfather investments on educational attainment is driven by absent-father investments. In contrast, absent-father investments could be an important factor for behavioural difficulty, as stepfather investments were found to be ineffective. If so, this complements my suggestion that paternal direct investments may be particularly important for children's socio-emotional development. For future studies, it would be interesting to investigate if and how stepfather presence effects are affected by absent fathers.

One unaddressed issue, especially relevant if stepfather investments exist as mating effort, is the impact of sibling competition. While I control for additional births which include half-siblings from stepfathers, whether the impact of stepfathers differ after the birth of a half-sibling has not been explored. Lawson & Mace (2009), using similar ALSPAC data, have shown that each additional sibling leads to lower levels of direct parenting per child. Under HBE, we would expect stepfather parenting for focal children to decrease with a birth of a half-sibling even more than expected in paternal parenting, as stepfathers have a greater incentive to invest in their biological child. In stepfather households, focal children may lose out a greater proportion of direct investments to half-siblings. While I control for investment levels the focal child receives, which should partially address the

issue of half-siblings, this sibling competition could impact focal children in other ways. For instance, the quality of stepfather parenting, not captured in the current parenting scores, could decrease as stepfathers have less incentive to provide high quality direct investments. A greater level of sibling competition may serve as a cue of environmental harshness, which may encourage children to follow a faster life history strategy. This could mean that the "negative" effect of stepfather presence may be greater and stepfather direct investments less effective in stepfather households with half-siblings.

Finally, it is important to note that our current sample of stepfather households is unusual in that stepfathers entered the household when children were very young, with household stability across time-points. While this allowed us to compare father and stepfather households, the negative effects on child outcomes associated with stepfather presence may be underestimated compared to the wider population. However, some academics suggest that early family disruption (between birth and age 7), has the greatest impact on child outcomes, potentially capturing children during their critical period of development regarding the adjustment of life history trajectory (Draper & Harpending, 1988; Belsky, Steinberg & Draper, 1991; Ellis et al., 2003). In the U.S. and New Zealand, father absence before age 5 had the greatest impact on girls' sexual maturity, where father absence in the first few years of life was associated with earlier sexual activity and pregnancy. If so, we are still likely to capture the impact of stepfather presence as an environmental cue of instability within the current analyses.

4.4.3 Conclusions: The Importance of Stepfathers as Allomothers in the UK

Despite the limitations, our findings highlight the potential influence of direct investments which contribute to the negative effects of stepfather presence regarding children's developmental outcomes. For school test score in particular, direct investment levels seem to drive stepfather effects, and other confounding factors specifically associated with stepfather presence are likely to be inconsequential. With behavioural difficulty score, stepfather presence effects persist even after controlling for investment levels. Therefore, it is possible that other confounding characteristics associated with stepfather households may be resulting in the observed detrimental effects on children's socio-emotional development.

The current study has shown that the differences in quantity and quality of investments between fathers and stepfathers within the household may explain, at least in part, why stepfather presence is associated with negative effects on child development. First,

children may be receiving lower levels of direct investments within stepfather households. Second, for some aspects of development, the direct investments from stepfathers may be ineffective. Our findings suggest that, for children's educational achievement in particular, the negative effects associated with stepfather presence may be overcome if stepfathers are encouraged to interact more with their stepchildren. However, for children's behavioural difficulties, encouraging stepfathers to interact with stepchildren is unlikely to have positive effects.

Are stepfathers important allomothers in terms of childrearing in the UK? From the available literature and the current result, we could conclude that they are not. Overall, stepfather presence is generally negative for child development outcomes. This is due to multiple factors, including the trend that stepfathers invest less, and these investments may be less effective compared to fathers. However, we could also argue that there is potential for stepfathers to be important allomothers, and they may indeed be important in certain households. The current results suggest that stepfather direct investments do have benefits on some child outcomes, meaning there is scope for stepfather presence to have positive effects. In contexts where other allomothers are unavailable and mothers are dependent on investments from her partner, we could speculate that stepfathers could be a particularly important source of direct investments. However, for the majority of households stepfathers may not be beneficial allomothers from the child's perspective in contemporary developed populations such as the UK, especially given that stepfathers may be present to invest in reproduction, leading to greater sibling competition between children in the household.

Part 2: Grandparents

Chapter 5: Introducing Part 2 and the MCS Dataset

5.1 Aims of Part 2

5.1.1 Theoretical Background: The Determinants of Grandparental Effects on Child Outcomes

In Chapter 1, we saw that grandparents can often have positive effects on child survival in high fertility, high mortality populations. In their review, Sear & Coall (2011) found that maternal grandmothers seem to be particularly important in these populations, with their presence linked to a reduced risk in child mortality in nine out of 13 cases (69%). This was followed by paternal grandmothers who had a beneficial effect on child survival in ten out of 18 cases (55%). Grandfathers seemed to be the least important overall, with maternal grandfathers having a positive effect in two out of 12 cases (17%) and paternal grandfathers having a positive effect in three out of 13 cases (23%). Interestingly, paternal grandfather presence had the highest frequency of detrimental effects on child survival, with four out of 13 cases reporting an increase in child mortality.

Overall, Sear & Coall (2011) found a relatively consistent positive effect of grandmothers, particularly in maternal grandmothers. At the same time, there is clear variation between the populations in terms of which combination of grandparents have beneficial effects on child survival. For instance, Sear et al. (2002) found that maternal grandmothers were the only grandparent type to have positive effects on child survival in rural Gambia, while Tymicki (2009) found that all categories of grandparents had positive effects in 18th century Poland. This indicates, perhaps, that multiple factors are influencing the levels of allomaternal investments by individual grandparents. In the following section, I elaborate on some of these factors raised in Chapter 1, and introduce further points to consider regarding the determinants of grandparental investment and the consequent effects on child outcomes.

Lower Cost for Grandmothers

From a behavioural ecological perspective, the determinants of grandparental investments should be related to the cost and benefits to direct and indirect fitness (Coall & Hertwig, 2010). There is reason to believe that these costs and benefits differ between

grandparent type, and between populations, leading to the observed patterns across societies. For instance, it has been proposed that grandmothers are a particularly important type of allomother due to their reproductive cessation which usually occurs between ages 45 and 60 (Hrdy, 2005b; 2007; Coall & Hertwig, 2010). The grandmother hypothesis proposes that the menopause and the extended postreproductive lifespan in females coevolved due to the importance of grandmothering for successful childrearing in humans (Hawkes et al., 1998). While there is still debate surrounding the evolution of the menopause and the longer lifespan (e.g., Morton et al., 2013; Skjærvø & Røskaft, 2013), the fact remains that women go through reproductive cessation potentially followed by decades of life. Due to their inability to produce their own offspring, grandmothers should experience low direct fitness costs and high indirect fitness benefits through allomaternal investments. Compared to grandfathers, grandmothers should have a bigger incentive to assisting in the reproduction and childrearing efforts of their children. This may explain why grandmother presence is repeatedly found to have protective effects against child mortality across multiple populations. However, this alone does not explain why maternal grandmothers are more frequently found to have positive effects than paternal grandmothers.

Differences in the Costs and Benefits between Grandparent Types

The differences in the frequency of positive effects found between maternal and paternal grandmothers may be linked to paternity uncertainty, where higher degrees of uncertainty reduces the inclusive fitness benefits in allomaternal investments by grandparents (Coall & Hertwig, 2010). Following paternity uncertainty alone, we would expect investments to be highest for maternal grandmothers, followed equally by maternal grandfathers and paternal grandmothers (1 degree of uncertainty), and finally followed by paternal grandfathers (2 degrees of uncertainty) (Bishop et al., 2009). Combining this with the suggestion that grandmothers experience lower costs in allomaternal investments, we would expect the investment levels and the associated positive effects of grandparents to follow: maternal grandmothers > paternal grandmothers > maternal grandfathers > paternal grandfathers. Indeed, the frequency of positive grandparent effects across traditional populations reviewed in Sear & Coall (2011) seems to reflect this pattern.

A further point to consider is that the quality of grandchildren may be of higher importance for maternal rather than paternal grandparents (Mace & Sear, 2005). To

elaborate, a "poor quality child" is likely to be more costly to the reproductive success of mothers than fathers, as mothers experience a higher cost of reproduction than fathers and female fecundity is lower than male fecundity, meaning mothers have a reduced opportunity to "make up" for the poor quality by increasing fertility. To maximise their own inclusive fitness, maternal grandparents may have a greater interest in making sure their grandchildren is of good quality. If so, maternal grandparents may invest more than paternal grandparents. Furthermore, paternal grandparents may push mothers to have more children and invest less in child quality, as the optimal fertility for fathers is likely to be higher due to the lower reproduction costs (Mace & Sear, 2005; Coall & Hertwig, 2010). This incentive for paternal grandparents to push for offspring quantity over quantity may lead to intergenerational conflict between mothers and paternal grandparents. In situations where mothers "lose out," associations with paternal grandparents could lead to higher fertility but lower offspring quality. In rural Gambia, for instance, paternal grandparents were associated with greater maternal fertility (Sear, Mace & McGregor, 2003), while maternal grandmothers improved the nutritional status and the survival of children (Sear, Mace & McGregor, 2000). This difference in optimal strategies between maternal and paternal grandparents could explain why paternal grandparents, compared to maternal grandparents, are less likely to positively impact offspring survival across traditional populations.

In western developed populations, maternal grandmothers are usually found to invest the most, and paternal grandfathers the least. However, the difference between maternal grandfathers and paternal grandmothers seem to vary between studies. For instance, in a sample of US college students with grandparents, maternal grandmothers were reported to have invested the most, followed by maternal grandfathers who invested equally as paternal grandmothers, followed by paternal grandfathers who invested the least (Bishop et al., 2009), while in the Netherlands maternal and paternal grandmothers were found to invest more than grandfathers (Kaptijn et al., 2013). Other studies have found that maternal grandmothers invest the most, followed by maternal grandfathers, paternal grandmothers, and finally paternal grandfathers (Germany: Euler & Weitzel, 1996; UK: Lussier et al., 2002; Germany & US: Chrastil et al., 2006; UK: Pollet et al., 2008; Europe: Danielsbacka et al., 2011).

Overall, previous research strongly suggests that relatedness affects the costs and benefits of grandparental investments, in conjunction with other factors such as the lower investment cost for grandmothers and greater investment incentives for maternal grandparents. Considering all these points, we expect maternal grandmothers to invest

the most, paternal grandfathers the least, and maternal grandfathers and paternal grandmothers somewhere in between. However, a few populations exhibit investment patterns which do not follow this expectation. For example, studies using data from China (Kaptijn et al., 2013) and rural Greece (Pashos, 2000) both found that paternal grandparents, especially paternal grandmothers, invest more than maternal grandparents. This suggests there are other elements to consider which may affect the costs and benefits of grandparental investments.

Differences in Grandparental Investments by Local Context

The majority of research on grandparental investments in contemporary developed populations have taken place in the Western populations where descent systems are weakly patrilineal or ambilineal, and neolocal residence is relatively common (Reher, 1998). However, both the Chinese (Pashos, 2000) and the rural Greek (Kaptijn et al., 2013) populations function in a strong patrilineal cultural system with patrilocal residence. With children in these populations generally having greater proximity to paternal grandparents, there may simply be greater opportunities for paternal grandparents to invest, at a lower cost.

Another point to consider which may influence grandparental investments is the level of competition between kin members. A meta-analysis by Strassman & Garrard (2011), mainly using studies on patrilocal pastoralists groups, found that maternal grandparents were important for child survival despite not living with the children. This is in contrast to the study in China (Pashos, 2000) and rural Greece (Kaptijin et al., 2013), even though they are all patrilineal and patrilocal. Strassman & Garrard (2011) suggests that their results are driven by the high levels of competition between paternal grandparents and the mother/children in their populations. In their analysed populations, polygyny and communal living is relatively common, which may mean the levels of local resource competition between kin members who live together may be particularly high.

5.1.2 How Might Grandparents Affect Child Outcomes in the UK?

Overall, allomothering by grandparents are affected by the costs and benefits surrounding grandparental investments, which is likely to vary between grandparent types and local contexts. What is the typical context surrounding grandparenting in

contemporary developed populations such as the UK? What can we expect in terms of how grandparents affect child outcomes?

In Western developed populations, family structures have been described as "beanpoles" where kin networks are multigenerational and slim (Harper, 2003, 2005). The extended family networks are generally vertical, with three-generational networks being the norm, and four-generational networks also common (Harper, 2003, 2005). Consequently, grandparents are likely to be one of the most common types of allomothers within the extended family. The general lack of alternative kin members could mean that grandparents are an especially important source of allomothers, where they provide direct and indirect investments to parents and children. With neolocal residence being the norm, local resource competition as described in Strassman & Garrard (2011) could be minimal, encouraging investments from maternal and paternal grandparents. At the same time, societal shifts where families rely on "institutional allomothering" such as schooling, and a reliance on allomothers within the nuclear household (e.g., fathers and stepfathers) may mean grandparents as allomothers are nonessential with little consequence on child outcomes. Furthermore, with the difference in the costs and benefits surrounding allomaternal investments between maternal grandmothers/grandfathers and paternal grandmothers/grandfathers, the impact of allomothers investments may vary by grandparent type. For instance, investments from maternal grandparents may positively influence child quality, while investments from paternal grandparents may influence maternal fertility with neutral, or even a negative, effect on child quality.

Note, some scholars question whether grandparents provide investments at all in contemporary developed populations. With increased longevity, there have been suggestions that intergenerational transfers of wealth and other investments now go up the lineage from parents to grandparents, rather than grandparents to parents and children (e.g., Lee, 2007). This "upward flow" of investments clash with the idea that grandparents act as allomothers. If so, grandparents may have no effects, or even negative effects, on child outcomes. However, several studies have emerged which find that older generations are generally net givers rather than receivers. For instance, analysis on a large-scale European survey conducted in 2004 found that financial transfers and social support are predominantly given from the older generation to the younger (Albertini, Kohli & Vogel, 2007). Similarly, a longitudinal study in Germany found that intergenerational transfers of wealth and social support tended to flow down the generation, with grandparents helping parents and their children (Hoff, 2007). In Europe at least, it seems

that grandparents are in a position to provide direct and indirect investments for child rearing.

With this in mind, note that grandparents could affect children directly or indirectly. As covered in the introduction, grandparents may have direct effects by providing direct investments into children, and they could also have indirect effects by affecting parental investment levels which feed into child outcomes. Exploring direct effects are relatively straight forward, where we must simply focus on how grandparental direct investments affect child outcomes while controlling for parental investments. Exploring indirect effects are slightly more complex as we must focus on how grandparental investments affect parental investments, where the impact of grandparental investments may vary by the substitutability of parental investment behaviours as well as parental strategy (i.e., optimising quality or quantity).

Table 5.1 displays the expected associations between grandparental investments, parental investments and child quality depending on parental reproductive strategy and the substitutability of parental investments. Firstly, if parental investments are substitutable, we may expect that contributions by grandparents towards one dimension of investments would lead to a reduction in that dimension of parental investments (e.g., grandparent direct investments may lead to lower parental direct investments). However, if the parental strategy is to optimise child quality, grandparent investment substitutions in one dimension may increase parental investments in the other. For instance, grandparental substitutions in provisioning may lead to reduced levels of parental provisioning, but increased levels of parental direct care. Similarly, grandparental substitutions in direct care may lead to increased levels of parental provisioning. In both instances, we would expect grandparental investments to lead to greater child quality. Of course, if parents utilise the "spare" investments in other areas such as mating effort and optimising child quantity, grandparental substitutions will simply reduce parental investment levels. If so, we may expect grandparental investments to have minimal effects on child quality. Finally, if parental investments are not substitutable, grandparental investments should not affect parental investment levels. The extra investments children receive should lead to greater child quality.

Table 5.1: Expected associations between grandparental investments, parental investments and child quality by substitutability of investments and parental reproductive strategy.

Grandparental Investment:	Direct Investment		Indirect Investment	
	Sub.	**Add.**	**Sub.**	**Add.**
Parental Strategy: Child Quality				
Impact on…				
Parental Direct Investment	-	No Effect	+	No Effect
Parental Indirect Investment	+	No Effect	-	No Effect
Child Quality	+	+	+	+
Parental Strategy: Child Quantity				
Impact on…				
Parental Direct Investment	-	No Effect	No Effect	No Effect
Parental Indirect Investment	No Effect	No Effect	-	No Effect
Child Quality	No Effect	+	No Effect	+

Overall, there are many factors to keep in mind when exploring the effects of grandparents on child development in the UK: There is a need to consider the differences in the costs and benefits surrounding grandparent investments between grandparent types and the local contexts. We must also note that grandparents can affect children directly and indirectly, grandparental investments may substitute parental investments, and the impact of grandparental investments may vary by parental strategy. The aim of Part 2 is to investigate the importance of grandparents as allomothers in contemporary developed populations such as the UK. With this, I ask, how do grandparents affect maternal and paternal investment behaviours in the UK? How do grandparents affect child development outcomes in the UK? To tackle these questions, I use the UK Millennium Cohort Study (MCS). Below, I introduce MCS and the variables of interest, followed by a brief outline of the research question for Chapters 6 and 7.

5.2 MCS Dataset Description

The Millennium Cohort Study is an ongoing longitudinal cohort study which covers the whole of the UK (i.e., England, Wales, Scotland and Northern Ireland). Participants for the MCS were selected from the eligible recruitment pool of children born between 1st September and 31st August 2001 in England and Wales, and children born between 24th November 2000 and 11th January 2002 for Scotland and Northern Ireland. In addition, all children must have been alive and living in the UK at age 9 months, and eligible to receive child benefit. This means that the majority of children born in the millennium and shortly after were eligible, excluding some groups such as asylum seekers. The MCS intentionally oversampled children from particular backgrounds who are often underrepresented in cohort studies, such as children living in disadvantaged areas and ethnic minorities. In total, 18827 children were recruited belonging to 18552 households. The first sweep of data collection began at 9 months, and continues every 3 years on average. Sample attrition is relatively low, with 13857 households still participating at age 7. However, attrition rates have been higher for ethnic minorities and children from disadvantaged backgrounds. The full MCS cohort profile is available in Connelly & Platt (2014).

Like ALSPAC, MCS has collected data on various child outcomes including height, educational attainment and behavioural difficulty score. Compared to ALSPAC, the drawback of MCS is that the availability of information is less detailed in some areas such as parenting behaviour. Nevertheless, MCS is particularly useful regarding the current aims as they have information on grandparental behaviour, separating out the four categories of grandparents, which is often overlooked in other cohort studies including ALSPAC. As far as I am aware, MCS is the only large scale child-focused dataset in Europe where behaviours on individual grandparents have been collected.

5.3 Key Variables of the MCS for Part 2

Throughout Part 2, I focus on the same key variables. Some of these are similar to variables used in Part 1: As proxies of direct investments from mothers and fathers, I use their parenting scores. Additionally for mothers, I use breastfeeding initiation and duration as a type of direct investment. As proxies of child development, I use children's height, test scores, and behavioural difficulty scores. Grandparental investments are specific to Part 2, and to capture this I use grandparental contact frequency and financial investment. Information for these variables have been collected across 4 sweeps, when focal children were roughly 9 months, 3 years, 5 years and 7 years old.

5.3.1 MCS Measures of Parental Investment

Parenting Scores

Unlike ALSPAC, MCS has not specifically collected parenting scores. However, frequency of activities for certain parenting behaviours has been measured at around 9 months, 5 years and 7 years. For the first sweep at 9 moths, fathers were asked how frequently they look after the baby on their own, change nappies, and get up at night for the baby. Answers were coded as more than once a day, once a day, few times a week, once or twice a week, less than once a week, and never. Father scores were calculated by allocating the scores of 5-0 for each activity, with the highest score of 5 for "more than once a day" and the lowest score of 0 for "never." For mothers, however, parenting activities were measured relative to the father: Mothers were asked who is responsible for generally looking after children, changing nappies, and getting up at night for the baby. Answers were coded as mother does most, mother and father do equally, or mother does less. Consequently, mother scores in the first sweep were calculated with fathers as reference, ranging from 0 to 7. If mothers reported that they did more than the fathers, they were given higher scores than the father, and if they reported that they did less, they were given lower scores.

For the next two sweeps at 5 years and 7 years, frequency of various activities with the focal child was collected for both mothers and fathers. The frequency of activities were reported as every day, several times a week, once or twice a week, once or twice a month, less than once a month and never. Each activity was allocated a score on a scale of 0-5, with "every day" scored as 5. Further information on the reported frequency of parenting activities for all sweeps is available in table 5.2.

Parenting scores for mothers and fathers were calculated as the sum of the activity scores for each sweep. As the range of mother and father scores varied across sweeps, all scores were standardised to range from 0-15. The descriptive statistics for the standardised parenting scores are available in table 5.3. Like ALSPAC, these derived mother scores are higher than father scores, following the repeatedly observed patterns where mothers tend to invest more than fathers (e.g., Sayer, Bianchi & Robinson, 2004; Lawson & Mace, 2008). If we disregard the first sweep where the derivation of parenting scores is different, we see that the standard errors are similar between mother score and father score in the MCS. However, in ALSPAC, father scores consistently had higher variance than mother scores. This difference may be to do with the fact that parenting activities by mothers and fathers were self-reported individually in the MCS, while they were mother-reported in ALSPAC.

Table 5.2: Percentage of mothers and fathers who reported that they carried out these activities in the highest frequency category. The highest frequency category for mothers at 9 months is "more often than father," and for fathers at 9 months is "more than once a day." For 5 years and 7 years, the highest frequency category for mothers and fathers are "every day."

	% who reported highest frequency of activities: MCS					
	9 months		5 years		7 years	
	Mother	Father	Mother	Father	Mother	Father
Minimum N	14444	13217	15164	10483	13778	9170
Activities						
Generally look after child	59.7	18.3	NA	NA	NA	NA
Change nappy	69.6	37.2	NA	NA	NA	NA
Get up at night for child	58.6	7.4	NA	NA	NA	NA
Read to child	NA	NA	1.6	5.4	2.8	7.2
Tell stories to child	NA	NA	15.7	16.9	14.9	17.0
Musical activities	NA	NA	4.1	10.0	5.7	10.1
Draw/paint	NA	NA	8.8	16.3	14.5	21.5
Physically active games	NA	NA	13.8	6.3	14.7	7.2
Indoor play	NA	NA	4.5	4.9	7.5	6.1
Take to park/playground	NA	NA	8.2	12.1	11.5	13.9

Table 5.3: Descriptives of the standardised MCS parenting scores for mothers and fathers.

	Mother Score			Father Score		
Measurement Occasion	9m	5y	7y	9m	5y	7y
N	12481	15154	13767	13226	10476	9163
Mean	10.25	9.52	8.33	8.48	8.71	7.90
SE	2.32	2.30	2.44	3.37	2.35	2.41

Compared to the parenting scores in ALSPAC, the MCS parenting scores are based on fewer parenting activities. Furthermore, the first sweep focuses on caretaking activities, while the last two focus only on play. These points combined, the MCS parenting scores may be a less accurate proxy of parental direct investments compared to ALSPAC. In addition, the MCS parenting scores have similar issues with ALSPAC in that the frequency of activities does not necessarily reflect the quality of the length of activities. Nevertheless, the MCS undertook objective scoring of parenting activities, and the frequency of parenting activities was self-reported. This may mean that the MCS parenting scores are less biased than ALSPAC which was generally based on the mother's subjective perception of the frequency of activities for herself and her partner. While these parent scores are not perfect, it is likely to be a better proxy of direct parental investments compared to other commonly used variables such as presence, proximity or emotional closeness.

Breastfeeding

In addition to mother scores, I use information on breastfeeding to capture an additional aspect of maternal direct investments. Breastfeeding is taken to be a type of direct maternal investment as it is a behaviour which is directed to the child, increases child quality, with associated costs. In terms of child quality, breastfeeding is associated with extensive health benefits for the child including immunological protection and prevention of infectious disease, reduced risk of asthma and atopy, better cognitive and motor development, as well as reduced risk of obesity (Howie et al., 1990; Oddy, 2001; Allen & Hector, 2005; Sacker, Quigley & Kelly, 2006; Quigley, Kelly & Sacker, 2007). In terms of costs, breastfeeding is energetically costly for the mother, with exclusive breastfeeding estimated to require 400 to 750 kcal/day depending on milk production (Butte, Lopez-Alarcon & Garza, 2002; Picciano, 2003; Butt & King, 2005). Furthermore, breastfeeding is associated with a significant reduction in fecundity, termed lactational amenorrhea, which leads to a suppression of maternal reproduction (Vekemans, 1997).

I use two variables, breastfeeding initiation and breastfeeding duration (table 5.4), both of which were collected in the first sweep at 9 months. For breastfeeding initiation, mothers were asked if they had ever tried to breastfeed their child. Therefore, this measure does not necessarily capture breastfeeding success, but an attempt by the mother to provide direct investments through breastfeeding. Breastfeeding duration is restricted to mothers who reported that they had initiated breastfeeding. At around 9 months, mothers were retrospectively asked about the age of the child when they last received breast milk,

and breastfeeding duration has been coded in months ranging from 0 to 8+. Note that breastfeeding duration is not limited to exclusive breastfeeding, and includes children who were given supplementary formula milk and solid food.

Table 5.4: Descriptive statistics for breastfeeding initiation and duration.

Breastfeeding Initiation	**N**	**%**	
Yes	12389	67	
No	6109	33	
Total	18498	--	
Breastfeeding Duration	**N**	**Mean(sd)**	**Range**
	12388	3.54	0-8

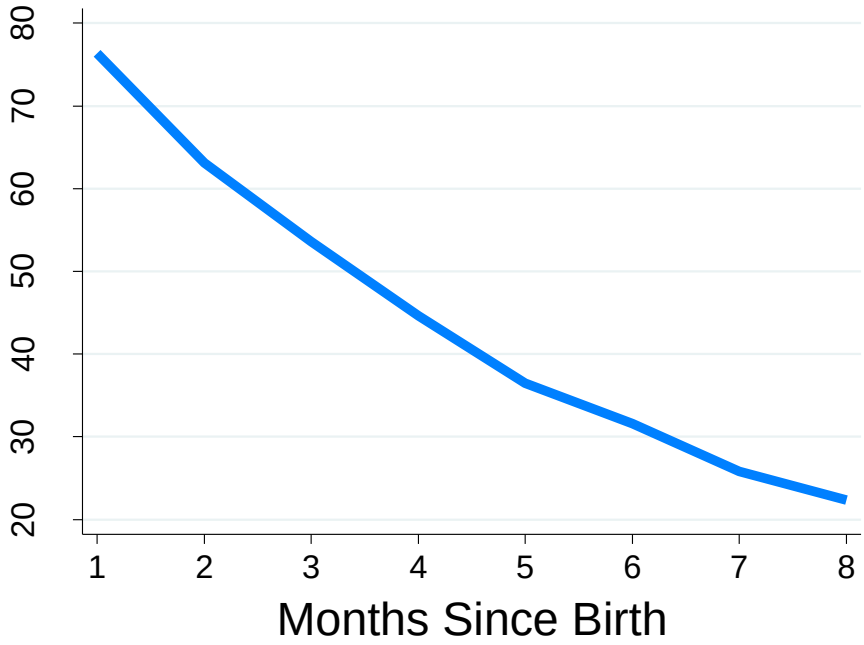

Fig 5.1: Percentage of mothers who reported to have breastfed their child, by months since birth. Only includes mothers who reported ever breastfeeding.

It is interesting to note that, while WHO recommends 6 months of exclusive breastfeeding (Butte, Lopez-Alarcon & Garza, 2002), this is not met by the majority of MCS mothers: Of the 67% of mothers who initiated breastfeeding, just over 30% reported breastfeeding up to 6 months (fig 5.1). As this figure includes mothers who did not exclusively breastfeed, it is evident that a significant proportion of MCS mothers did not achieve the recommended duration of exclusive breastfeeding.

5.3.2 MCS Measures of Grandparental Investment

Grandparent Contact Frequency

As a proxy of grandparental direct investments, I use information on contact frequency between parents and grandparents. On two occasions, when focal children were around 9 months and 3 years old, mothers and fathers were individually asked how often they see their own mothers and fathers. From this, contact frequency for each grandparent type was derived, categorised as: every day, at least once a week, at least once a month, once every few months, once a year or less, and never. If grandparents were reported to have died, contact frequency was coded as never. Due to correlation issues within maternal and paternal grandparent pairs, grandparents who lived with parents and children were removed.

One potential issue of including contact frequency for all grandparent types in one analysis is multicolinearity, which may lead to inaccurate coefficient estimates and inflated standard errors. Table 5.5 is a correlation table of contact frequencies between each grandparent type. Expectedly, grandparent contact frequencies correlate moderately within maternal and paternal grandparents, with r_s of around 0.45. This level of correlations are unlikely to be problematic, especially in a large sample such as the MCS where analyses should tolerate collinearilty to a certain extent due to the increased precision in parameter estimates and lower standard errors.

Table 5.5: Spearman correlations for contact frequency between maternal grandmothers (MGM), maternal grandfathers (MGF), paternal grandmothers (PGM), and paternal grandfathers (PGF).

9 months				
	MGM	**MGF**	**PGM**	**PGF**
MGM	**1**	--	--	--
MGF	**0.470**	**1**	--	--
PGM	**0.143**	**0.124**	**1**	--
PGF	**0.121**	**0.110**	**0.455**	**1**
3 years				
	MGM	**MGF**	**PGM**	**PGF**
MGM	**1**	--	--	--
MGF	**0.446**	**1**	--	--
PGM	**0.122**	**0.099**	**1**	--
PGF	**0.112**	**0.104**	**0.444**	**1**

Table 5.6 displays the measures of central tendency for grandparent contact. Fig 5.2 and 5.3 displays the percentage of each grandparent type in a contact frequency category at 9 months and 3 years, respectively. For both measurement occasions (9 months and 3 years), maternal grandmothers are most frequently reported to have daily contact with parents, with around 20% of maternal grandmothers having daily contact. The largest category of contact (mode) is "at least once a week" for all grandparents, with an exception of paternal grandfathers at 3 years. Maternal and paternal grandfathers are most frequently reported to "never" have contact, which presumably captures the higher mortality of grandfathers compared to grandmothers. Comparing the medians in table 5.5, maternal and paternal grandmothers are found to have more frequent contact compared to maternal and paternal grandfathers at 9 months. At 3 years, the contact frequency is highest for maternal grandmother, followed by maternal grandfather and paternal grandmother, followed by paternal grandfather. Overall, the contact frequency pattern within the MCS is similar to other studies where maternal grandmothers are found to provide most investment and paternal grandfather the least, with maternal grandfather and paternal grandmother in-between (Euler & Weitzel, 1996; Lussier et al., 2002; Chrastil et al., 2006; Pollet et al., 2008; Bishop et al., 2009; Danielsbacka et al., 2011; Kaptijn et al., 2013).

The main issue of using contact frequency as a proxy of grandparental direct investments is that contact does not necessarily equate to direct investments. This issue is exacerbated by the fact that the reported contact frequency focuses on contact with the parent rather than the child. However, following logic that contact is necessary with direct investments, reported contact frequency must correlate with grandparent direct investment levels. With this, it is likely to be a better measure of investments than other

commonly used measures such as "dead/alive." Crucially, the MCS has gathered information on grandparent contact *separately for each grandparent type*. This distinction is relatively rare in cohort studies, with many surveys simply gathering information on "grandparents" in general. Indeed, other measures of grandparent direct investments in the MCS is also ambiguous regarding the exact caregiver, with questions relating to childcare only addressing "grandparents" in general. Following evolutionary theory, the distinction between grandparent types is important as the costs and benefits surrounding allomaternal investments are predicted to vary between maternal grandmothers, maternal grandfathers, paternal grandmothers, and paternal grandfathers. Considering these points, I believe the current proxy of grandparent direct investments is an adequate measure to fulfil the aims of Part 2.

Table 5.6: Descriptive statistics of central tendency for grandparent contact frequency; an ordinal variable. 1=Daily contact, 2=Weekly contact, 3=Monthly contact, 4=Contact every few months, 5=Contact yearly or less, 6= No contact.

	9 Months			3 Years		
	N	**Mode**	**Median**	**N**	**Mode**	**Median**
MGM	13,834	Weekly	Weekly	11,851	Weekly	Weekly
MGF	13,834	Weekly	Monthly	12,069	Weekly	Monthly
PGM	11,900	Weekly	Weekly	9,484	Weekly	Monthly
PGF	11,900	Weekly	Monthly	9,979	Never	Few Months

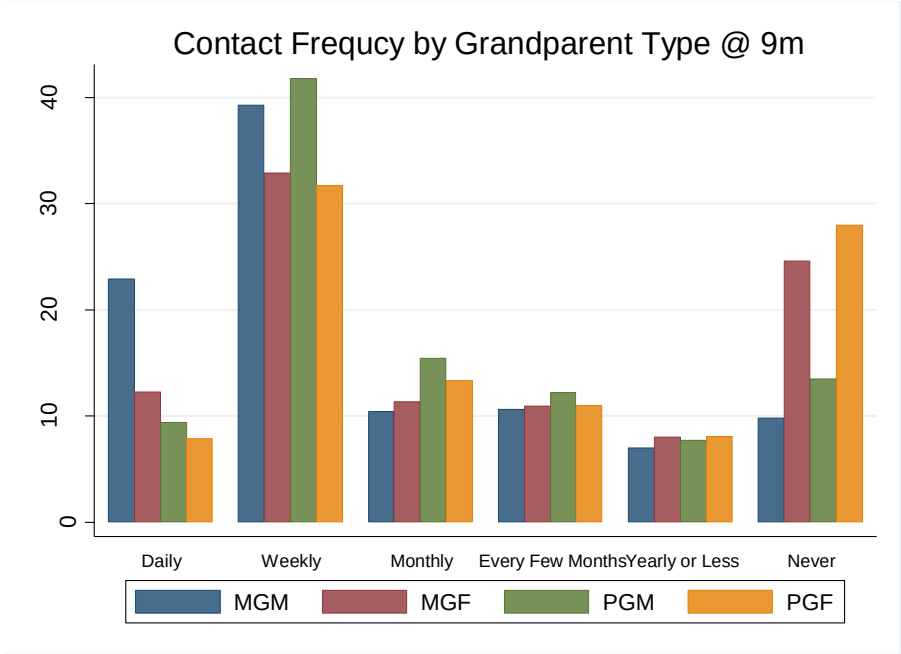

Fig 5.2: Percentage of each grandparent type in contact frequency categories at 9 months.

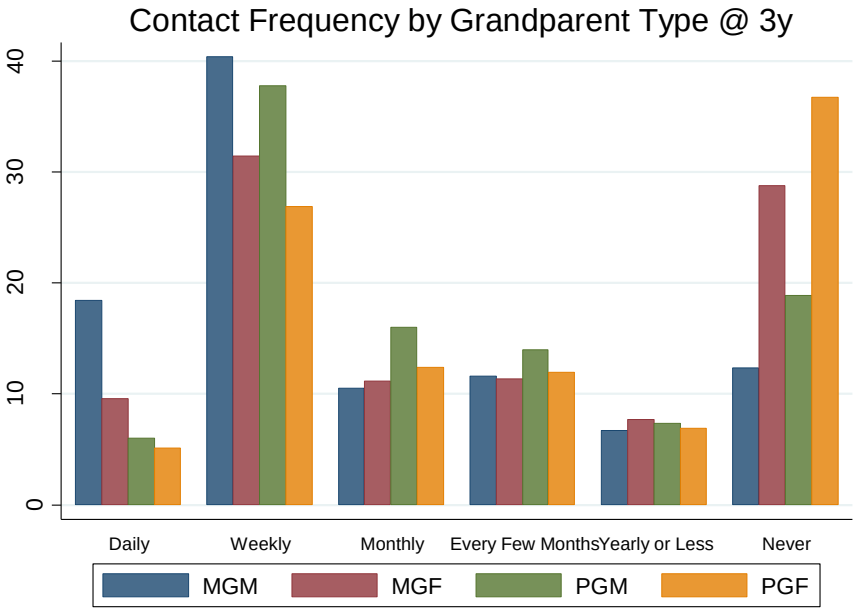

Fig 5.3: Percentage of each grandparent type in contact frequency categories at 3 years.

Grandparent Financial Assistance

As a proxy of grandparental indirect investments, I use information on financial assistance from grandparents given to parents. This information was reported by mothers and fathers for their own parents at 9 months, 3 years and 5 years. Unlike contact frequency, information on grandparent financial assistance is separated between maternal and paternal grandparents rather than each grandparent type. MCS recorded a wide range of financial assistance, from buying essentials for the baby, contribution to childcare costs, contributions to holidays, mortgage payments, trust funds and more. However, the categories vary between sweeps, parents are able to report multiple categories of financial assistance, and the monetary amount of contributions is unknown. Consequently, grandparental financial assistance was simply categorised as a binary variable to any financial assistance (yes) and no financial assistance (no). The descriptive statistics of this variable across sweeps are available in table 5.7. Across all sweeps, between 70 to 80% of mothers and fathers reported that they had received financial assistance from grandparents. Maternal grandparents were consistently more likely to provide financial assistance than paternal grandparents.

Table 5.7: Descriptive statistics for financial assistance from maternal and paternal grandparents.

	9 months		**3 years**		**5 years**	
Financial Assistance	**N**	**%**	**N**	**%**	**N**	**%**
Maternal Grandparents						
Yes	10,336	75.30	8,927	79.30	8,199	74.53
No	3,390	24.70	2,330	20.70	2,802	25.47
Total	13,726	--	11,257	--	11,001	--
Paternal Grandparents						
Yes	8,347	70.71	6,287	70.36	6,220	70.00
No	3,458	29.29	2,649	29.64	2,666	30.00
Total	11,805	--	8,936	--	8,886	--

The greatest issue with the current measure is its simplicity, where grandparents who set up trust funds for children are included in the same category as grandparents who contributed towards buying nappies. As they are very different forms of financial assistance, it is conceivable that their effects on parents and children may differ. Nonetheless, the key purpose of this measure, fulfilled in its current form, is to capture a form of grandparental indirect investments. Because the final variable stems from a diverse range of financial assistance reported by parents, we can be relatively confident with the distinction between those who received financial assistance and those that did not. Consequently, I believe the current variable is a good starting point in exploring the effects of grandparental direct investments on parental investments and child outcomes.

5.3.3 MCS Child Outcomes

Following the same motivations throughout part 1 (outlined in Chapter 2), I use height, cognitive test score and behavioural difficulty score as a proxy of physical development, cognitive development and socio-motional development, respectively. The descriptive statistics of these variables will be presented in Chapter 7. Below, I elaborate on the methods by MCS to collect information used to create these three child outcomes.

Height

Children's height measurements were collected by MCS interviewers who were trained to take anthropometric measurements at around 3 years, 5 years and 7 years. Typically, this occurred within the focal child's home, and height was recorded to the nearest millimetre. Exclusively for 3 years, if height measurements were refused, interviewers recorded the most recent height measurement from the personal child health record (also known as red book) if permission was granted. Personal child health records are a record of children's health and development, given to parents in the UK at the birth of their child. The records are typically updated each time the child is seen in a healthcare setting, usually by the child's general practitioner or health visitors. In all, the collection method of height data is very similar to ALSPAC. The main difference is in the sample and frequency of data collection. Whereas ALSPAC had frequent clinical height measurements for a 10% subsample of children, MCS has less frequent height measurements for the full sample. As outlined in Chapter 2, I take greater height to be an indicator of an accelerated life history strategy and lower child quality.

Cognitive Test Score

As a proxy cognitive development, I use the cognitive test scores based on assessments on maths, reading and pattern construction administered to children at around age 7. These assessments were led by MCS interviewers, typically within the focal child's home. For maths, MCS administered 20 questions based on the *Progress in Maths 7* assessment, developed by the National Foundation for Educational Research. These assessments were created for use in schools to assess maths skills, aimed at children between 7 and 8 years old, and is similar to the KS1 maths tests taken by ALSPAC children between 6 and 7 years. For reading, the MCS assessment was based on the word-reading tests from the *British Ability Scales: Second Edition*, which is a standardised test developed to assess children's cognitive ability and educational achievement across the UK. Specifically, children were given a maximum of 90 words to read out loud to the interviewer. This tasks differs from the KS1 English tests in that it only assesses children's reading ability, while KS1 also tests comprehension and writing skills.

MCS also assessed children's pattern construction abilities, which is not available in ALSPAC. Like the reading assessments, the pattern construction assessments are based on the British Ability Scales tests, and have been developed to assess children's non-verbal reasoning and spatial visualisation. For the assessments, children were presented with a series of patterns and were asked by the MCS interviewer to replicate each pattern using foam squares or plastic cubes. Further details on assessments methods are available in Gray et al. (2010).

For each assessment, the range of the scores were standardised so that children could score between 0 and 10 points. Therefore, the final cognitive test scores range from 0 to 30. Higher scores are taken as an indicator of greater cognitive development.

Behavioural Difficulty Score

Behavioural difficulty scores for children in the MCS were collected at 3 years, 5 years and 7 years in a similar way to ALSPAC. Mothers were asked to complete questionnaires based on the Strength and Difficulties Questionnaire (Goodman, 1997), which attempts to capture children's hyperactivity, emotional symptoms, conduct problems, and peer problems. Mothers were asked "how true" statements were regarding children's behaviour

and sociality, and children could score a maximum of 40 points. Lower scores are taken as an indicator of better socio-emotional development.

5.4 Overview of the Research Questions in Part 2

The aim of Part 2 is to investigate the importance of grandparents as allomothers in the UK, by exploring their effects on direct parental investment and child development. Chapter 6 investigates the effects of grandparental contact and financial assistance on breastfeeding initiation, breastfeeding duration, mother score and father score. Chapter 7 investigates the effects of grandparental contact and financial assistance on height, cognitive test score and behavioural difficulty score.

While human behavioural ecologists in particular have been interested in the associations between grandparents and child fitness, research in contemporary developed populations have tended to focus on nuclear families. Consequently, the availability of research exploring the influence of grandparents on parental behaviour and child development in contemporary developed populations is limited. Throughout Part 2, I review the handful of studies which explore grandparent effects on parental investment (Chapter 6) and child outcomes (Chapter 7) in contemporary developed populations, with relevant literature from high fertility, high mortality populations also presented. With the lack of previous studies, my focus in Part 2 is to simply explore the effects of grandparent direct and indirect investments.

Chapter 6: Grandparent Effects on Parental Investment

6.1 Introduction to Chapter 6

6.1.1 Grandparents as Allomothers: Indirect Effects on Child Quality through Influence on Paternal Investments

Evolutionary anthropologists, and human behavioural ecologists in particular, have identified grandparents as good candidates for allomothers. As explained in the previous chapter, however, the costs and benefits surrounding grandparent allomaternal investments vary between grandparent types. From a human behavioural ecological perspective, we would expect maternal grandmothers to gain most through allomaternal investments, and paternal grandfathers to gain the least. In fact, some researchers have argued that grandmothers are a special and important type of allomothers, with characteristics such as the menopause coevolving with the human childrearing system as it became more cooperative (e.g., Hrdy, 2005a,b, 2007; Hawkes et al., 1998).

In general, research on grandparental investments have focused on its effects on fertility and child outcomes (see Sear & Coall, 2011), with only a handful of studies exploring grandparent effects on parental behaviour. On a theoretical level, grandparental investments may have indirect effects on child development by influencing parental investment trade-offs which feed into parental behaviour. Investigating grandparent effects on parental behaviour should lead to a better understanding of the association between grandparental investments and child outcomes, and deeper knowledge of the human childrearing system.

In this chapter, I explore how direct and indirect grandparental investments may influence parental direct investments in the UK. Ultimately, grandparental impact on parental investments may feed into child outcomes (this will be explored in Chapter 7). Specifically, I investigate the associations between grandparental contact/financial help and breastfeeding, maternal parenting and paternal parenting. Overall, literature on the impact of grandparental investments on parental investments is limited, and available studies typically concentrate on grandmother effects on maternal behaviour. In the following sections, I review the available literature relating to grandparent effects on direct parental investments, treating breastfeeding and parenting separately. Due to the

limited availability of studies, I include previous findings from high mortality, high fertility populations, and also touch upon allomother support in general.

6.1.2 Grandparent Effects on Breastfeeding in Traditional Populations

In traditional, high-fertility high-mortality populations, breastfeeding is an obligate maternal investment behaviour which is essential for child survival. Mothers incur energetic costs (Butte, Lopez-Alarcon & Garza, 2002; Picciano, 2003; Butt & King, 2005) and reduced fecundity (Vekemans, 1997) to provide the only adequate food source available for infants. Breastfeeding is often incompatible with subsistence and other labour activities, meaning breastfeeding mothers can struggle to provide adequate resources for themselves and their children (Marlowe, 2003; Quinlan & Quinlan, 2007, 2008). Consequently, breastfeeding mothers in traditional contexts are dependent on allomothers such as fathers and grandmothers for support, especially in terms of resource provisioning (Marlowe, 2003; Quinlan & Quinlan, 2007, 2008). Under natural fertility conditions such support could increase fertility and reduce infant mortality, thus enhancing reproductive success (Sear et al., 2002; Shanley et al., 2007). Some evolutionary anthropologists have argued that allomother support is an obligate human trait which accompanies breastfeeding, and is an important part of the human breeding system (Hrdy, 2005).

Several previous studies on traditional populations support this assertion. In the Hadza hunter-gatherers, Hawkes et al. (1997) reported that mothers' foraging activities were reduced if they were breastfeeding, and grandmothers seem to compensate for this reduction by increasing their own foraging time. Similarly, in the Karo Batak farmers of Indonesia, breastfeeding mothers were more likely to report that they had received help from kin (Kushnick, 2012). However, analysis on 58 traditional societies in the Standard Cross Cultural Sample found that the availability of alloparental care across societies is associated with earlier age at weaning (Quinlan & Quinlan, 2008). This finding seems to contradict the studies on the Hadza and the Karo Batak, where alloparents seemed to facilitate breastfeeding.

It is possible that the contrasting results are driven by a slight difference in research focus: The studies on the Hadza and Karo Batak focused on alloparental behaviour when mothers were breastfeeding, while the cross-cultural study on alloparental availability focused on breastfeeding duration. During breastfeeding, mothers may be especially dependent on allomaternal investments. However, after the "critical period" where

children no longer need to be breastfed, the availability of allomothers may encourage mothers to stop breastfeeding to resume provisioning activities and/or regain their fecundity. Similarly, the opposing results may stem from assessing allomother effects within populations vs. across populations. It could be a case where, a positive association between allomothers and breastfeeding duration exists within a population, but if this population has shorter breastfeeding duration on average, a cross-population study may pick up a negative association between allomothers and breastfeeding. Such scenarios may be conceivable, for instance, if populations with high levels of allomaternal care have shorter inter-birth intervals which is likely to correlate with shorter breastfeeding durations. Information on fertility rates was not available for the cross-cultural analysis by Quinlan & Quinlan (2008).

Overall, while none of these studies specifically explore grandparents, they suggest that grandparental investments may influence maternal breastfeeding in high fertility, high mortality populations. While it is difficult to confidently reach conclusions due to the small number of studies, it seems likely that breastfeeding is initially a critical, non-substitutable activity. During this period, allomothers such as grandparents provide assistance in a substitutable type of investment activity such as provisioning. However, when breastfeeding is no longer critical, allomothers may begin to substitute direct care, encouraging mothers to wean.

6.1.3 Potential Grandparent Effects on Breastfeeding in Contemporary Developed Populations

The Costs and Benefits of Breastfeeding in Contemporary Developed Populations

Like traditional populations, mothers in contemporary developed contexts incur costs through breastfeeding: Breastfeeding is energetically costly for the mother, with exclusive breastfeeding estimated to require 400 to 750 kcal/day depending on milk production (Butte, Lopez-Alarcon & Garza, 2002; Picciano, 2003; Butt & King, 2005). Furthermore, like traditional populations, studies suggest breastfeeding clashes with production activities including wage labour. Studies on the MCS have found that employed mothers are less likely to initiate breastfeeding (Hawkins et al., 2007a). Of the MCS mothers who were employed, full-time maternal employment was associated with a shorter duration of breastfeeding compared to part-time or self-employment (Hawkins et al., 2007b). Similar results, where maternal employment negatively predicts breastfeeding, have also been

found in the US (Arora et al., 2000; Berger, Hill & Waldfogel, 2005) and Australia (Scott et al., 2006).

However, there is a fundamental difference surrounding breastfeeding between traditional and developed populations. In contemporary developed populations, breastfeeding can be substituted through formula milk. Consequently, the costs and benefits of breastfeeding may differ. First, breastfeeding is unlikely to be critical for child survival, reducing the benefits of breastfeeding. Second, formula reduces the dependency of infant feeding away from the mother as infant feeding becomes substitutable. Unlike traditional populations, mothers in developed contexts face additional trade-offs surrounding infant feeding: Formula feeding may be associated with greater financial expenses, but it introduces the potential for mothers and allomothers to share infant feeding and other associated costs.

With the reduced benefit of breastfeeding regarding child survival, along with the greater opportunity to share the costs of infant feeding, it is not very surprising to find that the availability of commercial formula milk in the West was followed by a reduction in breastfeeding rates starting in the 1930s/40s, reaching the lowest level in the 1970s (Fomon, 2001). However, recent studies have found that breastfeeding, compared to formula feeding, is associated with extensive health benefits for children in developed populations (Howie et al., 1990; Oddy, 2001; Allen & Hector, 2005; Sacker, Quigley & Kelly, 2006; Quigley, Kelly & Sacker, 2007). Furthermore, studies have generally found a small but beneficial effect of breastfeeding on cognitive development. In a meta-analysis on 11 studies, breastfeeding, compared to formula feeding, was associated with greater cognitive development, with a positive association between breastfeeding duration and cognitive development (Anderson, Johnstone & Remley, 1999). Similarly, a large randomised trial involving 31 Belarussian maternity hospitals found that, mothers in the intervention groups who experienced breastfeeding promotion increased breastfeeding duration, which in turn was associated with better academic achievement in children at 6.5 years (Kramer et al., 2008a). These benefits on cognitive development seem to have lasting effects, as breastfeeding has been found to predict higher academic achievement in older teenagers (Horwood & Fergusson, 1998) and higher adult I.Q. (Mortensen et al., 2002).

Note, the literature on the benefits of breastfeeding is not entirely consistent. For instance, in a recent study which carried out sibling comparisons to control for unobserved heterogeneity using a large US cohort study, breastfeeding initiation or duration had no long-term effects on children's health, cognitive development or socio-emotional development (Colen & Ramey, 2014). Similarly, a large randomised trial in

Belarus found no effect of breastfeeding on children's socio-emotional development (Kramer et al., 2008b). Nonetheless, as it stands, the literature points to a trend where breastfeeding is generally beneficial for child health, with potential positive effects on cognitive development. This is reflected in the opinions of public health and medical professionals who generally argue that breastfeeding is the optimal way to feed infants (e.g., Leung & Sauve, 2005). The WHO recommends mothers to breastfeed exclusively for six months, and has taken steps with UNICEF to promote breastfeeding through the Baby-Friendly Hospital Initiative, providing a 10-step guide for hospitals to increase breastfeeding rates (WHO & UNICEF, 1989; Leung & Sauve, 2005).

The health and development benefits may be one factor which could encourage mothers to breastfeed over formula feed in contemporary developed populations, even though breastfeeding is unlikely to be critical for child survival. Indeed, perhaps due to a greater awareness of the benefits of breastfeeding, Western breastfeeding rates have been rising over the last few decades (Fomon, 2001; Yngve & Sjöström, 2001). In the UK, breastfeeding initiation rates have risen from 62% in 1990 to 81% in 2010, and any breastfeeding at 6 months has risen from 21% in 1995 to 34% in 2010 (McAndrew et al., 2010). However, only 1% of UK mothers achieved the WHO recommended exclusive breastfeeding for 6 months in 2010 (McAndrew et al., 2010), and breastfeeding rates in the UK is among the lowest in Europe (Yngve & Sjöström, 2001). In contrast, in 1997, breastfeeding initiation in Sweden was near 100% while exclusive breastfeeding at 6 months was at 42%, highlighting cross-national disparities in breastfeeding rates (Yngve & Sjöström, 2001). This suggests that the costs and benefits surrounding breastfeeding is likely to vary within and between populations, and in some cases the health benefit of breastfeeding does not compensate for the costs incurred by the mother.

Grandparent Investments and Breastfeeding in Contemporary Developed Populations

Overall, it seems that mothers in contemporary developed populations face trade-offs between breastfeeding and bottle feeding. On the one hand, breastfeeding is beneficial for child quality in terms of health and development, and is financially cheaper. On the other hand, breastfeeding is energetically costly, and there is limited opportunity for mothers to share infant feeding with allomothers. With this greater flexibility in infant feeding practices in contemporary developed populations (i.e., breastfeed vs. bottle feed), there is potentially greater scope for grandparents to influence maternal breastfeeding.

The available literature surrounding allomothers and breastfeeding in contemporary developed populations come from non-evolutionary social science disciplines. These researchers have made analogous arguments to evolutionary anthropologists by suggesting that mothers require support for successful breastfeeding (Britton et al., 2007; Meedya, Fahy & Renfrew, 2007). Such support has been broadly categorised into two themes (Stansfeld, 2005): *Emotional/Informational Support* relates to the provisions of supportive information, as well as interactions which improve self-appraisal and self-esteem. *Instrumental/Practical Support* often relates to supportive behaviours such as active assistance and financial support.

The expectation has been that social support, including grandparent support, encourages mothers to breastfeed, and the positive impact of support on breastfeeding initiation and duration is claimed to be well established (Britton et al., 2007; Meedya, Fahy & Renfrew, 2007). However, a review of the literature points to ambiguity as well as bias surrounding the definition of support. In a systematic review of 34 quasi-randomised controlled trials surrounding social support, support was defined as "Contact with an individual (either professional or volunteer) offering support that is supplementary to standard care (in the form of, for example, appropriate guidance and encouragement) with the purpose of facilitating continued breastfeeding (Britton et al., 2007)." With this definition, the distinction between the two types of support is not explicit, though the example suggests the focus is on emotional and informational support. It is also common to find that social support is not explicitly defined, though such studies often focus on positive attitudes and encouragements towards breastfeeding (Raj & Plichta, 1998; Ekström, Widström & Nissen, 2003; Meedya, Fahy & Renfrew, 2007) which again overlaps with emotional support. Social pressure to breastfeed may also be treated as a form of social support (Meedya, Fahy & Renfrew, 2007), though it is possible that this reflects emotional coercion than support *per se*.

Such ambiguity surrounding the definition of social support in the non-evolutionary literature is problematic if the two different types of support have different functions and pathways. This may well be the case. From an evolutionary anthropological perspective, whether or not you carry out a behaviour is influenced by the social norms relating to that behaviour as highlighted by evolutionary psychologists (Chudek & Henrich, 2011; Sear, Lawson & Dickins, 2007; Nettle, 2009), as well as the costs and benefits surrounding that behaviour as highlighted by human behavioural ecologists (Sear, Lawson & Dickins, 2007; Nettle, 2009; Borgerhoff Mulder & Schacht, 2012). While feedback is expected between the two pathways, they are treated as separate entities with independent effects (Nettle,

2009). Whether or not a mother breastfeeds depends on the norms she experiences surrounding breastfeeding, as well as the costs and benefits she incurs from breastfeeding.

Emotional and informational support centres on the transfer and maintenance of pro-breastfeeding attitudes, such as supporting the idea to breastfeed and boosting maternal confidence to do so. This type of social support from grandparents may be inherently linked to *breastfeeding promotion*, and one could even argue against its conceptualisation as support, given that such information and attitudes can only be supportive if mothers have a desire to breastfeed in the first place. This connection between emotional/informational support and breastfeeding promotion is an important point to highlight, as it is conceivable that breastfeeding promotion primarily affects *maternal breastfeeding norms*.

In contrast, practical grandparent support is likely to have a different pathway regarding its effect on maternal breastfeeding, influencing the costs and benefits surrounding maternal behaviour. From and HBE perspective, practical support for mothers such as direct caregiving and financial transfers is analogous to grandparental investments. Grandparental investments could encourage breastfeeding if it leads to the substitution of other maternal activities (e.g., substitution of domestic and/or paid work), where mothers are better able to focus on breastfeeding. On the other hand, grandparental investments could also *discourage* breastfeeding: Formula-fed infants are presumably less dependent on mothers for feeding, which may increase opportunities for helpers to provide practical childrearing support. This potential to share the costs of childrearing may serve as an incentive for mothers to formula-feed.

With this in mind, how do grandparent investments influence maternal breastfeeding in contemporary developed populations? Despite the claims of a well-established positive association between social support and breastfeeding, only a handful of studies have explicitly investigated the relationship between grandparents and breastfeeding, all of which have focused on grandmothers. In general, the few available studies report mixed results. Some studies find that grandmother support encourages breastfeeding. For instance, in a survey of 123 US mothers with infants and toddlers, mothers reported that greater support from grandmothers and other family members would have encouraged them to breastfeed (Arora et al., 2000). In an Australian randomised controlled trial involving 72 mothers attending antenatal breastfeeding classes, mothers in the intervention group who brought a female breastfeeding supporter, often the maternal grandmother, breastfed for longer (Winterburn, Jiwa & Thompson, 2003).

In contrast, other studies suggest that support from grandmothers may in fact discourage breastfeeding. In the US, maternal co-residence with grandparents predicted lower rates of breastfeeding initiation for a disadvantaged sample of households, and shorter duration of breastfeeding for both a disadvantaged and a nationally representative sample of households (Pilkauskas, 2014). A study on Brazilian mothers found that daily contact with maternal grandmothers, compared to less frequent contact, had a negative association with breastfeeding duration (Susin, Giugliani & Kummer, 2005). Interestingly, the importance of grandmother support may vary between cultural groups. In a small study of Pueto Rican, Cuban and White mothers in the US, maternal grandmothers were identified as an important source of breastfeeding support for Pueto Rican and Cuban mothers, but not for White mothers (Byrant, 1982).

It is noteworthy that the studies which find positive associations between grandmother support and breastfeeding seem to centre on emotional and informational support, perhaps capturing norm transmission. In contrast, the studies which focus on grandmother contact, potentially capturing practical support, indicate a negative association. This suggests that practical support for mothers (investments) may indeed function differently to emotional or informational support (norms). Unlike emotional support, practical support from grandparents may discourage breastfeeding if infant feeding is a substitutable activity. Bottle-fed infants are presumably less dependent on mothers for feeding, which may increase opportunities for grandparents to provide direct care. This could serve as an incentive for mothers to bottle feed.

Overall, what does the reviewed literature tell us regarding grandparent investments and maternal breastfeeding? Firstly, there has been ambiguity in the non-evolutionary literature regarding grandparental support, with a lack of distinction between norm promotion and investments. Following an evolutionary anthropological perspective, we expect grandparent investments to influence the costs and benefits surrounding maternal breastfeeding, which may function differently to the "social support" often investigated by social scientists. Indeed, there is some evidence in the reviewed literature that grandmother investments are associated with lower levels of maternal breastfeeding, potentially highlighting the process where infant feeding is substituted by grandmothers. However, with very few studies available, no strong conclusions can currently be made regarding the impact of grandparent support and maternal breastfeeding in contemporary developed contexts.

Furthermore, there is a distinct lack of studies addressing the different types of grandparents, as the sole focus has been on grandmothers. From an HBE perspective, we

would expect that the impact of grandparents on maternal breastfeeding may differ between maternal and paternal grandmothers and grandfathers. First, with the lower fitness costs/higher inclusive fitness benefits associated with post-menopausal grandmother investments compared to grandfather investments, grandmothers could be a more important allomother regarding their influence on maternal breastfeeding. Second, due to a greater level of paternity certainty, maternal grandmothers could have the greatest impact, followed by maternal grandfathers and paternal grandmothers, and finally paternal grandfathers. Lastly, the optimal strategies may differ between maternal and paternal grandparents, whereby maternal grandparents encourage maternal investments in child quality, while paternal grandparents encourage maternal investments in child quantity. The differences in optimal strategies could lead to conflicting effects, where maternal grandparent investments may increase breastfeeding, while paternal grandparent investments decrease breastfeeding.

We are unable to assess the validity of the outlined possibilities due to the limited availability of studies which investigate grandparent investments and maternal breastfeeding in contemporary developed populations. More studies are clearly required. In this chapter, I carry out an investigation into the associations between grandparent investments and maternal breastfeeding. I extend from previous studies by focusing on direct and indirect investments (rather than emotional support), and by focusing on each grandparent type (rather than just grandmothers).

6.1.4 Grandparent Effects on Other Parenting Activities in Traditional Populations

In addition to breastfeeding, grandparents may indirectly affect child development by influencing the levels of maternal and paternal parenting. First, grandparents may substitute direct care, which may lead to a reduction in parental direct investments, but potentially an increase in indirect investments. Second, grandparents may substitute indirect investments, which may lead to an increase in parental direct investments, and decrease parental indirect investments.

A few studies are available exploring allomother effects on maternal behaviour in traditional populations, highlighting substitutions of investment activities. In a study on the Karo Batak farmers of Indonesia, reported assistance from patrilateral kin was associated with an increase in maternal subsistence activities, while help from matrilateral kin was associated with an increase in maternal direct care activities (Kushnick, 2013). In the Aka foragers, grandmother presence was associated with a reduction in maternal

subsistence activities, and grandmother direct care was associated with a reduction in maternal direct care (Meehan, Quinlan & Malcom, 2013). Furthermore, direct childcare assistance from allomothers was associated with a reduction in maternal direct care and an increase in maternal foraging activities (Meehan, 2009). A similar result was found in the Ngandu farmers of the Central African Republic, where direct childcare assistance from allomothers was associated with a reduction in maternal direct care. However, unlike the Aka, allomother childcare assistance did not lead to a higher level of subsistence activities by the mothers (Meehan, 2009).

While the differences in the measures of allomaternal investments bring difficulty to direct comparisons, and the studies only address allomother effects on mothers, these results hint at a trend where grandparent direct care may decrease parental direct investments and grandparent indirect care may increase parental direct investments. Furthermore, the study by Kushnick (2013) on the Karo Batak suggests that maternal and paternal grandparents may have different effects. There may also be variations across cultures, as highlighted by Meehan (2009) where childcare assistance led to higher maternal subsistence activities in the Aka but not the Ngandu.

6.1.4 Grandparent Effects on Other Parenting Activities in Contemporary Developed Populations

A similar pattern is found across low fertility populations. In a study using large survey data spanning eight Chinese provinces, grandparental co-residence was associated with a reduction in maternal direct care. Similarly, residential proximity to paternal grandparents predicted lower levels of maternal direct care, though this effect was not found with maternal grandparents (Chen, Short & Entwisle, 2000). In a study across 10 European countries, direct caregiving by maternal grandmothers was associated with an increase in maternal labour force participation, while financial assistance did not affect maternal employment (Dimova & Wolf, 2011). A similar result was found in the US, where proximity to maternal or paternal grandmothers was associated with an increase in maternal labour force participation (Compton & Pollak, 2014), and in Japan, where co-residence with maternal or paternal grandparents had a positive effect on maternal labour force participation (Sasaki, 2002). In fact, researchers have suggested that grandparent assistance, usually through childcare, is particularly important for working mothers due to the clash between caregiving activities and maternal employment (e.g., Wheelock & Jones, 2002; Gray, 2005). However, the effects of grandmothers on maternal investments

may differ between populations. A study by Assave, Arpino & Goisis (2012) found that the grandparent childcare had a positive effect on maternal labour force participation in Bulgaria, France, Germany and Hungary, but had no significant effect in Georgia, Russia and the Netherlands.

In general, studies on grandparental investments in contemporary developed populations focus on how grandparent direct care affects maternal provisioning activities (i.e., maternal employment). These studies suggest a trend where grandparent direct care substitutes maternal direct care, allowing mothers to increase indirect investment activities. However, studies addressing this topic are limited, and the association between grandparental investments and parental direct investments are still unclear: Do direct and indirect grandparental investments have different effects on parental direct investments? Do the effects of grandparental investments differ between maternal and paternal direct investments? Do the effects differ between maternal and paternal grandmothers and grandfathers? Clearly, further studies are needed to address these questions.

6.1.4 Objectives of Chapter 6

As outlined in Chapter 1 and Chapter 5, grandparents may invest in parents to increase their reproductive success. The available literature suggests that parental direct investments in contemporary developed populations are substitutable, be it infant feeding or direct parental caregiving. Grandparental investments may impact parental direct investments differently depending on whether the grandparent investments are direct (e.g., direct caregiving) or indirect (e.g., financial assistance), and whether parents are optimisng the quality or quantity of children: If grandparent investments are being used to invest in *child quality*, grandparents may 1) substitute parental direct investment activities to facilitate parental resource acquisition, leading to lower levels of parental direct investments but higher levels of parental indirect investments. Grandparents may also 2) substitute parental indirect investment activities to facilitate parental caregiving, leading to higher levels of parental direct investments and perhaps lower levels of parental indirect investments. If grandparent investments are used by parents to optimise *child quantity*, 3) parental direct investment levels may decrease overall.

If humans in contemporary developed populations operate as cooperative breeders, grandparents could potentially be important allomothers who indirectly influences in child quality. However, there is a lack of available literature regarding the influence of grandparent investments on parental investment behaviours. There are only a handful of

studies distinguishing and simultaneously exploring the effects of direct and indirect grandparental investments on parental investment behaviour. Furthermore, the research focus of previous studies has been on grandmother effects on maternal behavior. From the available literature, it is unclear whether maternal grandmothers, maternal grandfathers, paternal grandmothers and paternal grandfathers have different effects on parental direct investments. It is also unclear whether grandparental investments influence maternal and paternal direct investments in the same way. These questions are interesting to address in the context of exploring the UK childrearing system, as grandparents may have indirect effects on child quality through influencing parental direct investment levels.

The aim of this chapter is to investigate how direct and indirect grandparental investments affect maternal and paternal direct investment levels, taking an exploratory approach given the lack of previous studies. Specifically, I investigate how grandparent contact frequency (proxy of direct investments; see Chapter 5) and grandparent financial assistance (proxy of indirect investments; see Chapter 5) affect breastfeeding initiation, breastfeeding duration, maternal parenting activities, and paternal parenting activities. I investigate the associations between grandparent investment and parental direct investments separately for each grandparent type, given the different costs and benefits surrounding allomaternal investments for maternal and paternal grandmothers and grandfathers. Furthermore, following the suggestion that grandparental assistance is particularly important for working mothers, I explore whether the effects of grandparental investments differ by the mother's employment status.

With this, I hope to contribute to the existing literature by: 1) distinguishing between direct and indirect grandparental investments, 2) distinguishing between grandparent types (i.e., maternal/paternal grandmothers/grandfathers), 3) investigating grandparent effects on both maternal and paternal direct investments, and 4) investigating grandparent effects on different types of parental direct investment activities. Notably, breastfeeding is potentially a non-substitutable maternal direct investment activity, while maternal and parental parenting is potentially a substitutable direct investment activity. In the context of this thesis, this chapter will contribute to the understanding of the UK childrearing system, uncovering whether grandparents are relevant allomothers in a population with smaller family sizes, nuclear family norms, grandparent longevity, and maternal economic self-sufficiency.

6.2 Analysis Methods of Chapter 6

6.2.1 Sample Selection

As outlined in the previous chapter, I use data from the Millennium Cohort Study collected on four occasions when the focal children were around 9 months, 3 years, 5 years, and 7 years. The current sample consists of stable, biparental households as information on paternal grandparental investments is only available in father-present households. This means there are no single mothers included in the following analyses. Furthermore, as the purpose of this chapter is to compare how direct and indirect investments from different types of grandparents affect maternal and paternal direct investment levels, stepfather household are removed. Households with co-residents grandparents have also been removed due to a high correlation between grandmother and grandfather contact in co-resident households. Finally, households where focal children are from multiple births (e.g., twins and triplets) are removed due to the uncertainty with the interpretation of investment levels between siblings.

6.2.2 Variables

Outcomes

As indicators of parental direct investments, the outcomes variables I use are breastfeeding initiation, breastfeeding duration, mother score and father score. Information on maternal breastfeeding was retrospectively self-reported by mothers at around 9 months. Initiation is a binary variable (yes/no). Duration is recorded monthly (0-8+ months), where a value of 1 represents that the focal child has been breastfed for at least 1 month but less than 2 months. Mother and father scores are based on self-reported play-based parenting activities, collected at 9 months, 5 years and 7 years. Scores have been standardised to range from 0 to 15. Detailed descriptions of these variables are presented in Chapter 5.

Main Predictors

Main predictors of interest are grandparent contact frequency and grandparent financial assistance, reported by mothers for maternal grandparents and reported by fathers for paternal grandparents. Information on contact frequency is available separately for maternal grandmothers (MGM), maternal grandfathers (MGF), paternal

grandmothers (PGM) and paternal grandfathers (PGF), which were reported at 9 months and 3 years. The contact frequency categories are daily contact (non-resident), at least once a week, at least once a month, at least once every few months, once a year or less, and never (including grandparent deceased). Information on grandparent financial assistance is available separately for maternal grandparents (MG) and paternal grandparents (PG), categorised as any financial help and no financial help. This information was reported at 9 months, 3 years, and 5 years. Detailed descriptions of these variables are presented in Chapter 5.

Information on maternal employment is available across all 4 sweeps, and is categorised as employed or unemployed. Self-employment, part-time employment and full-time employment are all categorised as employed, as well as mothers on maternity leave.

Controls

As controls, I include country (England, Wales, Scotland, Northern Ireland), indicator of multiple deprivation (range 0-9 in 10% bands; 0=most deprived), household income (bottom 25%, middle 50%, top 25%), paternal employment (employed or not employed), number of siblings in household, financial difficulty (living comfortably, doing alright, just about getting by, finding it quite difficult, finding it very difficult), home ownership (renting, own home, other), maternal education (O-level, A-level, degree, overseas qualification, none), paternal education (O-level, A-level, degree, overseas qualification, none), child's ethnicity (White, South Asian, Black, other), child's sex, and mother's age at birth of child (mean-centred). For analyses on breastfeeding initiation and duration, I also control for birth weight (kg, mean-centred) and gestation length (weeks, mean-centred). Descriptive statistics for all controls, along with outcomes and predictors, are available in table 6.1

Table 6.1: Descriptive statistics of variables used in all analyses of Chapter 6.

Outcome Variables				
Measurement Occasion/ Time	**9m**	**3y**	**5y**	**7y**
Breastfeeding Initiation (%)				
N	18498	-	-	-
Yes	67.00	-	-	-
No	33.00	-	-	-
Breastfeeding Duration (completed months) (%)				
N	12388	-	-	-
0	48.88	-	-	-
1	8.84	-	-	-
2	6.40	-	-	-
3	6.00	-	-	-
4	5.47	-	-	-
5	3.27	-	-	-
6	3.85	-	-	-
7	2.32	-	-	-
8+	14.98	-	-	-
Mother Score				
N	12481	-	15154	13767
mean	10.25	-	9.52	8.33
(sd)	2.32	-	2.30	2.44
range	0-15	-	0-15	0-15
Father Score				
N	13226	-	10476	9163
mean	8.48	-	8.71	7.90
(sd)	3.37	-	2.35	2.41
range	0-15	-	0-15	0-15
Grandparent Variables				
MGM Contact (%)				
N	17164	14661	-	-
Daily	24.92	20.04	-	-
Weekly	38.37	38.96	-	-
Monthly	9.63	9.86	-	-
Every Few Months	9.79	10.68	-	-
Yearly or Less	6.72	7.07	-	-
Never	10.57	13.38	-	-
MGF Contact (%)				
N	17163	14912	-	-
Daily	12.93	10.27	-	-
Weekly	31.92	30.06	-	-
Monthly	10.65	10.49	-	-
Every Few Months	10.41	10.86	-	-
Yearly or Less	8.10	8.01	-	-
Never	25.99	30.31	-	-

Table 6.1: Descriptive statistics, continued.

Measurement Occasion/ Time	**9m**	**3y**	**5y**	**7y**
PGM Contact (%)				
N	12599	10390	-	-
Daily	9.48	6.45	-	-
Weekly	41.82	37.47	-	-
Monthly	15.30	15.68	-	-
Every Few Months	12.12	13.53	-	-
Yearly or Less	7.66	7.89	-	-
Never	13.61	18.98	-	-
PGF Contact (%)				
N	12599	10853	-	-
Daily	7.90	5.33	-	-
Weekly	31.83	26.44	-	-
Monthly	13.28	12.24	-	-
Every Few Months	10.86	11.74	-	-
Yearly or Less	8.05	7.31	-	-
Never	28.09	36.95	-	-
MG Financial Assistance (%)				
N	13726	11257	11001	-
Yes	75.30	79.30	74.53	-
No	24.70	20.70	25.47	-
PG Financial Assistance (%)				
N	11805	8936	8886	-
Yes	70.71	70.36	70.00	-
No	29.29	29.64	30.00	-
Other Variables				
Maternal Employment (%)				
N	17191	-	14220	12965
Yes	48.05	-	57.27	63.13
No	51.95	-	42.73	36.87
Paternal Employment (%)				
Yes	12.30	-	8.78	8.47
No	87.70	-	91.22	91.53
Birth Weight (kg)				
mean	3.34	-	-	-
(sd)	0.590	-	-	-
range	0.39-7.23	-	-	-
Gestation Length (weeks)				
mean	39.55	-	-	-
(sd)	2.04	-	-	-
range	23-42.29	-	-	-
Mother's Age at Birth (yrs.)				
mean	28.73	-	-	-
(sd)	5.79	-	-	-
range	13-63	-	-	-
Country (%)				
England	61.93	-	63.94	64.04
Wales	15.02	-	14.15	14.33
Scotland	12.73	-	11.90	11.80
Northern Ireland	10.32	-	10.00	9.83

Table 6.1: Descriptive statistics, continued.

Measurement Occasion/ Time	**9m**	**3y**	**5y**	**7y**
Household Income (N)				
Top 25%	3975	-	2476	2432
Middle 50%	8531	-	5236	4676
Bottom 25%	3212	-	2225	2020
Indices of Multiple Deprivation				
mean	3.67	-	4.08	4.21
(sd)	2.93	-	2.99	2.98
range	0-9	-	0-9	0-9
Financial Difficulty (%)				
Living comfortably	23.55	-	23.44	21.93
Doing alright	37.16	-	38.00	36.20
Just about getting by	28.16	-	27.79	29.19
Finding it quite difficult	8.35	-	7.98	9.11
Finding it very difficult	2.79	-	2.80	3.57
Home Ownership (%)				
Renting	36.60	-	31.87	30.71
Own Home	61.14	-	66.37	68.03
Other	2.26	-	1.76	1.26
Maternal Education (%)				
O-level	37.12	-	-	-
A-level	13.96	-	-	-
Degree	30.30	-	-	-
Overseas	2.86	-	-	-
None	15.75	-	-	-
Paternal Education (%)				
O-level	33.97	-	-	-
A-level	15.30	-	-	-
Degree	34.15	-	-	-
Overseas	3.47	-	-	-
None	13.11	-	-	-
Ethnicity of Child (%)				
White	84.17	-	-	-
South Asian	8.55	-	-	-
Black	3.57	-	-	-
Other	3.70	-	-	-
Sex of Child (%)				
Male	51.27	-	-	-
Female	48.73	-	-	-
Number of Focal Child's Siblings in Household				
mean	0.98	-	1.42	1.52
(sd)	1.09	-	1.08	1.09
range	0-9	-	0-12	0-12

6.2.3 Analyses

For breastfeeding initiation, I carry out a logistic regression with 0=no and 1=yes. For breastfeeding duration, I carry out a discrete time event history analysis, which is used to estimate the probability of an event occurring through discrete units of time, called the hazard function (Allison, 1982; Singer & Willett, 2003). The discrete-time hazard function can be denoted as:

$$h_j(t) = \Pr(y_j(t) = 1 | y_j(t-1) = 0)$$

where the hazard function $h_j(t)$ is the probability of having an event y at time t for individual j, given that there has been no earlier event occurrence. For the current event history analysis I fit a logistic model with categorical time intervals expressed as:

$$\log\left[\frac{h_j(t)}{1-h_j(t)}\right] = \alpha(t) + \beta_1 x_{1j}(t) + \beta_2 x_{2j}(t) + \cdots + \beta_p x_{pj}(t)$$

$$\alpha(t) = \alpha_1 D_1 + \alpha_2 D_2 + \cdots + \alpha_p D_p$$

where $\alpha(t)$ represents the log-baseline hazard function through time, and $\beta_p x_{pj}(t)$ represents the coefficient, β, for the p^{th} covariate, x, for individual j at time t. Specifically, $\alpha(t)$ is a categorical function of time with dummy variables D_1, D_2, …, D_p for time intervals t=1, 2, …, p.

For the current analysis regarding breastfeeding duration, the event represents breastfeeding termination, and the time units are months since birth. This method is appropriate due to the right-censored nature of the data, where some mothers had not terminated breastfeeding by 8 months. Ignoring the right-censored nature of data, or removing right-censored cases introduces bias and a reduction in sample size (Allison, 1982; Singer & Willett, 2003). The model assumes that the effects of covariates are constant over time, known as the proportional hazards assumption. For both breastfeeding initiation and breastfeeding duration, I use predictor variables collected at 9 months.

For mother score and father score, I carry out random-intercept random-slope linear regression models. The random-intercept is added to account for the repeated data collection within households, and the random-slope term is added due to better model fit based on AIC and BIC. The detailed outline of multilevel models can be reviewed in Chapter 3. To minimise the reverse causality, the grandparent investment variables are lagged if possible. For grandparent contact, information collected at 9 months is used to predict parent scores at 9 months, but 3 years is used to predict 5 years and 7 years. For

grandparent financial help, information collected at 9 months is used to predict parent scores at 9 months, but 3 years is used to predict 5 years, and 5 years to predict 7 years.

The current analytical approach is to assess the importance of the predictors of interest using penalised model fit values, AIC and BIC. I use both AIC and BIC, as AIC tends to suggest larger models as best fitting, while BIC tends to suggest smaller models (Kuna, 2004). If AIC and BIC both agree in terms of model fit, one can be relatively confident in the model fit values. If there are differences, caution and informed qualitative judgement may be necessary when assessing model fit. In general, a reduction in AIC and BIC score by 2 or more points is taken to be evidence for better model fit, though the bigger the reductions in scores the stronger the evidence for the better fit model (Kass & Raftery, 1993; Burnham, Anderson & Huyvaert, 2011).

To investigate the effects of grandparent contact frequency and financial help on breastfeeding and parenting score, I run a maximum of four models for all outcomes. The *Base Model* is of the controls, and the *Full Model* is of the controls + grandparent variables. The *Best Fit: AIC Model* is of the controls + grandparent variables which improves AIC by a minimum of 2 points, and the *Best Fit: BIC Model* is of the controls + grandparent variables which improves BIC by a minimum of 2 points.

To test whether the effects of grandparental investments differ by maternal employment, I carry out interactions between maternal employment status and grandparent contact/financial help. However, to facilitate interactions, I collapse grandparent contact frequency into a binary category of having weekly or more contact frequency (no=0, yes=1). For all outcomes, I show the *Base Model* which is of the controls + binary grandparent variables. Separate models are presented for each interaction between maternal employment and MGM contact, MGF contact, PGM contact, PGF contact, MG financial help, and finally PG financial help. AIC and BIC values are provided for all models, and this is used to assess whether the interaction improves model fit compared to the base model.

6.3 Results of Chapter 6

6.3.1 Grandparental Investments and Breastfeeding

The full results for the best fit (AIC) models are displayed in the appendix (breastfeeding initiation: table A4; breastfeeding duration: table A5). Table 6.1 displays the key results for breastfeeding initiation. I find that inclusion of MGM contact, MGF contact,

and PGM contact is the best fit model according to AIC, where it improves model fit by 192 AIC points compared to the base model, and 5 AIC points compared to the full model. However, the best fit model according to BIC only includes MGM contact, where the best fit model improves model fit by 105 BIC points compared to the base model, and 79 points compared to the full model. This suggests that MGM contact is a good predictor for breastfeeding initiation, and we should evaluate the importance of MGF contact and PGM contact further.

In the AIC model, the odds of breastfeeding initiation, compared to the reference category of "every day contact," are significantly higher with less contact for MGM and PGM (table 6.2). However, for MGF contact, "contact every few months" is the only significantly different category to the reference, predicting higher odds of initiation. The predicted probability of breastfeeding initiation by grandparent contact frequency, according to the best fit AIC model, is presented in fig. 6.1 for MGM contact, 6.2 for MGF contact, and 6.3 for PGM contact.

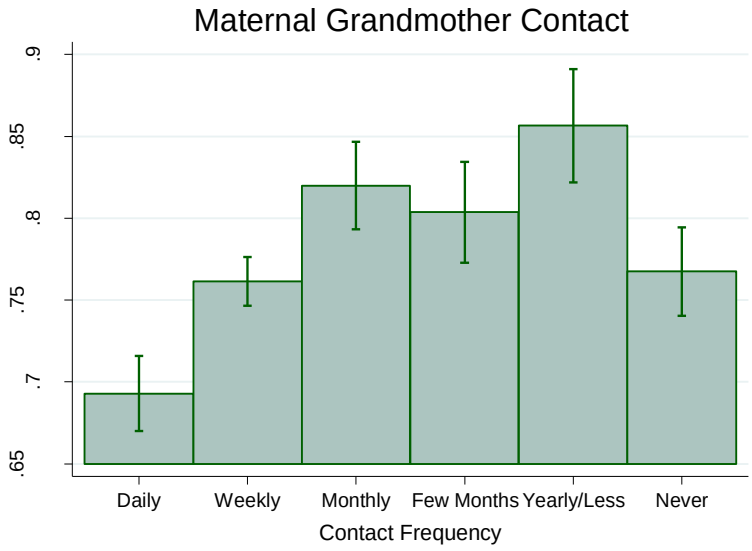

Fig. 6.1: Maternal grandmother contact frequency and predicted probability of breastfeeding initiation with 95% confidence intervals: best fit AIC model.

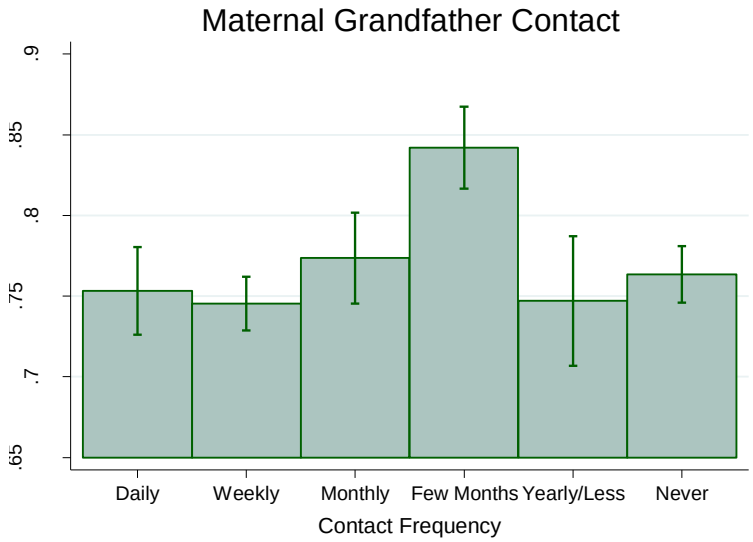

Fig. 6.2: Maternal grandfather contact frequency and predicted probability of breastfeeding initiation with 95% confidence intervals: best fit AIC model.

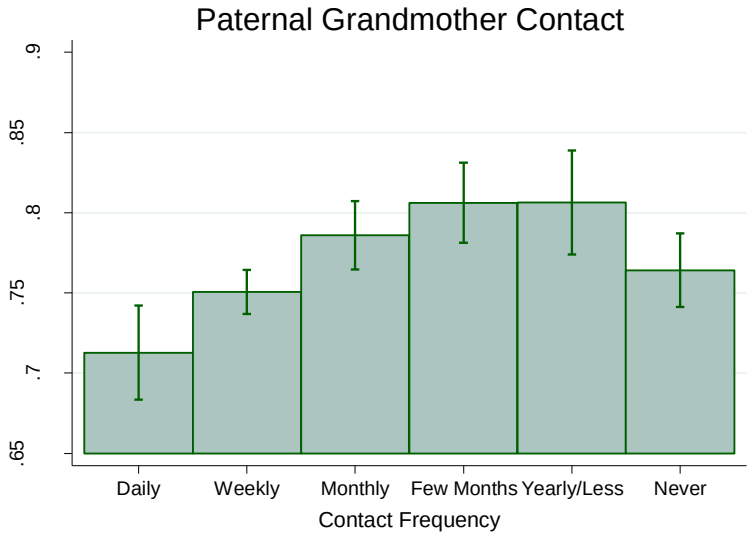

Fig. 6.3: Paternal grandmother contact frequency and predicted probability of breastfeeding initiation with 95% confidence intervals: best fit AIC model.

Figures 6.1 and 6.3 show a clear linear trend for MGM contact and PGM contact, where the probability of breastfeeding initiation is higher with lower frequencies of contact, with the exception of the "never" category. For MGM, the predicted probability of breastfeeding initiation for daily contact is 0.693 (95% CI: 0.670, 0.716), going up to 0.820 (95% CI: 0.793, 0.847) for monthly contact, and 0.856 (95% CI: 0.822, 0.891) for yearly or less contact. For PGM, contact has smaller effects in the same direction where the predicted probability of breastfeeding initiation for daily contact is 0.713 (95% CI: 0.68, 0.742), going up to 0.786 (95% CI: 0.765, 0.807) for monthly contact, and 0.806 (95% CI: 0.774, 0.839) for yearly or less contact. It is likely that PGM contact was not retained in the BIC model due to the small effects.

For MGF, fig 6.2 highlights that there are no trends in the frequency of contact and the probability of breastfeeding initiation. Despite its retention in AIC model, there is no clear evidence that MGF contact frequency is an important predictor for breastfeeding initiation, and may be a false positive result due to random noise and a large sample size. Combined, these results suggest that maternal and paternal grandmother contact is associated with a negative effect on breastfeeding initiation, where the higher the contact frequency the lower the probability of initiation.

Table 6.2: Logistic regression results for grandparent contact and financial assistance on odds of breastfeeding initiation.

	Base		Full		Best Fit: AIC		Best Fit: BIC	
N=11471								
Breastfeeding Initiation	**OR**	**95%CI**	**OR**	**95%CI**	**OR**	**95%CI**	**OR**	**95%CI**
MGM Contact								
Every Day (ref)	-	-	-	-	-	-	-	-
Weekly	-	-	1.415***	1.238, 1.617	1.414***	1.238, 1.615	1.393***	1.248, 1.555
Monthly	-	-	2.005***	1.614, 2.491	2.018***	1.626, 2.505	2.242***	1.861, 2.701
Every Few Months	-	-	1.811***	1.435, 2.285	1.814***	1.438, 2.287	2.493***	2.044, 3.040
Yearly or Less	-	-	2.658***	1.949, 3.625	2.644***	1.944, 3.597	2.580***	1.970, 3.376
Never	-	-	1.471***	1.211, 1.786	1.463***	1.218, 1.757	1.500***	1.265, 1.781
MGF Contact								
Every Day (ref)	-	-	-	-	-	-	-	-
Weekly	-	-	0.962	0.814, 1.137	0.959	0.812, 1.134	-	-
Monthly	-	-	1.120	0.896, 1.401	1.120	0.896, 1.400	-	-
Every Few Months	-	-	1.747***	1.365, 2.236	1.746***	1.365, 2.234	-	-
Yearly or Less	-	-	0.970	0.745, 1.261	0.968	0.744, 1.259	-	-
Never	-	-	1.062	0.895, 1.261	1.058	0.892, 1.125	-	-
PGM Contact								
Every Day (ref)	-	-	-	-	-	-	-	-
Weekly	-	-	1.225*	1.015, 1.478	1.213*	1.039, 1.417	-	-
Monthly	-	-	1.318*	1.045, 1.662	1.480***	1.223, 1.791	-	-
Every Few Months	-	-	1.525***	1.177, 1.976	1.677***	1.351, 2.080	-	-
Yearly or Less	-	-	1.616***	1.203, 2.170	1.680***	1.311, 2.152	-	-
Never	-	-	1.300*	1.040, 1.614	1.306**	1.083, 1.575	-	-
PGF Contact								
Every Day (ref)	-	-	-	-	-	-	-	-
Weekly	-	-	0.979	0.797, 1.203	-	-	-	-
Monthly	-	-	1.242	0.969, 1.591	-	-	-	-
Every Few Months	-	-	1.199	0.914, 1.573	-	-	-	-
Yearly or Less	-	-	1.083	0.813, 1.444	-	-	-	-
Never	-	-	1.016	0.829, 1.246	-	-	-	-
MG Financial Help								
No (ref)	-	-	-	-	-	-	-	-
Yes	-	-	1.008	0.892, 1.139	-	-	-	-
PG Financial Help								
No (ref)	-	-	-	-	-	-	-	-
Yes	-	-	1.029	0.916, 1.156	-	-	-	-
AIC	11695		11508		11503		11553	
BIC	11923		11897		11841		11818	

*$P \leq 0.05$ **$P \leq 0.01$ ***$P \leq 0.001$

Table 6.2 displays the key results for breastfeeding duration. I find that inclusion of MGM contact, PGM contact, and PGF contact is the best fit model according to AIC, where it improves model fit by 73 AIC points compared to the base model, and 4 AIC points compared to the full model. However, the best fit model according to BIC only includes MGM contact, where the best fit model improves model fit by 6 BIC points compared to the base model, and 125 points compared to the full model. This suggests that MGM contact is a good predictor for breastfeeding initiation, and we should evaluate the importance of PGM contact and PGF contact further.

In the AIC model, the odds of breastfeeding termination, compared to the reference category of "every day contact," are generally lower with less contact for MGM and PGM (table 6.3). However, for PGF contact, "weekly contact" is the only significantly different category to the reference, predicting lower odds of termination. The predicted probability of breastfeeding duration by grandparent contact frequency, according to the best fit AIC model, is presented in fig. 6.4 for MGM contact, 6.5 for PGM contact, and 6.6 for PGF contact.

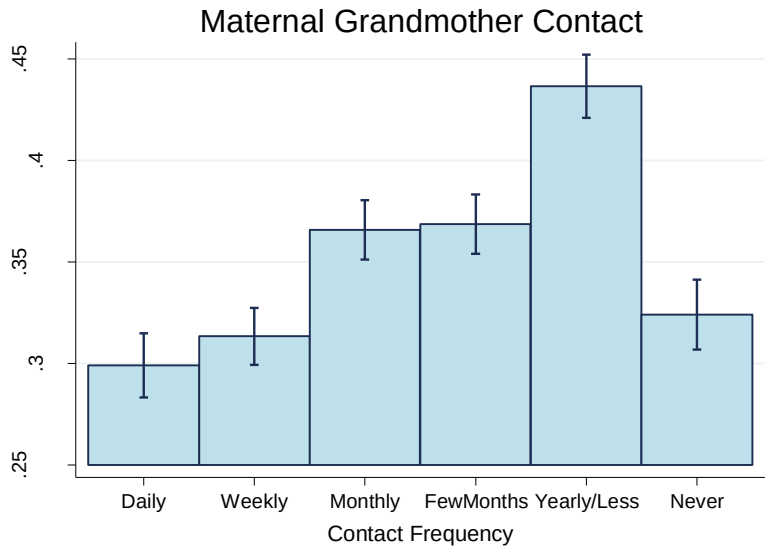

Fig. 6.4: Maternal grandmother contact frequency and predicted probability of breastfeeding at 6 months with 95% confidence intervals: best fit AIC model.

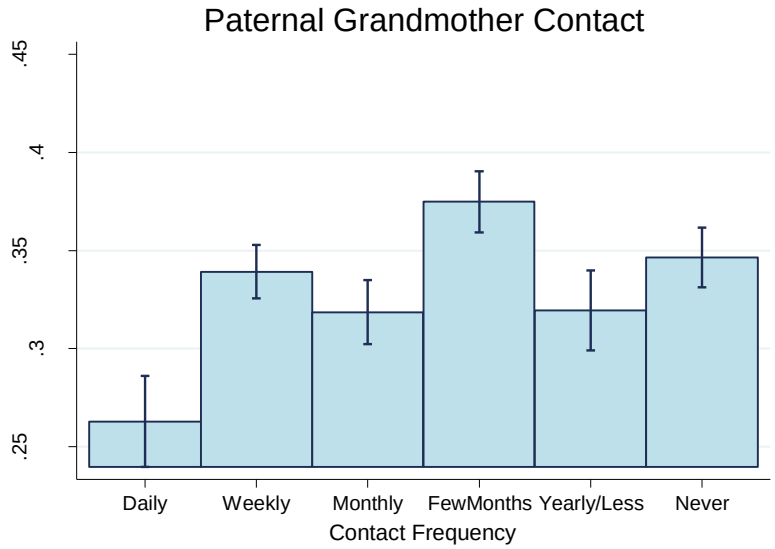

Fig. 6.5: Paternal grandmother contact frequency and predicted probability of breastfeeding at 6 months with 95% confidence intervals: best fit AIC model.

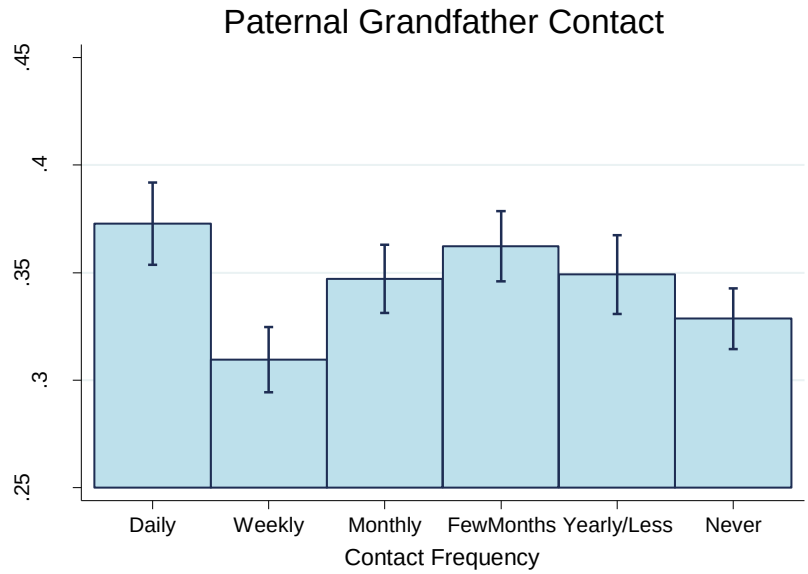

Fig. 6.6: Paternal grandfather contact frequency and predicted probability of breastfeeding at 6 months with 95% confidence intervals: best fit AIC model.

Like breastfeeding initiation, figures 6.4 shows a linear trend for MGM contact where the probability of breastfeeding at 6 months is higher with lower frequencies of contact, with the exception of the "never" category. The predicted probability of breastfeeding at 6 months for daily contact is 0.299 (95% CI: 0.283, 0.315), going up to 0.366 (95% CI: 0.351, 0.380) for monthly contact, and 0.436 (95% CI: 0.421, 0.452) for yearly or less contact.

For PGM, while figure 6.5 does not shows a clear trend, the predicted probability of breastfeeding at 6 months is lowest at 0.263 (95% CI: 0.240, 0.286) when mothers have daily contact. The retention in the best fit AIC model is likely driven by the significant difference between daily contact and most other categories (see table 6.3). It is possible that PGM daily contact is categorically different in its effect from other contact frequencies if there is a threshold effect, where very frequent contact is necessary for PGMs to influence maternal breastfeeding. However, given that there are no clear trends, and that PGM contact is not retained in the best fit BIC model, we should be cautious regarding the interpretation of the importance of PGM for breastfeeding duration.

For PGF, figure 6.6 does not show a clear trend, and the predicted probability of breastfeeding at 6 months is lowest at 0.309 (95% CI: 0.294, 0.325) when mothers have weekly contact. Retention in the best fit AIC model is likely driven by the significant difference between weekly contact and most other contact categories. While it is possible that there is something categorically different between PGF weekly contact and other contact frequencies, this is unlikely due to the somewhat arbitrary nature of the contact frequency categorisation. The results may be a false positive result due to random noise and a large sample size

Overall, these results suggest that maternal grandmother contact has a negative effect on breastfeeding duration, where the higher the contact frequency the lower the probability of initiation. These results also indicate that paternal grandmother contact may have a negative effect on breastfeeding duration, if contact is very frequent.

Table 6.3: Logistic regression (discrete-time event history analysis) results for grandparent contact and financial assistance on breastfeeding duration (odds of breastfeeding termination).

	Base		Full		Best Fit: AIC		Best Fit: BIC	
N Obs=36604 N Mothers=8206 ***Breastfeeding Duration: Odds of termination***	**OR**	**95%CI**	**OR**	**95%CI**	**OR**	**95%CI**	**OR**	**95%CI**
MGM Contact								
Every Day (ref)	-	-	-	-	-	-	-	-
Weekly	-	-	0.992	0.889, 1.094	0.956	0.882, 1.035	0.962	0.888, 1.042
Monthly	-	-	0.878	0.769, 1.001	0.812***	0.730, 0.904	0.725***	0.725, 0.896
Every Few Months	-	-	0.889	0.776, 1.018	0.806***	0.723, 0.897	0.782***	0.702, 0.869
Yearly or Less	-	-	0.717***	0.603, 0.851	0.655***	0.568, 0.756	0.659**	0.572, 0.760
Never	-	-	0.962	0.842, 1.099	0.924	0.822, 1.039	0.922	0.821, 1.036
MGF Contact								
Every Day (ref)	-	-	-	-	-	-	-	-
Weekly	-	-	0.927	0.818, 1.051	-	-	-	-
Monthly	-	-	0.870	0.749, 1.010	-	-	-	-
Every Few Months	-	-	0.837*	0.718, 0.975	-	-	-	-
Yearly or Less	-	-	0.837*	0.705, 0.994	-	-	-	-
Never	-	-	0.925	0.815, 1.049	-	-	-	-
PGM Contact								
Every Day (ref)	-	-	-	-	-	-	-	-
Weekly	-	-	0.785**	0.681, 0.905	0.784***	0.680, 0.903	-	-
Monthly	-	-	0.833**	0.709, 0.980	0.836*	0.711, 0.982	-	-
Every Few Months	-	-	0.703***	0.592, 0.834	0.702***	0.592, 0.833	-	-
Yearly or Less	-	-	0.826*	0.685, 0.995	0.833	0.692, 1.003	-	-
Never	-	-	0.749***	0.639, 0.877	0.766***	0.657, 0.893	-	-
PGF Contact								
Every Day (ref)	-	-	-	-	-	-	-	-
Weekly	-	-	1.214**	1.042, 1.414	1.217*	1.045, 1.418	-	-
Monthly	-	-	1.083	0.912, 1.286	1.082	0.912, 1.285	-	-
Every Few Months	-	-	1.035	0.864, 1.239	1.033	0.863, 1.236	-	-
Yearly or Less	-	-	1.069	0.885, 1.292	1.075	0.890, 1.299	-	-
Never	-	-	1.137	0.977, 1.322	1.146	0.986, 1.332	-	-
MG Financial Help								
No (ref)	-	-	-	-	-	-	-	-
Yes	-	-	0.994	0.922, 1.072	-	-	-	-
PG Financial Help								
No (ref)	-	-	-	-	-	-	-	-
Yes	-	-	0.947	0.881, 1.018	-	-	-	-
AIC	32116		32047		32043		32066	
BIC	32447		32566		32502		32441	

*$P \leq 0.05$ **$P \leq 0.01$ ***$P \leq 0.001$

6.3.2 Grandparental Investments and Parent Scores

The full results for the best fit (AIC) models are displayed in the appendix (mother score: table A6; father score: table A7). Table 6.4 displays the key results for mother score and father score. For mother score, I find that inclusion of PGF contact is the best fit model according to AIC, and improves model fit by 5 points compared to the base model and 21 points compared to the full model. However, the best fit model according to BIC was the base model, and did not include any grandparent variables.

In the AIC model, lower frequency of PGF contact is associated with higher mother scores (table 6.4). Fig 6.7 displays the predicted mother score by PGF contact, which shows that daily contact predicts a lower mother score at 9.47 (95% CI: 9.35, 9.59) compared to all other categories which range between 9.68 and 9.74. It is possible that PGF daily contact is categorically different in its effect from other contact frequencies, where very frequent contact is necessary for PGFs to influence maternal parenting. Given that there is no clear trend, and that PGF is not retained in the best fit BIC model, we should be cautious regarding the interpretation of the importance of PGM for mother score.

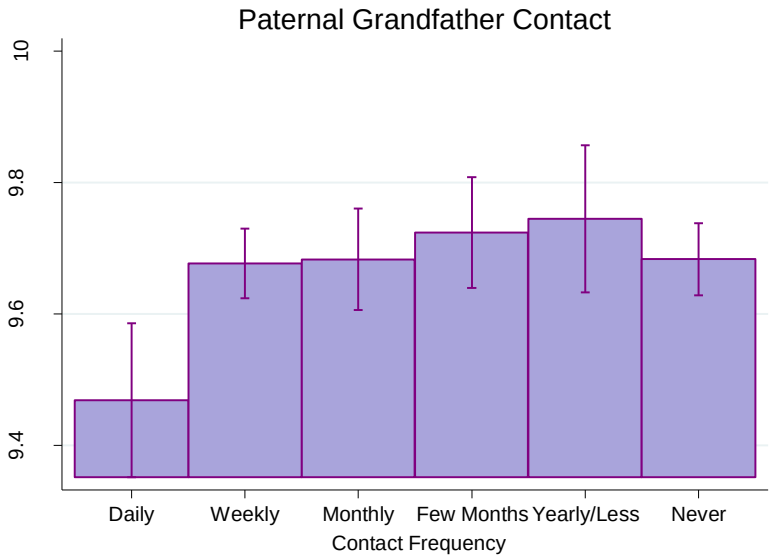

Fig 6.7: Paternal grandfather contact and predicted mother score with 95% confidence intervals: best fit AIC model.

For father score, I find that inclusion of PG financial help is the best fit model according to both AIC and BIC, where financial help from paternal grandparents is associated with an increase in father score by 0.14 ($P \leq 0.001$, SE=0.037). Compared to the base model, the best fit model improves AIC by 45 points and BIC by 37 points. Compared to the full model, the best fit model improves AIC by 58 points and BIC by 226 points.

Taken together, the results suggest that very frequent contact with paternal grandfathers is associated with lower mother scores, while financial help from paternal grandparents are associated with high father scores.

Table 6.4: Random-intercept random-slope linear regression results for grandparent contact and financial assistance on mother score and father score.

N Obs=22320 N Mothers=11592	***Mother Score***						***Father Score***					
	Base (Best Fit: BIC)		**Full**		**Best Fit: AIC**		**Base**		**Full**		**Best Fit: AIC & BIC**	
	B	**SE**	**B**	**SE**	**B**	**SE**	**B**	**SE**	**B**	**SE**	**B**	**SE**
MGM Contact												
Every Day (ref)	-	-	-	-	-	-	-	-	-	-	-	-
Weekly	-	-	0.012	0.049	-	-	-	-	0.007	0.061	-	-
Monthly	-	-	-0.103	0.069	-	-	-	-	0.002	0.086	-	-
Every Few Months	-	-	-0.009	0.072	-	-	-	-	0.033	0.090	-	-
Yearly or Less	-	-	0.156	0.093	-	-	-	-	0.035	0.116	-	-
Never	-	-	0.034	0.067	-	-	-	-	0.043	0.084	-	-
MGF Contact												
Every Day (ref)	-	-	-	-	-	-	-	-	-	-	-	-
Weekly	-	-	0.062	0.062	-	-	-	-	-0.055	0.078	-	-
Monthly	-	-	0.097	0.077	-	-	-	-	-0.110	0.096	-	-
Every Few Months	-	-	0.067	0.080	-	-	-	-	0.013	0.100	-	-
Yearly or Less	-	-	0.027	0.089	-	-	-	-	0.055	0.112	-	-
Never	-	-	0.052	0.063	-	-	-	-	-0.003	0.080	-	-
PGM Contact												
Every Day (ref)	-	-	-	-	-	-	-	-	-	-	-	-
Weekly	-	-	0.044	0.073	-	-	-	-	0.114	0.093	-	-
Monthly	-	-	-0.013	0.084	-	-	-	-	0.051	0.105	-	-
Every Few Months	-	-	0.034	0.088	-	-	-	-	0.105	0.110	-	-
Yearly or Less	-	-	0.066	0.099	-	-	-	-	0.084	0.122	-	-
Never	-	-	0.015	0.081	-	-	-	-	0.114	0.080	-	-
PGF Contact												
Every Day (ref)	-	-	-	-	-	-	-	-	-	-	-	-
Weekly	-	-	0.183*	0.079	0.208***	0.065	-	-	0.073	0.100	-	-
Monthly	-	-	0.233**	0.089	0.215**	0.072	-	-	0.028	0.112	-	-
Every Few Months	-	-	0.246**	0.092	0.255***	0.075	-	-	0.068	0.117	-	-
Yearly or Less	-	-	0.241*	0.100	0.276***	0.082	-	-	0.139	0.126	-	-
Never	-	-	0.201**	0.078	0.214***	0.066	-	-	0.128	0.099	-	-
MG Financial Help												
No (ref)	-	-	-	-	-	-	-	-	-	-	-	-
Yes	-	-	-0.008	0.037	-	-	-	-	0.048	0.044	-	-
PG Financial Help												
No (ref)	-	-	-	-	-	-	-	-	-	-	-	-
Yes	-	-	-0.009	0.034	-	-	-	-	0.145***	0.041	0.140***	0.037
AIC	93661		93677		93656		102295		102308		102250	
BIC	93941		94134		93977		102576		102765		102539	

*$P \leq 0.05$ **$P \leq 0.01$ ***$P \leq 0.001$

6.3.3 Grandparent Effects by Maternal Employment

To test whether the effects of grandparental investments on parental direct investments differ by maternal employment, I carry out interactions between grandparent contact/financial help and maternal employment. Note, grandparent contact frequency has been collapsed into "weekly contact or more" and "less than weekly contact," meaning all grandparent investment variables are binary.

Grandparent Effects on Breastfeeding by Maternal Employment

Table 6.5 displays the results of the interactions for breastfeeding initiation and duration. For breastfeeding initiation, I find a similar result to the previous analysis where MGM, MGF, and PGM weekly contact is associated with lower odds of initiation at the $P \leq 0.001$ level. Note, however, that the effect of MGF contact is likely driven by the higher odds of breastfeeding initiation for "contact once every few months" compared to other contact frequencies, as shown in the previous analysis. In the interaction models, I find that no interactions improve AIC or BIC, suggesting that the effects of grandparent investments on breastfeeding initiation does not differ by maternal employment.

In the base model for breastfeeding duration, like in the previous analysis, I find that MGM weekly contact predicts higher odds of breastfeeding termination at $P \leq 0.001$. Unlike the previous analysis, however, PGM and PGF contact is not a significant predictor of breastfeeding duration at the $P \leq 0.05$ level. MGF contact, which was a significant predictor in the previous analysis but had failed to be retained in the best fit models, is significant at the $P \leq 0.05$ level. MGF weekly contact is found to predict higher odds of breastfeeding termination. In the interaction models, no interactions are significant at the $P \leq 0.05$ level and fail to improve BIC, but interactions between MGM/MGF contact and maternal education is found to improve AIC by 1 point. While a reduction of AIC by 1 point means that model fit is not improved by any significant level, it also means that the model is comparable in fit to the base model.

Fig 6.8 displays the interaction between maternal employment and MGM contact. For both unemployed and employed mothers, weekly contact or more increases the probability of breastfeeding termination. However, this effect is bigger for unemployed mothers. Fig 6.9 displays the interaction between maternal employment and MGF contact, and a similar pattern is found. For both unemployed and employed mothers,

weekly contact or more increases the probability of breastfeeding termination. However, the effect seems to be bigger for unemployed mothers.

Note, again, that the interactions in the current analyses are not significant, and only improves AIC by 1 point. Consequently, this is not strong evidence that the effects of MGM and MGF contact varies by maternal employment. However, considering use of the collapsed, low-resolution variables, these results are interesting to note. They indicate that the effects of maternal grandparent contact on breastfeeding termination may be stronger for unemployed mothers, where higher contact frequency is associated with higher odds of breastfeeding termination.

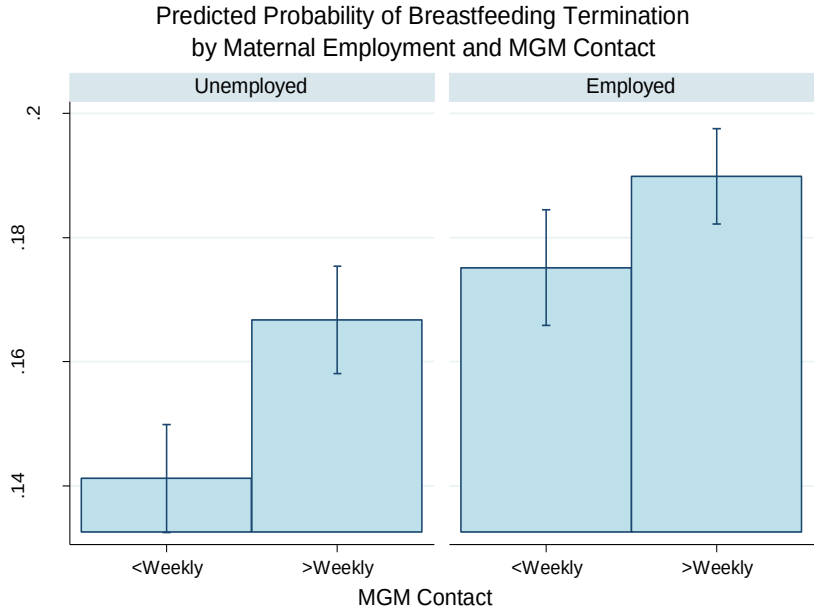

Fig 6.8: Probability of breastfeeding termination by maternal employment and MGF contact with 95% confidence intervals.

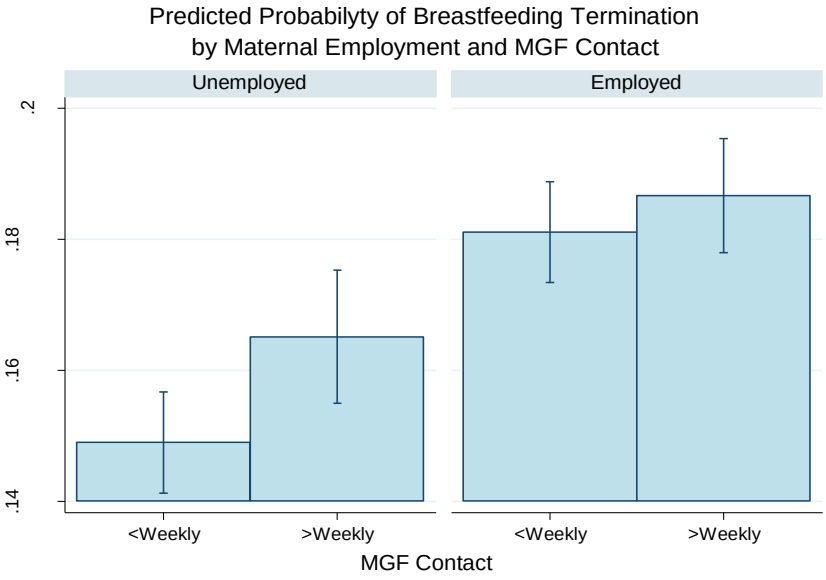

Fig 6.9: Probability of breastfeeding termination by maternal employment and MGF contact with 95% confidence intervals.

Table 6.5: Results on grandparental investment by maternal employment on breastfeeding initiation and breastfeeding duration.

(N=11471)	BASE		*MGM		*MGF		*PGM		*PGF		*MG Fin. Help		*PG Fin. Help	
Breastfeeding Initiation	**OR**	**95%CI**	**Added Interactions**	**OR**	**95%CI**	**OR**	**95%CI**	**OR**	**95%CI**	**OR**	**95%CI**	**OR**	**95%CI**	**OR**	**95%CI**
Mother Employed	0.948	1.011, 1.031	Mother Employed	0.939	0.781, 1.130	0.986	0.853, 1.141	0.896	0.769, 1.044	0.975	0.851, 1.117	0.892	0.732, 1.087	0.913	0.762, 1.095
MGM Weekly Contact	0.668***	0.591, 0.755	Weekly Contact	0.664***	0.568, 0.776	0.855*	0.741, 0.986	0.786***	0.678, 0.911	0.927	0.800, 1.073	1.011	0.864, 1.183	1.052	0.907, 1.222
MGF Weekly Contact	0.822***	0.740, 0.924	Employed * Weekly Contact	1.013	0.826, 1.243	0.930	0.775, 1.117	1.099	0.914, 1.323	0.943	0.786, 1.132	1.083	0.873, 1.343	1.053	0.860, 1.289
PGM Weekly Contact	0.824***	0.735, 0.924													
PGF Weekly Contact	0.898†	0.805, 1.001													
MG Financial Help	1.051	0.935, 1.181													
PG Financial Help	1.080	0.967, 1.206													
AIC	11573			11575		11574		11574		11575		11575		11575	
BIC	11845			11854		11854		11853		11864		11854		11854	
(N=8206)															
Breastfeeding Duration			**Added Interactions**												
Mother Employed	1.229***	1.150, 1.312	Mother Employed	1.305***	1.185, 1.437	1.276***	1.175, 1.387	1.248***	1.146, 1.359	1.239***	1.145, 1.342	1.191**	1.054, 1.347	1.280***	1.144, 1.433
MGM Weekly Contact	1.157***	1.074, 1.247	Weekly Contact	1.227***	1.109, 1.357	1.136*	1.026, 1.257	1.090†	0.984, 1.208	1.081	0.973, 1.201	0.953	0.859, 1.057	0.976	0.883, 1.080
MGF Weekly Contact	1.075*	1.001, 1.155	Employed * Weekly Contact	0.904†	0.804, 1.016	0.915	0.814, 1.029	0.968	0.862, 1.085	0.977	0.867, 1.100	1.041	0.910, 1.190	0.944	0.832, 1.072
PGM Weekly Contact	1.069†	0.991, 1.153													
PGF Weekly Contact	1.065†	0.988, 1.149													
MG Financial Help	0.974	0.907, 1.047													
PG Financial Help	0.944	0.882, 1.011													
AIC	32070			32069		32069		32071		32071		32071		32071	
BIC	32452			32460		32461		32463		32463		32463		32462	

† $P \leq 0.1$ *$P \leq 0.05$ **$P \leq 0.01$ ***$P \leq 0.001$

Grandparent Effects on Parenting Score by Maternal Employment

Table 6.6 displays the results of the interactions for mother score and father score. For mother score, I find that none of the grandparent variables are a significant predictor in the base model, unlike in the previous analysis where every-day paternal grandfather contact predicted lower mother scores. In the interaction models, I find that an interaction between PGF contact and maternal employment is significant at the $P \leq 0.05$ level and improves AIC by 1 point. Furthermore, an interaction between MG financial assistance and maternal employment, while not significant at the $P \leq 0.05$ level, improves AIC by 1 point.

Fig. 6.10 displays the interaction between maternal employment and PGF contact, which shows that weekly contact or more is associated with lower mother scores for unemployed mothers, but not employed mothers. Fig. 6.11 displays the interaction between maternal employment and MG financial help, which shows that the effect of MG financial help on mother score trends in different directions between employed and unemployed mothers. Financial help from MGs seems to have a negative effect on mother score for employed mothers, but a positive effect on unemployed mothers.

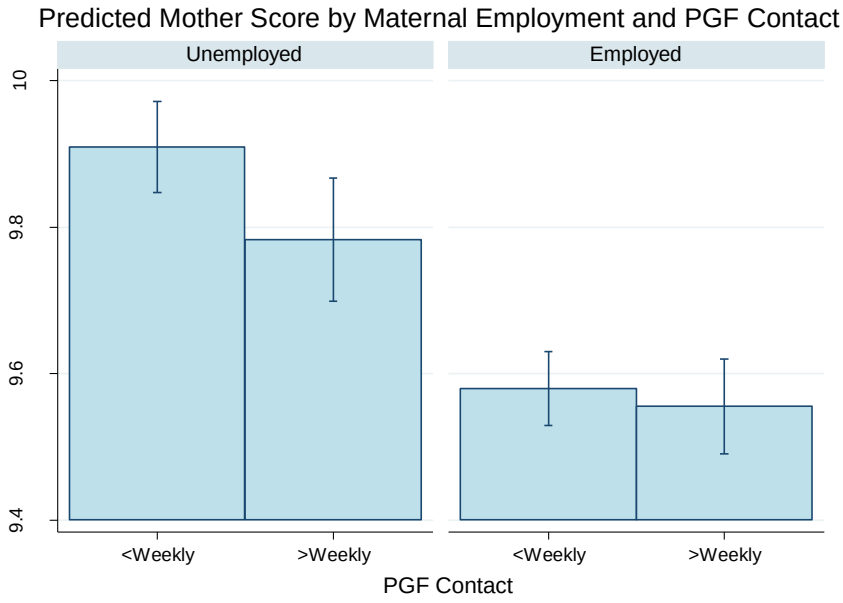

Fig 6.10: Predicted mother score by maternal employment and PGF contact with 95% confidence intervals.

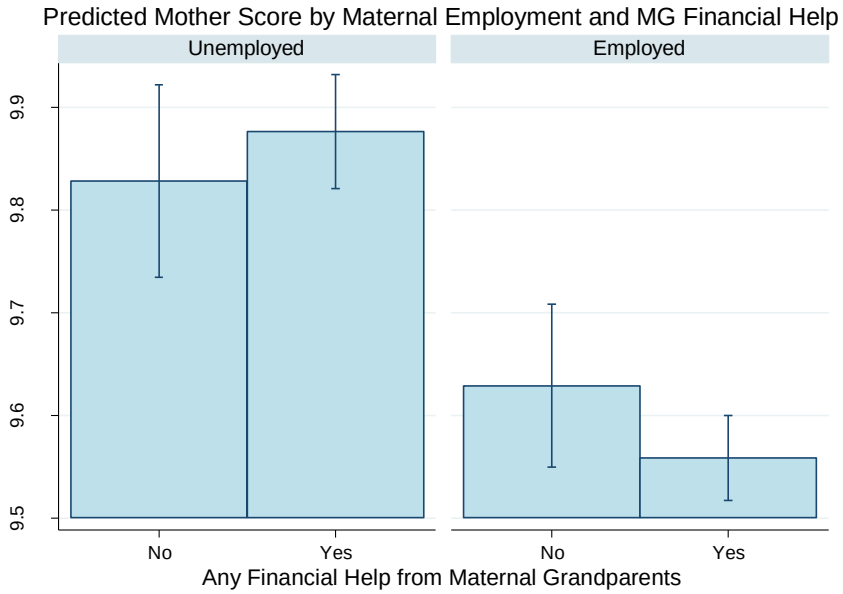

Fig 6.11: Predicted mother score by maternal employment and MG financial assistance with 95% confidence intervals.

For father score, I find a similar result to the previous analysis where PG financial help is a significant predictor in the base model at $P \leq 0.001$, where financial assistance from PGs is associated with an increase in father score. In the interaction models, I find that no interactions improve AIC or BIC.

Overall, these results suggest that the effect of PGF contact and MG financial assistance on mother score may differ by maternal employment. They indicate that the negative effect of paternal grandparent contact on mother score may be stronger for unemployed mothers. Furthermore, MG financial assistance may have opposite effects on employed and unemployed mothers, where financial assistance has a positive effect on mother score for employed mothers, but a negative effect for unemployed mothers. Again, while the current series of analyses do not provide strong evidence regarding the varying effects of grandparental investments by maternal employment, the results show an interesting trend which could be explored further in future studies.

Table 6.6: Results on grandparental investment by maternal employment on mother score and father score.

(N=11592)	BASE			*MGM		*MGF		*PGM		*PGF		*MG Fin. Help		*PG Fin. Help	
Mother Score	**OR**	**SE**	**Added Interactions**	**B**	**SE**	**B**	**SE**	**B**	**SE**	**B**	**SE**	**B**	**SE**	**B**	**SE**
Mother Employed	-0.292**	0.032	Mother Employed	-0.289***	0.048	-0.270***	0.041	-0.286***	0.042	-0.330***	0.039	-0.199**	0.061	-0.254***	0.054
MGM Weekly Contact	0.018	0.038	Weekly Contact	0.021	0.052	0.025	0.051	0.026	0.052	-0.127*	0.053	0.048	0.052	0.024	0.049
MGF Weekly Contact	-0.007	0.036	Employed * Weekly Contact	-0.006	0.059	-0.052	0.058	-0.014	0.058	0.102*	0.060	-0.119†	0.066	-0.053	0.061
PGM Weekly Contact	0.018	0.038													
PGF Weekly Contact	-0.062	0.038													
MG Financial Help	-0.021	0.035													
PG Financial Help	-0.008	0.032													
AIC	93669			93671		93670		93671		93668		93668		93671	
BIC	93998			94008		94007		94008		94005		94005		94007	
(N=11592)															
Father Score			**Added Interactions**												
Mother Employed	0.640***	0.039	Mother Employed	0.636***	0.059	0.625***	0.050	0.592***	0.051	0.623***	0.047	0.692***	0.074	0.614***	0.065
MGM Weekly Contact	-0.028	0.048	Weekly Contact	-0.031	0.066	-0.040	0.065	-0.033	0.065	-0.064	0.068	0.081	0.065	0.102	0.060
MGF Weekly Contact	-0.019	0.045	Employed * Weekly Contact	0.006	0.072	0.033	0.071	0.104	0.071	0.047	0.074	-0.067	0.080	0.035	0.073
PGM Weekly Contact	0.033	0.048													
PGF Weekly Contact	-0.034	0.048													
MG Financial Help	0.041	0.043													
PG Financial Help	0.124***	0.039													
AIC	102293			102295		102295		102293		102294		102294		102294	
BIC	102621			102631		102631		1022629		102631		102631		102631	

† $P \leq 0.1$ *$P \leq 0.05$ **$P \leq 0.01$ ***$P \leq 0.001$

6.4 Discussion of Chapter 6

6.4.1 Main Findings of Chapter 6

There have been very few studies investigating the associations between grandparent investments and parental investment behaviours in modern developed contexts. The aim of the current chapter was to explore the effects of grandparental investments on direct parental investments. Using data from MCS, I explored the association between grandparent contact frequency and financial help on breastfeeding and parenting. Following HBE, there are multiple possibilities regarding how grandparents may influence parenting. First, different grandparents may have different effects due to the different costs and benefits surrounding allomaternal investments. Second, the impact of grandparental investments may depend on the substitability of parental investments, as well as on the parental investment strategy: If parental investments are substitutable, an investment in financial help by grandparents may lead to a reduction in parental direct investments. If parental strategy is to optimise child quality, this substitution of direct care dimension may lead to a higher level of investment in resource acquisition.

Grandparental Investments and Breastfeeding

The results of this chapter indicate that there is an association between contact with maternal and paternal grandmothers and breastfeeding, where mothers who have frequent contact with grandmothers are less likely to initiate breastfeeding, and those that initiate breastfeeding are likely to do so for a shorter duration. Furthermore, the negative association between grandparent contact and breastfeeding duration may be stronger for unemployed mothers.

Why is grandmother contact associated with less breastfeeding? There are several possible reasons which may drive the current findings. Firstly, frequent contact may be associated with stronger formula-feeding norm transmissions between mothers and grandmothers. In developed western populations, breastfeeding rates gradually declined throughout the 20th century reaching an all-time low in the 1970s (Fomon, 2001). This means that many grandmothers are unlikely to have breastfed, and the norms they transmit to mothers may discourage breastfeeding. Indeed, there is some evidence to suggest that grandmother norms on breastfeeding influences maternal breastfeeding. In Ireland, it was found that maternal grandmother breastfeeding experience was a positive predictor of maternal breastfeeding initiation and duration (Sayers et al., 1995). In

Germany, maternal grandmothers' negative attitude to breastfeeding predicted lower probability of breastfeeding initiation, though it did not affect duration (Kohlhuber et al., 2008). However, results do not seem to be consistent, with one study finding that grandmother attitudes to breastfeeding having no influence on infant feeding in Bolivia (Ludvigsson, 2003), and a study which reported that White US mothers in Miami viewed grandmothers as having old-fashioned ideas on breastfeeding, and mothers did not rely on grandmothers for support and information on breastfeeding (Byrant, 1982).

Secondly, frequent contact with grandmothers may lead to lower levels of breastfeeding if grandmothers are substituting direct care activities. While breastfeeding itself is not a substitutable activity, infant feeding may be substituted by grandparents through the use of formula. Formula feeding is likely to reduce the dependency of the child on the mother, opening up more opportunities for grandmothers to assist with direct care activities, potentially discouraging mothers from breastfeeding. It is important to note that the causal direction of these associations is unknown. It may be that frequent grandparent contact creates an incentive for mothers not to breastfeed in order to take advantage of the available help. Equally, it may be that grandmothers increase contact with mothers and children when mothers are not breastfeeding, as there is a greater opportunity for them to provide help. Either way, the current results offer an interesting suggestion that mothers who breastfeed, and breastfeed for longer, may receive less grandmother direct support.

From an HBE perspective, it is interesting that grandfather contact had minimal effects on maternal breastfeeding. As discussed in Chapter 5 and the introduction to this chapter, post-menopausal grandmothers may have greater inclusive-fitness incentives to provide allomaternal investments for mothers. Consequently, the current findings may be a reflection of the different interactions during grandparent contact depending on grandparent type. During contact, grandmothers may be providing direct care, subsequently influencing maternal breastfeeding. Grandfather contact, on the other hand, may not involve direct care, consequently having minimal effects on maternal breastfeeding. If so, it suggests that grandmothers may be important allomothers within the UK childrearing context, as found in other traditional populations.

Why would grandparent contact have a stronger effect on breastfeeding termination for unemployed mothers? This difference may emerge due to the differences in the constraints on breastfeeding between employed and unemployed mothers. Unlike unemployed mothers, the main determinant of breastfeeding duration for employed mothers may be down to their work arrangements, such as length of maternity leave, work

environment and type of employment. If so, these constraints may reduce the influence of grandmother support on the decisions by employed mothers to terminate breastfeeding.

Overall, these results on breastfeeding is in line with previous studies which found that contact with grandmothers predicts lower levels of breastfeeding, and it is in contrast to those studies which suggested that grandmother emotional support leads to higher levels of breastfeeding. While literature generally suggests that support has a positive influence on breastfeeding initiation and duration, the current findings, combined with findings from previous studies, indicate that different types of support may have different effects. As outlined in the beginning of the chapter, perhaps there is a need to at distinguish between breastfeeding promotion and practical support.

Grandparental Investments and Parenting Score

In terms of parenting, I found that grandparent investments generally did not influence maternal and paternal parenting levels. However, everyday contact with paternal grandfathers was associated with lower levels of maternal parenting, particularly for unemployed mothers. While this association could be driven by grandfathers substituting maternal direct care, Following HBE theory I believe this is unlikely. Paternal grandfathers are consistently found to invest the least across populations, explained by the idea that paternal grandfathers have the least inclusive-fitness incentive to invest in their grandchildren (see Chapter 5). In fact, the presence of paternal grandfathers was associated with higher child mortality in some high fertility/mortality populations (Sear & Coall, 2011). If direct care substitutions occur, this effect is more likely to be seen in other grandparents.

Paternal grandfathers are often the oldest of the grandparents. Considering that the results were driven by everyday contact, especially for unemployed mothers, it may be that this association is the result of mothers having to sacrifice some direct care to support older paternal grandfathers. It is probable that the caretaking of paternal grandfathers is more likely to be carried out by unemployed mothers who do not have work commitments.

Interestingly, I also found that financial assistance from maternal grandparents may have opposite effects on maternal parenting depending on maternal employment, where financial help is associated with higher mother score for unemployed mothers but lower

mother score for employed mothers. It is possible that this result captures the different uses of financial assistance between employed and unemployed mothers. For employed mothers, given the work constraints on maternal direct investments, financial assistance may be primarily related to the substitution of direct care, such as payment for formal childcare. In contrast, financial assistance for unemployed mothers may be related to the substitution of provisioning activities (i.e., paid work), so mothers can concentrate on direct care. Interestingly, however, 1107 mothers reported receiving MGM financial help for childcare at 5 years, of which 47% of mothers were unemployed and 53% were employed. This suggests that there is no real difference in financial assistance for childcare depending on maternal employment. Therefore, the observed trend may stem from the differences in the use of supplemented resources by maternal employment status. In short, any financial help may increases household resources, and the extra resources may be used differently to meet the contrasting needs of employed and unemployed mothers.

Finally, I found strong evidence that financial assistance from paternal grandparents is associated with higher levels of paternal parenting. This association could be the result of norm transmission, whereby investments from paternal grandparents display an investment norm, encouraging fathers to increase their direct caregiving. Similarly, high levels of paternal direct investments may send an investment signal to paternal grandparents, for example by reflecting a high level of paternity certainty, which could encourage paternal grandparents to invest. However, it is unclear why the encouragement to invest would only exist with financial investments, and not with direct contact. Alternatively, it may be that there is some substitution in provisioning through paternal grandparent financial assistance, allowing fathers to increase their levels of direct care. As discussed in Chapter 5, this result would be expected is provisioning was a substitutable investment activity in the UK, where fathers are investing in child quality over quantity. The findings from Chapter 3 complement this idea, where paternal direct investments in ALSPAC were found to have positive effects on children's developmental outcomes, implying that fathers in the UK may be optimising child quality over quantity.

Overall Findings: Grandparental Investments and Parental Direct Investments

All together, the results of this chapter suggest that grandparental direct investments may reduce maternal direct investments, while grandparental indirect investments may increase paternal direct investments. This suggests that parental investments in the UK are a substitutable activity. The differences maternal and paternal investments could

mean that the substituted investments are parent specific, in that grandparents substitute maternal direct investments but paternal indirect investments. These differences in the patterns may emerge if grandparents target the most common investment activity for mothers and fathers: Like most other populations across the world, mothers in the UK are usually the primary caregiver (main provider of direct care) while fathers usually fulfil the provider role (main provider of resources) (see 1.2.2 Patterns of Allomaternal Care across Cultures and 1.6.2 The Allomaternal Context in the UK). Consequently, grandparents may direct allomaternal investments to substitute maternal direct care, while they substitute paternal provisioning.

Overall, the associations between grandparental investments and parental direct investments are not straight forward in that the effects depend on factors such type of grandparent, type of parental direct investment, and maternal employment. Our findings suggest that grandmothers may be more important in terms of direct care substitutions regarding maternal investments, as expected following and HBE approach. Interestingly, it seems grandparent direct investments may have a stronger negative effect on unemployed mothers, possibly due to the differences in the constraints to investments faced by unemployed and employed mothers.

The current findings highlighted that parental direct investment activities are substitutable, and the substitution depends on grandparent type. This was an important point to explore regarding the childrearing system in contemporary developed contexts, as grandparental investments may have indirect effects on child quality through impact on parental direct investments. To fully address the role of grandparents in the childrearing system of the UK, there is a need to examine grandparental investments and child outcomes, which I address in the next chapter.

6.4.2 Limitations of the Current Analyses

In this chapter, I presented strong evidence that maternal grandmother contact is associated with reduce breastfeeding, and paternal grandparent financial assistance is associated with increased paternal parenting. These associations were retained in the best fit BIC models. Regarding other findings, especially the different effects of grandparental investments by maternal employment, further investigations are necessary to reach strong conclusions. In addition, given the correlational nature of this study, the mechanisms behind these results are unclear. Furthermore, it is important to note that the parenting scores are based on play activities with the focal child, and is less detailed than ALSPAC.

Consequently, if grandparents have stronger or different effects on basic caretaking behaviour, this would not have been picked up in the current analyses.

Following an HBE perspective, the current chapter approached grandparental investments in terms of the impact it may have on the costs and benefits of parental investment behaviours. However, as outlined in the introduction on this chapter, parental investment behaviours may also be influenced by cultural norms. Specifically regarding breastfeeding, previous studies have found that "emotional support" in the form of breastfeeding promotion seems to increase breastfeeding intention, initiation or duration, highlighting the potential impact of norm transmission on parental behaviour. The findings of this chapter are in contrast to previous studies on emotional support and breastfeeding, in that direct contact with grandmothers was associated with lower levels of breastfeeding. This may be reflecting that direct contact is capturing allomaternal investments rather than norm transmission. However, to accurately determine the impact of grandparental investments on parental behaviour, there is a need to control for breastfeeding norms. This is especially important for breastfeeding, as the grandparent generation is less likely to have breastfed, meaning they may have stronger norms for formula feeding. It is therefore unclear whether the current findings are entirely down to grandparental direct investments impacting the costs and benefits surrounding breastfeeding, or whether this association is down to the norm transmission of "bottle feeding." Of course, both mechanisms may be operating simultaneously to influence maternal breastfeeding behaviour. Either way, interesting to see that mothers who breastfeed, and breastfeed for longer, less support from grandmothers. For future studies, it would be interesting to explore the process of grandparental norm transmission and direct investments simultaneously.

Finally, it is important to remember that the current sample consists of stable, biparental households due to the fact that investment information on paternal grandparents was only available for father-present households. It is possible that the relationship between grandparental investments and parental direct investments vary by family type. For instance, in father-absent households, maternal grandparents may be especially important to compensate for the reduction in paternal direct investment. In the current sample, we saw evidence of direct investment substitutions for maternal breastfeeding but not maternal parenting. In father-absent households, we may observe the substitution effect in maternal parenting. In addition, the parental reproductive strategy may vary depending on the types of households. Under HBE, we would predict unstable households to follow a faster life history strategy, investing in quantity over

quality of children. Consequently, the impact of grandparental investments may differ in that substitution in one dimension of investments may not increase parental investments in the other. In the current chapter, we saw that grandparent financial help lead to greater paternal direct investments. In unstable households, we may not observe this effect if fathers invest the allomaternal investments into mating effort.

Despite these limitations, the current series of analyses have been useful in highlighting the trends between grandparental investments and parental direct investments, especially in a topic with minimal research. Previous studies on grandparents in high fertility, high mortality populations have tended to use grandparent presence as a proxy of investments. Here, the proxies of grandparental investment involved greater detail by using information on grandparent contact and financial assistance.

6.4.3 Conclusions: The Impact of Grandparent Investments on Parental Investments in the UK

This chapter provides evidence to suggest that grandparental investments affect parental direct investment levels in contemporary developed populations such as the UK. Exploring this relationship is important in order to further understand how the childrearing system functions in the UK. In a wider context, this provides us with some evidence towards examining whether humans exist as cooperative breeders in contemporary developed populations.

Previous studies from HBE suggest that mothers are especially reliant on allomaternal investments during maternal breastfeeding, and that grandmothers may be a particularly important type of allomother. Overall, the current findings are in line with this assertion: Grandmothers, especially maternal grandmothers, were found to have clear effects on maternal breastfeeding. The less robust finding on parenting behaviour also suggests that the importance of grandparental allomothering may be strongest during breastfeeding.

The effects of allomothers on parental investment are generally understudied, and more research is clearly needed. In future, researchers may want to explore grandparental investments with greater information on grandparental behaviour, such as the type and frequency of activities grandparents carry out with children, whether they contribute to housework, and so on. Are grandparents important allomothers in the UK childrearing system? The observed influence of grandparent investments on parental direct investments provides us with some evidence that grandparents are involved as

allomothers in the UK. To comment on their importance, however, we must explore how grandparents affect child outcomes. This will be explored in next chapter.

Chapter 7: Grandparent Effects on Multiple Child Outcomes

7.1 Introduction

7.1.1 Grandparents as Allomothers: Direct and Indirect Effects on Child Quality

As discussed in the previous chapters, grandparents in contemporary developed populations may invest in children through providing direct childcare and financial assistance to families. In the last chapter, I investigated the potential indirect effects of such investments on child quality by exploring how grandparental contact and financial help affects parental direct investments. In addition to these indirect effects, grandparental investments may also directly influence children's developmental outcomes. Note, grandparental investments are costly for grandparents. The obvious costs are time and money, and highly involved grandparenting could be a stressful experience. In a study in the US, for example, full-time caregiving grandmothers had lower levels or reported life satisfaction than part-time caregivers or non-caregiving grandmothers who had regular contact with children (Bowers & Myers, 1999), reflecting the costs of highly involved allomothering. Given these costs, do grandparents gain any indirect fitness benefits from providing grandparental investments? Specifically, do grandparental investments have any beneficial influences on child development?

In this chapter, I explore how direct and indirect grandparental investments may impact multiple child development outcomes in the UK. From an HBE perspective, we expect that grandparental investments are driven by the indirect fitness benefits they gain, either from greater child quality or number of grandchildren. In the previous chapters, I have outlined how the differences in the indirect fitness benefits surrounding grandparental investments, the difference in the optimal strategies between maternal and paternal grandparents, and the different strategies of parental reproduction may influence the impact grandparents have on parental behaviour and child quality. The results from Chapter 6 suggests that grandparental direct investments may reduce maternal direct investments, while grandparental indirect investments may increase paternal direct investments in the UK. By expanding the investigation into the association between grandparental investments and child quality, we are better able to understand the childrearing system in the UK, including greater insight into the mechanism which encourages such a system: By exploring the direct and indirect effects of grandparental

investments on child quality, we gain a greater understanding of the indirect fitness benefits surrounding allomaternal investments, as well as the different investment strategies grandparents and parents may have in contemporary developed populations such as the UK.

Like before, I use grandparent contact and financial assistance as a proxy of grandparental direct and indirect investments. Much of the literature on grandparent effects on child quality in high fertility, high mortality populations have been covered in the introduction. In the following section, I review available literature relating to grandparent effects on multiple child outcomes in contemporary developed populations.

7.1.2 The Impact of Grandparents on Child Development in Contemporary Developed Populations

Research surrounding kin effects on child development in developed populations predominantly focus on mothers and fathers. Consequently, the available literature on grandparent effects on child outcomes is not extensive. Nevertheless, Sear & Coall (2011) identified 19 studies in post demographic transition societies. These studies, published between 1986 and 2010, examined the influence of grandparent involvement, relationship quality or contact frequency on multiple child outcomes. Of these, 13 explored grandparent effects on socio-emotional development, three on depression, two on academic achievement, and one on mental and physical development. While the sample size is notably small, Sear & Coall (2011) found that 77% of studies reported a positive effect of grandparents on child outcomes. For example, Henderson (2009) found that a good quality relationship with maternal grandmothers predicted better socio-emotional competency for older teenagers in the US, and Attar-Schwartz et al. (2009) found that greater grandparent involvement was associated with better socio-emotional development for teenagers aged 11-16 years old in England and Wales. As indicated by Sear & Coall (2011), however, the positive effects are not consistently found across studies, and some even report negative effects. In a study using ALSPAC data, Fergusson, Maughan & Golding (2008) found that grandparent childcare was associated with increased behavioural difficulties in children, specifically hyperactivity and peer problems.

In the handful of other available studies not reviewed in Sear & Coall (2011), grandparents are also found to have positive influences on child development. In the US, it was found that children raised solely by grandparents did just as well as children in biparental household in terms of health and behaviour, though they were less likely to

achieve highly at school (Solomon & Marx, 1995). This suggests that grandparent investments may be adequate substitutes for parental investments regarding children's physical and socio-emotional development. Similarly, again in the US, maternal grandmother involvement was associated with lower levels of socio-emotional behavioural difficulties in 3 and 4 year old children (Barnett et al., 2010). Other studies have suggested that grandparents may be particularly important for resource-stressed households. In the UK, children receiving grandmother childcare had better cognitive development compared to children receiving other types of non-maternal childcare, but only between children living in poverty (Baydar & Brooks-Gunn, 1991). In the US, grandparent SES, controlling for nuclear family characteristics, did not have a positive effect on children's educational attainment. However, grandparent SES had a positive association with children's educational attainment in low-SES nuclear families (Jaeger, 2012). The author suggested that this SES-dependent effect was observed because resources from grandparents are more important for low-SES parents and children. Combined, the available literature points towards the positive effects of grandparents on multiple aspects of child development. This suggests that grandparental investments are driven by the inclusive fitness benefits to child quality, as expected in a family context where parents are optimising child quality over quantity (see Chapter 5; 5.1.2 How Might Grandparents Affect Child Outcomes in the UK?).

However, many studies do not take parental direct investments into account (e.g., Attar-Schwartz et al., 2009; Fergusson, Maughan & Golding, 2008; Jaeger, 2012). In the previous chapter, I found a significant association between grandparental investments and parental direct investments in the MCS, suggesting that parental direct investments in the UK may be substitutable. Given this result, the positive effects of grandparent investments found in previous studies may be mediated by its impact on parental investments. For a deeper understanding of the childrearing system in the UK, there is a need to control for parental investment levels to get to the true direct effects of grandparental investments.

In addition, none of these studies have differentiated grandparent types by relatedness: Grandparents are usually handled within a single category, and more often than not the focus is solely on the grandmother, usually the maternal. As discussed in Chapters 1, 5 and 6, evolutionary theory suggests that different grandparents may have different effects on child quality, following the differences in inclusive fitness and investment strategies. The importance of treating grandparent type separately is highlighted in the findings of the previous chapter, where grandmother direct contact,

but not grandfather, was associated with lower levels of maternal breastfeeding. Furthermore, financial help from paternal grandparents, but not maternal grandparents, was associated with higher levels of paternal parenting.

Grandparental investment levels vary between grandparent types (Chapter 5), and from an HBE perspective it would be interesting to explore whether the benefits of investments on child quality also differ between grandparents. For instance, given the theorised difference in optimal strategy between maternal and paternal grandparent, where maternal grandparents may benefit more by maximising grandchild quality while paternal grandparents may benefit more by maximising grandchild quantity (Mace & Sear, 2005), maternal grandparents may have a greater impact on child quality. To explore such differences, it is crucial that grandparents are not collapsed into one category.

Finally, the theoretical approach in many of these studies mean that the predictors of interest are often grandparent involvement and relationship quality, often expressed as latent variables. While these findings are interesting and suited to the aims of their paper, it is unclear how these variables translate into actual direct and indirect investments. Consequently, it is unclear if and how grandparental direct investments influence child outcomes, and whether the effects differ between direct and indirect investments. This distinction is important as direct and indirect grandparental investments are expected to have different effects on parental direct investments. For instance, as outlined in Chapter 5, grandparent direct investments may lead to lower levels of parental direct investments if direct investments are substituted. The impact of this substitution on child quality depends on the reproductive strategy of the parents. If investing into quality over quantity, we would expect the substitution in direct investments to be redirected into child quality. In investing in quantity over quality, we would expect the substitution in direct investments to be redirected into mating effort. By distinguishing between direct and indirect grandparental investments, we are able to explore the relationships between grandparental investments, parental investments and child outcomes in more detail. Overall, this should provide us with greater insight into the childrearing system in the UK, as well as the investment and reproductive strategies of parents and grandparents.

7.1.3 Objectives of Chapter 7

Overall, there is a gap in the available literature addressing grandparent effects on child quality, in that grandparent types are not treated separately by relatedness, and it is generally unclear if and how direct and indirect investments influence child development.

Furthermore, grandparent effects are not clear without incorporating parental direct investments: Grandparental investments could have direct and indirect effects on child development, where the indirect effects are mediated through parental direct investments.

The aim of this chapter is to explore the importance of grandparental investments on child development. In the previous chapter, I focused on exploring the potential indirect effects of grandparental investments by investigating how grandparent contact and financial help relates to parental direct investments. In this chapter, I extend the previous analyses to fully explore the effects of grandparents on multiple child development outcomes in the UK. Specifically, I investigate if and how grandparent contact and financial help affects children's physical, cognitive and socio-emotional development while taking parental direct investments into account.

With this, I hope to contribute to the existing literature by: 1) distinguishing between direct and indirect grandparental investments, 2) distinguishing between grandparent types (i.e., maternal/paternal grandmothers/grandfathers), 3) investigating the direct effects of grandparents on multiple child outcomes, and 4) investigating the indirect effects of grandparents on multiple child outcomes. In the context of this thesis, this chapter will help us understand the importance of grandparents as allomothers in the UK childrearing system. The findings should reveal, to a greater detail, the relationships between grandparental investments, parental investments and child quality, potentially reflecting the different investment strategies of parents and grandparents.

7.2 Methods

7.2.1 Sample Selection

As with the previous chapter, I use data from the Millennium Cohort Study collected on four occasions when the focal children were around 9 months, 3 years, 5 years, and 7 years. The current sample consists of stable, biparental households as information on paternal grandparental investments is only available in father-present households. This means there are no single mothers included in the following analyses. Furthermore, as the purpose of this chapter is to compare how direct and indirect investments from different types of grandparents affect maternal and paternal direct investment levels, stepfather household are removed. Households with co-residents grandparents have also been removed due to a high correlation between grandmother and grandfather contact in co-

resident households. Finally, households where focal children are from multiple births (e.g., twins and triplets) are removed due to the uncertainty with the interpretation of investment levels between siblings.

7.2.2 Variables

Outcomes

As dependent variables, I use three proxies of child development. As outlined in Chapter 5, I use children's height as a proxy of physical development, test score as a proxy of cognitive development, and behavioural difficulty score (BDS) as a proxy of socio-emotional development. Children's height measurements were collected by MCS interviewers who were trained to take anthropometric measurements at around 3 years, 5 years and 7 years. Test scores have a maximum score of 30, and are derived from maths, reading and pattern construction assessments conducted at around age 7. Behavioural difficulty scores have a maximum score of 40, and are derived from Strength and Difficulty Questionnaires completed by the mother at 3 years, 5 years and 7 years. Further information on these child outcomes can be reviewed in Chapter 5, and the descriptive statistics are available in table 7.1.

Main Predictors

Main predictors of interest are grandparent investments and parent scores. As with the previous chapter, I use grandparent contact frequency as a proxy of grandparent direct investments, and grandparent financial assistance as a proxy of indirect investments. Information on contact frequency is available separately for maternal grandmothers (MGM), maternal grandfathers (MGF), paternal grandmothers (PGM) and paternal grandfathers (PGF), which were reported at 9 months and 3 years. The contact frequency categories are daily contact (non-resident), at least once a week, at least once a month, at least once every few months, once a year or less, and never (including grandparent deceased). Information on grandparent financial assistance is available separately for maternal grandparents (MG) and paternal grandparents (PG), categorised as any financial help and no financial help. This information was reported at 9 months, 3 years, and 5 years. Detailed descriptions of these variables are presented in Chapter 5.

I use mother score and father score as proxies of parental direct investments. These scores are based on self-reported play-based parenting activities, collected at 9 months, 5 years and 7 years. Scores have been standardised to range from 0 to 15, and mean-centred by measurement occasion. Detailed descriptions of these variables are presented in Chapter 5.

Controls

As controls, I include country (England, Wales, Scotland, Northern Ireland), indicator of multiple deprivation (range 0-9 in 10% bands; 0=most deprived), household income (bottom 25%, middle 50%, top 25%), maternal employment (employed or not employed), paternal employment (employed or not employed), number of siblings in household, financial difficulty (living comfortably, doing alright, just about getting by, finding it quite difficult, finding it very difficult), home ownership (renting, own home, other), maternal education (O-level, A-level, degree, overseas qualification, none), paternal education (O-level, A-level, degree, overseas qualification, none), child's ethnicity (White, South Asian, Black, other), child's sex, mother's age at birth of child (mean-centred), and children's age. For the height analyses, I also include birth weight (kg), gestation length (wks.) and mother's height (cm). Descriptive statistics for all controls, along with outcomes and predictors, are available in table 7.1.

Table 7.1: Descriptive statistics of variables used in all analyses of Chapter 7.

Outcome Variables				
Measurement Occasion/ Time	**9m**	**3y**	**5y**	**7y**
Children's Height (cm)				
N	-	10643	11374	10864
mean	-	95.90	110.76	123.65
(sd)	-	4.20	5.00	5.62
range	-	70.9-120.1	79-131	87-151.6
Children's Test Score				
N	-	-	-	12733
mean	-	-	-	13.96
(sd)	-	-	-	4.06
range	-	-	-	0-27
Children's BDS				
N	-	11455	12107	11497
mean	-	9.47	7.69	7.29
(sd)	-	4.63	4.32	5.34
range	-	0-31	0-32	0-35
Parenting Scores				
Mother Score				
N	12481	-	15154	-
mean	10.25	-	9.52	-
(sd)	2.32	-	2.30	-
range	0-15	-	0-15	-
Father Score				
N	13226	-	10476	-
mean	8.48	-	8.71	-
(sd)	3.37	-	2.35	-
range		-		-
Grandparent Variables				
MGM Contact (%)				
N	17164	14661	-	-
Daily	24.92	20.04	-	-
Weekly	38.37	38.96	-	-
Monthly	9.63	9.86	-	-
Every Few Months	9.79	10.68	-	-
Yearly or Less	6.72	7.07	-	-
Never	10.57	13.38	-	-
MGF Contact (%)				
N	17163	14912	-	-
Daily	12.93	10.27	-	-
Weekly	31.92	30.06	-	-
Monthly	10.65	10.49	-	-
Every Few Months	10.41	10.86	-	-
Yearly or Less	8.10	8.01	-	-
Never	25.99	30.31	-	-

Table 7.1: Descriptive statistics of variables used in all analyses, continued.

Measurement Occasion/ Time	**9m**	**3y**	**5y**	**7y**
PGM Contact (%)				
N	12599	10390	-	-
Daily	9.48	6.45	-	-
Weekly	41.82	37.47	-	-
Monthly	15.30	15.68	-	-
Every Few Months	12.12	13.53	-	-
Yearly or Less	7.66	7.89	-	-
Never	13.61	18.98	-	-
PGF Contact (%)				
N	12599	10853	-	-
Daily	7.90	5.33	-	-
Weekly	31.83	26.44	-	-
Monthly	13.28	12.24	-	-
Every Few Months	10.86	11.74	-	-
Yearly or Less	8.05	7.31	-	-
Never	28.09	36.95	-	-
MG Financial Assistance (%)				
N	13726	11257	11001	-
Yes	75.30	79.30	74.53	-
No	24.70	20.70	25.47	-
PG Financial Assistance (%)				
N	11805	8936	8886	-
Yes	70.71	70.36	70.00	-
No	29.29	29.64	30.00	-
Other Variables				
Maternal Employment (%)				
Yes	48.05	-	57.27	63.13
No	51.95	-	42.73	36.87
Paternal Employment (%)				
Yes	87.70	-	8.78	8.47
No	12.30	-	91.22	91.53
Mother's Age at Birth (yrs.)				
mean	28.73	-	-	-
(sd)	5.79	-	-	-
range	13-63	-	-	-
Country (%)				
England	61.93	-	63.94	64.04
Wales	15.02	-	14.15	14.33
Scotland	12.73	-	11.90	11.80
Northern Ireland	10.32	-	10.00	9.83
Household Income (N)				
Top 25%	3975	-	2476	2432
Middle 50%	8531	-	5236	4676
Bottom 25%	3212	-	2225	2020
Indices of Multiple Deprivation				
mean	3.67	-	4.08	4.21
(sd)	2.93	-	2.99	2.98
range	0-9	-	0-9	0-9

Table 7.1: Descriptive statistics of variables used in all analyses, continued.

Measurement Occasion/ Time	**9m**	**3y**	**5y**	**7y**
Financial Difficulty (%)				
Living comfortably	23.55	-	23.44	21.93
Doing alright	37.16	-	38.00	36.20
Just about getting by	28.16	-	27.79	29.19
Finding it quite difficult	8.35	-	7.98	9.11
Finding it very difficult	2.79	-	2.80	3.57
Home Ownership (%)				
Renting	36.60	-	31.87	30.71
Own Home	61.14	-	66.37	68.03
Other	2.26	-	1.76	1.26
Maternal Education (%)				
O-level	37.12	-	-	-
A-level	13.96	-	-	-
Degree	30.30	-	-	-
Overseas	2.86	-	-	-
None	15.75	-	-	-
Paternal Education (%)				
O-level	33.97	-	-	-
A-level	15.30	-	-	-
Degree	34.15	-	-	-
Overseas	3.47	-	-	-
None	13.11	-	-	-
Ethnicity of Child (%)				
White	84.17	-	-	-
South Asian	8.55	-	-	-
Black	3.57	-	-	-
Other	3.70	-	-	-
Sex of Child (%)				
Male	51.27	-	-	-
Female	48.73	-	-	-
Birth Weight (kg)				
mean	3.34	-	-	-
(sd)	0.590	-	-	-
range	0.39-7.23	-	-	-
Gestation Length (weeks)				
mean	39.55	-	-	-
(sd)	2.04	-	-	-
range	23-42.29	-	-	-
Mother's Height (cm)				
mean	163.54	-	-	-
(sd)	7.04	-	-	-
range	121.92-205.74	-	-	-
Number of Focal Child's Siblings in Household				
mean	0.98	-	1.42	1.52
(sd)	1.09	-	1.08	1.09
range	0-9	-	0-12	0-12
Children's age (years)				
mean	3.14	-	5.22	7.23
(sd)	0.21	-	0.25	0.25
range	2.65-4.57	-	4.41-6.13	6.34-8.15

7.2.3 Analyses

Based on the distribution of the three outcomes, measurement frequency and model fit, I run the following models: 1) random-intercept random-slope linear regression models for height, 2) linear regression models for test score, and 3) random-intercept random-slope Poisson models for behavioural difficulty score. Further information on multilevel models can be reviewed in Chapter 3. To minimise reverse causality, the parental/grandparental investment variables are lagged. Parenting scores collected at 9 months is used to predict outcomes at 3 years and 5 years, and parenting scores collected at 5 years is used to predict outcomes at 7 years. Grandparent contact frequency at 9 months is used to predict outcomes at 3 years, and grandparent contact frequency collected at 3 years is used to predict outcomes at 5 years and 7 years. Finally, grandparent financial help collected at 9 months, 3 years and 5 years is used to predict outcomes at 3 years, 5 years and 7 years, respectively.

For all outcomes, I run 3 models: 1) Model 1 - the parent model - only includes parenting scores, 2) Model 2 - the grandparent model - only includes grandparent contact and financial help, and 3) Model 3 - the full model - includes both parenting scores and grandparental investment variables. Model 3, controlling for parental direct investments, will highlight direct effects of grandparents on children's development outcomes. The combined result of Model 1, 2, and 3 should highlight any indirect effects of grandparental investments mediated through parental direct investments.

In the previous chapter, we found that PGF contact was associated with reduced mother score, and PG financial help was associated with increased father sore. If mother score is a significant predictor of child outcomes in Model 1, and PGF contact is a significant predictor of child outcomes in Model 2, then there may be an indirect effect of PGF on child outcomes mediated through mother score. If PGF contact is significant in Model 2, and is no longer significant in Model 3, it would suggest that the effect of PGF contact on child outcome is fully mediated by mother score. If PGF contact is still significant in Model 3, the effect of PGF contact on child outcome may be partially mediated by mother score.

Similarly, if father score is a significant predictor of child outcomes in Model 1, and PG financial help is a significant predictor of child outcomes in Model 2, then there may be an indirect effect of PG financial help on child outcomes mediated through father score. If PG financial help was significant in Model 2, and is no longer significant in Model 3, it would suggest that the effect of PG financial help on child outcome is fully mediated by

father score. If PG financial help is still significant in Model 3, the effect of PG financial help on child outcome may be partially mediated by mother score.

Any indication of a mediation effect will be explored further through a path analysis. Path analysis is an extension of regression models which allows us to investigate chains of influence (Streiner, 2005). For example, we can explore how grandparental investments affect parental investments, and how parental investments affect child outcomes, as well as how grandparental investments directly influence child outcomes.

7.3 Results of Chapter 7

Height

The full results for height are available in the appendix (table A8). The key results for height are displayed in table 7.2. I find that parenting score, grandparent contact, and grandparent financial help is not associated with children's height apart from PGM contact frequency. The results show that PGM everyday contact is associated with greater height in children compared to all other categories (fig. 7.1). Note, a similar result was found for BMI, whereby MGM and PGM everyday contact was associated with greater BMI in children compared to most other categories (see appendix table A9).

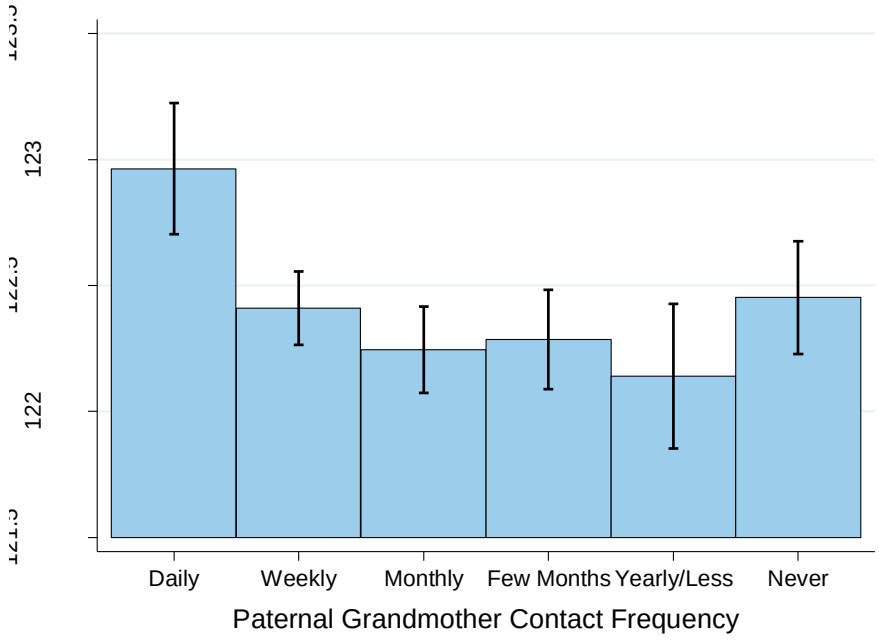

Fig. 7.1: PGM contact and children's estimated height at age 7.

Test Score

The full results for test score are available in the appendix (table A10). The key results for test score are displayed in table 7.3. In model 1, I find that father score is a significant predictor, where a one point increase in father score is associated with a 0.09 point increase in children's test score ($P \leq 0.001$). In model 2, I find that there are no clear trends between grandparent contact frequency and children's test score, though PG financial help is associated with 0.285 point increase in children's test score ($P \leq 0.05$). In model 3, father score remains significant ($B=0.087$, $P \leq 0.001$), while PG financial help is borderline significant ($B=0.259$, $P=0.051$). As PG financial help is associated with higher father score, these results suggest that the effect of PG financial help may be partially mediated by father score.

Given these results for test score, I carry out a path analysis with simplified predictors to test the relationship between PG financial help, father score and test score. The initial model with test score as the only endogenous outcome included the following exogenous predictors: father score (mean-centred), PG financial assistance, mother score (mean-centred), MGM weekly contact, MGF weekly contact, PGM weekly contact, PGF weekly contact, MG financial help, maternal employment, financial difficulty, number of siblings, indices of multiple deprivation, sex of child, and age of child (mean-centred) (results not shown). Based on improvement of BIC model fit statistics by 2 or more points, MGF weekly contact and PGF weekly contact was removed, mother score, maternal employment, number of siblings and sex of child was identified to have an indirect effect on test score via father score, and mother score was identified not to have a direct effect on test score. Using this as the base model, I explore the effects of PG financial help and father score on children's test score.

Table 7.4 displays the key results of three different models: 1) The base model, with direct effects of PG financial help and father score on test score, 2) the full mediation model, with the indirect effect of PG financial help on test score via father score, and the direct effect of father score on test score, and 3) the partial mediation model, with the indirect effect of PG financial help on test score via father score, and the direct effects of PG financial help and father score on test score. The full result of the partial mediation model is available in the appendix (table A11).

For all three models, the CFI is larger than 0.9, and RMSEA is smaller than 0.06, indicating that the model fit is acceptable. However, the partial mediation model is the only model to reproduce the covariance matrix of the variables at an acceptable level

($X^2(7)=10.22$, $P=0.177$), indicating that this is the best fit model. In fact, the partial mediation model improves fit by 20 AIC and 12 BIC points compared to the base model, and 17 AIC and 10 BIC points compared to the full mediation model. This suggest that PG financial help affects children's test scores both directly and indirectly, with its effect partially mediated through paternal parenting. The results show that PG financial help has a total effect of improving children's test score by 0.509 ($P\leq0.001$, SE=0.112), of which 0.025 is through its effect on father score ($P\leq0.001$, SE=0.008).

Behavioural Difficulty Score

The full results for behavioural difficulty score are available in the appendix (table A12). The key results for behavioural difficulty score are displayed in table 7.5. I find parenting score, grandparent contact, and grandparent financial help is not a significant predictor for children's behavioural difficulty score.

Table 7.2: Key results: Grandparent investment and height.

N Children=8541 N Obs.=18745	Model 1		Model 2		Model 3	
	B	**SE**	**B**	**SE**	**B**	**SE**
Height (cm)						
Mother Score	-0.010	0.009	--	--	0.006	0.011
Father Score	0.007	0.011	--	--	-0.010	0.009
MGM Contact						
Every Day (ref)	--	--	--	--	--	--
Weekly	--	--	0.031	0.095	0.030	0.095
Monthly	--	--	0.020	0.139	0.019	0.139
Every Few Months	--	--	0.087	0.155	0.086	0.155
Yearly or Less	--	--	0.161	0.204	0.159	0.204
Never	--	--	-0.025	0.156	-0.026	0.156
MGF Contact						
Every Day (ref)	--	--	--	--	--	--
Weekly	--	--	-0.221	0.121	-0.221	0.121
Monthly	--	--	-0.188	0.153	-0.190	0.153
Every Few Months	--	--	-0.363	0.166	-0.363*	0.166
Yearly or Less	--	--	-0.112	0.193	-0.113	0.193
Never	--	--	0.050	0.141	0.050	0.141
PGM Contact						
Every Day (ref)	--	--	--	--	--	--
Weekly	--	--	-0.586***	0.149	-0.586***	0.149
Monthly	--	--	-0.757***	0.172	-0.757***	0.172
Every Few Months	--	--	-0.733***	0.187	-0.733***	0.187
Yearly or Less	--	--	-0.896***	0.215	-0.896***	0.215
Never	--	--	-0.573***	0.180	-0.573***	0.180
PGF Contact						
Every Day (ref)	--	--	--	--	--	--
Weekly	--	--	0.080	0.161	0.081	0.161
Monthly	--	--	0.096	0.184	0.097	0.184
Every Few Months	--	--	0.128	0.198	0.129	0.198
Yearly or Less	--	--	0.169	0.216	0.170	0.216
Never	--	--	0.276	0.173	0.276	0.173
MG Financial Help						
No (ref)	--	--	--	--	--	--
Yes	--	--	0.038	0.055	0.037	0.055
PG Financial Help						
No (ref)	--	--	--	--	--	--
Yes	--	--	0.052	0.051	0.052	0.051
AIC	97404		97394		97397	
BIC	97717		97864		97883	

*$P \leq 0.05$ **$P \leq 0.01$ ***$P \leq 0.001$

Table 7.3: Key results: Grandparent investment and test score.

N Children=5191	Model 1		Model 2		Model 3	
	B	**SE**	**B**	**SE**	**B**	**SE**
Test Score						
Mother Score	-0.017	0.025	--	--	-0.017	0.025
Father Score	0.090***	0.024	--	--	0.087***	0.024
MGM Contact						
Every Day (ref)	--	--	--	--	--	--
Weekly	--	--	0.155	0.179	0.152	0.179
Monthly	--	--	0.513*	0.239	0.498*	0.239
Every Few Months	--	--	0.122	0.250	0.121	0.250
Yearly or Less	--	--	0.460	0.326	0.435	0.326
Never	--	--	0.116	0.233	0.114	0.233
MGF Contact						
Every Day (ref)	--	--	--	--	--	--
Weekly	--	--	-0.028	0.232	-0.031	0.232
Monthly	--	--	-0.217	0.275	-0.199	0.274
Every Few Months	--	--	0.255	0.286	0.260	0.285
Yearly or Less	--	--	0.051	0.323	0.049	0.323
Never	--	--	-0.043	0.233	-0.034	0.233
PGM Contact						
Every Day (ref)	--	--	--	--	--	--
Weekly	--	--	0.313	0.289	0.302	0.289
Monthly	--	--	0.390	0.316	0.398	0.316
Every Few Months	--	--	0.421	0.326	0.404	0.325
Yearly or Less	--	--	0.809*	0.373	0.812*	0.373
Never	--	--	0.615*	0.311	0.611*	0.312
PGF Contact						
Every Day (ref)	--	--	--	--	--	--
Weekly	--	--	0.094	0.301	0.094	0.301
Monthly	--	--	0.085	0.329	0.080	0.328
Every Few Months	--	--	-0.019	0.334	-0.019	0.333
Yearly or Less	--	--	-0.145	0.366	-0.156	0.366
Never	--	--	-0.032	0.296	-0.039	0.296
MG Financial Help						
No (ref)	--	--	--	--	--	--
Yes	--	--	0.193	0.138	0.192	0.138
PG Financial Help						
No (ref)	--	--	--	--	--	--
Yes	--	--	0.285*	0.133	0.259†	0.133
AIC	27784		27813		27804	
BIC	27994		28154		28158	

† $P \leq 0.1$ *$P \leq 0.05$ **$P \leq 0.01$ ***$P \leq 0.001$

Table 7.4: Unstandardised estimates of key variables and model fit statistics for the path models exploring the effect of paternal grandparent financial help and father score on children's test score.

Outcome	Direct Effect		Indirect Effect		Total Effect		Model Fit Statistics
Base Model	**B**	**SE**	**B**	**SE**	**B**	**SE**	**N=6131**
PG Financial Help →Test Score	0.483***	0.112	--	--	0.483***	0.112	$X^2(8)=30.87$, $P\leq0.001$ CFI=0.983 RMSEA=0.022 AIC=195190 BIC=195317 $R^2=0.192$
PG Financial Help →Father Score	--	--	--	--	--	--	
Father Score →Test Score	0.091***	0.021	--	--	0.091***	0.021	
Full Mediation Model							
PG Financial Help →Test Score	--	--	0.026***	0.008	0.026***	0.008	$X^2(8)=28.74$, $P\leq0.001$ CFI=0.985 RMSEA=0.021 AIC=195187 BIC=195315 $R^2=0.193$
PG Financial Help →Father Score	0.275***	0.061	--	--	0.275***	0.061	
Father Score →Test Score	0.096***	0.021	--	--	0.096***	0.021	
Partial Mediation Model							
PG Financial Help →Test Score	0.484***	0.112	0.025**	0.008	0.509***	0.112	$X^2(7)=10.22$, $P=0.177$ CFI=0.998 RMSEA=0.009 AIC=195170 BIC=195305 $R^2=0.195$
PG Financial Help →Father Score	0.275***	0.061	--	--	0.275***	0.061	
Father Score →Test Score	0.091***	0.021	--	--	0.091***	0.021	

*$P\leq0.05$ **$P\leq0.01$ ***$P\leq0.001$

Table 7.5: Key results: Grandparent investment and behavioural difficulty score.

N Children=8268 N Obs.=17951	Model 1		Model 2		Model 3	
	IRR	95%CI	IRR	95%CI	IRR	95%CI
BDS						
Mother Score	1.003	0.999,1.007	--	--	1.003	0.999,1.007
Father Score	0.998	0.996,1.001	--	--	0.998	0.996,1.001
MGM Contact						
Every Day (ref)	--	--	--	--	--	--
Weekly	--	--	0.992	0.965,1.019	0.991	0.965,1.019
Monthly	--	--	0.991	0.953,1.030	0.991	0.953,1.030
Every Few Months	--	--	1.003	0.962,1.046	1.003	0.962,1.046
Yearly or Less	--	--	0.966	0.911,1.025	0.966	0.911,1.025
Never	--	--	1.005	0.966,1.047	1.005	0.966,1.047
MGF Contact						
Every Day (ref)	--	--	--	--	--	--
Weekly	--	--	1.013	0.978,1.049	1.012	0.977,1.048
Monthly	--	--	1.011	0.968,1.056	1.010	0.968,1.056
Every Few Months	--	--	1.004	0.959,1.050	1.003	0.958,1.050
Yearly or Less	--	--	1.029	0.975,1.085	1.028	0.974,1.085
Never	--	--	1.022	0.985,1.061	1.022	0.984,1.060
PGM Contact						
Every Day (ref)	--	--	--	--	--	--
Weekly	--	--	0.974	0.934,1.016	0.974	0.933,1.016
Monthly	--	--	0.961	0.916,1.009	0.961	0.916,1.009
Every Few Months	--	--	0.958	0.909,1.009	0.958	0.910,1.009
Yearly or Less	--	--	0.978	0.920,1.038	0.978	0.920,1.038
Never	--	--	0.984	0.937,1.032	0.983	0.937,1.032
PGF Contact						
Every Day (ref)	--	--	--	--	--	--
Weekly	--	--	0.987	0.944,1.033	0.987	0.943,1.033
Monthly	--	--	0.991	0.941,1.043	0.990	0.941,1.042
Every Few Months	--	--	0.999	0.947,1.055	0.999	0.946,1.054
Yearly or Less	--	--	0.989	0.932,1.050	0.988	0.932,1.050
Never	--	--	0.997	0.952,1.044	0.996	0.952,1.044
MG Financial Help						
No (ref)	--	--	--	--	--	--
Yes	--	--	1.010	0.990,1.031	1.010	0.990,1.031
PG Financial Help						
No (ref)	--	--	--	--	--	--
Yes	--	--	0.997	0.979,1.015	0.997	0.978,1.015
AIC	93854		93885		93886	
BIC	94127		94314		94330	

*$P \leq 0.05$ **$P \leq 0.01$ ***$P \leq 0.001$

7.4 Discussion of Chapter 7

7.4.1 Main Findings of Chapter 4: Grandparental Investments and Child Outcomes in the MCS

In summary, I find that PGM everyday contact is associated with greater height, father score is associated with higher test score, and PG financial help is also associated with higher test score with its effect partially mediated by father score. We find mother score, maternal grandparent contact, and maternal grandparent financial help is not a significant predictor for any child outcomes.

In ALSPAC, we saw that father score predicted shorter height, greater test score, and lower behavioural difficulty score, while mother score predicted lower behavioural difficulty score. The current results differ in that parenting scores had no significant association with height and behavioural difficulty score. This could potentially be a product of the differences in how parenting scores were derived between MCS and ALSPAC. In the MCS, parenting scores are based mainly on several play activities. In contrast, the ALSPAC parenting scores are based on a wider range of activities including both play and caretaking. Consequently, ALSPAC is likely to be a more accurate measure of parental direct investments. It may be that caretaking is the component which drives the significant relationship between parent score and children's height/behavioural difficulty score.

PGM everyday contact was associated with greater height, which I take as an outcome representing a faster life history strategy. It is unclear why the same association was not observed for maternal grandmothers, though it could be that maternal grandmother direct investments are less dependent on the need for allomaternal help (e.g., maternal grandmothers may invest maximally regardless of need). However, note that both MGM and PGM everyday contact was associated with greater BMI (see appendix table A9), highlighting the possibility that the association between MGM contact and physical development trajectory was simply not captured at a significant level in the height analysis. This may emerge if children's BMI is more sensitive to environmental effects than height, which is likely as a weight-gain based growth in height is somewhat more constrained than weight-gain based growth in BMI. Overall, it is interesting that for both height and BMI, grandmother everyday contact is the sole category which significantly differs from other contact frequencies, predicting faster growth. Following an HBE perspective, it is unlikely that greater direct investments from grandmothers cause children to growth faster. Instead, it may be that levels of grandmother direct investments

are dependent on need; for instance, direct investments are increased for children in stressful environments associated with greater growth.

PG financial help was associated with higher test score, partially mediated through father score. Firstly, the mediation may be a product of the possible substitution of provisioning by paternal grandparents, leading to an increase in paternal direct investments. Fathers in stable, two-parent households in the UK may be utilising grandparent indirect investments to optimise child quality. Secondly, the direct effect may be a product of increased household resources: Household income and poverty levels are known to be strong predictor of child development, including cognitive development (Duncan, Brooks-Gunn & Klebanov, 1994; Duncan & Brooks-Gunn, 1997; Bradley & Corwyn, 2002; Linver, Brooks-Gunn & Kohen, 2002). Studies suggest that households with greater resources are more likely to have stimulating home environments, which facilitate children's cognitive development (Bradley & Corwyn, 2002; Linver, Brooks-Gunn & Kohen, 2002).

Overall, significant associations between grandparental investments and child outcomes were only found for paternal grandparents. Following HBE theory, this result is surprising given that maternal grandmothers are often the heaviest investors, and it is thought that this pattern emerges as maternal grandmothers have the greatest incentives to invest due to the greatest inclusive fitness benefits. Furthermore Mace & Sear (2005) suggest that maternal grandparents have a greater inclusive fitness incentive to invest in child quality, while paternal grandparents have a greater inclusive fitness incentive to invest in child quality. Clearly, the current results do not reflect these theoretical ideas. This brings forward two questions: Firstly, why are grandparents, particularly maternal grandmothers, providing investments when they have minimal effects on children's fitness outcomes? Secondly, why are paternal grandparent investments associated with some effects, but not maternal grandparents?

Are Grandparents Having an Effect on Fertility Instead of Child Quality?

One possible explanation which addresses both questions is if maternal grandparental investments are having an effect on parental fertility rather than child outcomes, whereby the inclusive fitness benefits of allomaternal investments are recouped through child quantity rather than quality. As outlined in Chapter 5, grandparent investments are expected to have different effects depending on the reproductive strategy of parents, whereby parents who invest in quantity may utilise the grandparental investments

towards mating effort. While the current results suggest that fathers may be utilising paternal grandparent investments to increase child quality, mothers could be using grandparent investments to optimise quality.

For instance, Schaffnit & Sear (2014) found that maternal grandmothers being alive predicted earlier age at first birth in a large, cross-national European sample, though maternal grandfathers being alive had no effect. Similarly, in the 1970 British Cohort Study, Waynforth (2012) found that contact frequency and emotional closeness with grandparents was associated with a greater likelihood of birth between the ages of 30 and 34 years, though financial help and grandparent childcare was not associated with a significant effect. However, a study by Schaffnit & Sear (in prep, 2014) using the MCS found that mothers who intended on having a second child were less likely to do so if they were receiving financial help from maternal grandparents and childcare from paternal grandparents. This suggests that MG financial help is having an effect on parental fertility, but in the opposite direction to what we expect.

Combining current results, results from the last chapter, and Schaffnit & Sear (in prep, 2014), all from the MCS, we find that maternal grandmother investments are associated with lower levels of breastfeeding, lower fertility and no significant association with child outcomes, while paternal grandmother investments are also associated with lower levels of breastfeeding, lower fertility but a positive association with height (indicating a faster life history strategy). Indeed, it seems that investments are having no, or even a negative, effect on parental and child fitness! From an HBE perspective these results are puzzling. We would expect grandparents to invest for indirect fitness returns, but such returns were generally not found within the MCS with the exception of paternal grandparent financial help. This is in fact opposite to what we would expect following evolutionary theory, where we expect mothers and maternal grandmothers to be having a greater impact on child quality.

Are Grandparents Simply Having No Effect?

Mentioned previously, one possible explanation which addresses the lack of apparent inclusive fitness returns is if grandparents are providing investments when families are in need of support. If there is a correlation between grandparental investments and stressful household conditions, it could explain why investments are associated with lower maternal direct investments, lower fertility, and no positive effects on child outcomes. While I control for a variety of SES indicators such as income, financial difficulty and

parental education, if grandparent investments correlate with unobserved household characteristics related to stressful household environments, then the positive effect of investments may be hidden due to the negative effect of the confounding variable. In stressful household situations, grandparents, especially grandmothers who have more to gain in terms of inclusive fitness, may provide allomaternal support to families. If so, our analyses would subsequently highlight a neutral or even negative association between grandparent support and fitness outcomes, which seems to be the case in studies using the MCS.

In support, there have been suggestions that grandparents are more influential in a positive manner for child development in stepparent and single parent households (Sear & Coall, 2011), which is a household environment associated with greater levels of stress. The positive association between grandmother-grandchild relationship quality and socio-emotional competency in adolescents were stronger for youths from divorced families (Henderson, 2009), and the positive association between grandparent involvement and adolescent socio-emotional competency was stronger in stepparent and single families (Attar-Schwartz et al., 2009). It is possible, therefore, that the general lack of positive effects on child outcomes in the current analyses may be a product of unobserved heterogeneity.

Alternatively, the current result may be a reflection of how grandparent investments have minimal effects on parental and child fitness in the UK, where grandparents are relatively unimportant for child development in developed, low-fertility contexts. Rather than being motivated by the returns to indirect fitness, grandparental investments in contemporary developed populations may simply be due to the psychological predisposition for kin members to assist each other. A propensity for cooperation and helping behaviour between kin members is well established (e.g., see Barber, 1994; Kruger, 2003; Stewart-Williams, 2007; Madsen et al., 2007). The observed patterns of grandparental investments across contemporary developed populations may be a result of kin selection throughout our evolutionary history, where grandparent investments did have positive indirect fitness effects in ancestral environments. Indeed, as discussed, it seems grandparent investments do have positive effects on child survival in traditional and developing populations. In contemporary developed populations, however, there may be an environmental mismatch where grandparental investments do not lead to higher parental fertility or higher child quality.

The two different explanations regarding the current findings have very different implications regarding the childrearing system in the UK. The first explanation suggests

a system where greater grandparent support is provided in times of need, where grandparents are still important allomothers in the UK. In contrast, the second suggests a system where grandparent support is essentially unimportant. To gain further understanding of the role of grandparents in the UK childrearing system, there is a need for a more fine-detailed, causal analysis incorporating varying degrees of "stressed" households and investigating the impact of grandparents on child quality. While no clear conclusion can yet be drawn regarding the role of grandparents, the current series of exploratory analyses in a contemporary developed context has been useful: The results highlight a childrearing system in the UK where parents are the important, which is in contrast to most traditional populations where father presence has been found to be generally unimportant for child mortality while grandmothers, especially maternal grandmothers, have been found to be important.

In sum, with the exception of a positive effect of PG financial help on children's test score, I found very little evidence that grandparental investments have positive effects on child outcomes in the UK. This result is in contrast with several previous studies which found positive effects of grandparents on multiple child outcomes. This discrepancy may be due to the fact that many previous studies have focused on the effects of grandparent emotional closeness and involvement rather than actual investment behaviours. A closer relationship between grandparents, parents and children may be a reflection of a positive environment within the households (rather than investments per se), leading to positive child outcomes. There may also be an element of publication bias, where studies finding similar results to this chapter have not been published due to the non-significant results. While the extent of the publication bias is unclear, the limited research interest in this area may mean that non-significant results are less likely to be published compared to more popular topics (such as the effects of fathers and stepfathers on child development).

7.4.2 Limitations of the Current Analyses

It is important to note that the current sample of families only include stable, two-parent families with biological mothers and fathers, and the current findings may not be representative of grandparent effects on child outcomes in the UK population as a whole. This is an especially important point to note, as there have been suggestions that grandparents are more influential in a positive manner for child development in stepparent and single parent households (Sear & Coall, 2011). In support, the positive

association between grandmother-grandchild relationship quality and socio-emotional competency in adolescents were stronger for youths from divorced families (Henderson, 2009), and the positive association between grandparent involvement and adolescent socio-emotional competency was stronger in stepparent and single families (Attar-Schwartz et al., 2009). Allomother support may be provided to parents in times of need, when the support has the greatest fitness benefits for the parents, meaning there are greater inclusive fitness benefits for the supporting allomother. The current series of analyses focusing on stable families may be missing an important role of grandparents within the UK childrearing system: While I found minimal effects of grandparents on child outcomes in the current analyses, grandparent investments may be particularly important for unstable or stressed family environments.

Another point to consider regarding the non-significance of grandparents is the possibility that contact frequency and financial help are not adequate proxies of grandparent direct and indirect investments, and we may find associations between grandparent behaviour and child development outcomes with finer measures. However, in the last chapter we saw a significant association between grandparent contact/financial help and parental direct investments, suggesting these proxies are successfully capturing an element of investment. Furthermore, it is reasonable to assume that a significant association would be found with these proxies if there is a strong effect of grandparent investments on child development, given that these variables conceivably capture aspects of grandparent behaviour.

7.4.3 Conclusions: Grandparent Investments and Child Outcomes in the UK

In this chapter, I carried out an exploratory investigation into the potential effects of direct and indirect grandparental investment on multiple child outcomes. This extended from the previous chapter, investigating the possible impact of grandparent investments on parental direct investments. Together, the findings in the current and last chapter does not support the idea that grandparental investments have significant impact on child development in stable biparental families in the UK, though there is evidence that paternal grandparent financial help may have positive influences on children's cognitive development. These findings are useful in assessing the importance of grandparents for child development in the UK, and contribute to the investigation on whether humans function as cooperative breeders in contemporary developed populations:

In contemporary developed populations such as the UK, it is possible that the important allomothers are those within the nuclear family. In the current and previous chapters, as well as numerous other studies, we find fathers to have positive effects on multiple child outcomes in developed populations. Stepfathers are also found to influence child development, frequently in a negative manner, though Chapter 4 provided some evidence that stepfather direct investments do have positive effects on some child development outcomes. The influence of grandparents on children is less clear, and the presented findings do not strongly suggest that grandparent direct and indirect investments have positive effects on children's developmental outcomes. However, the role of grandparents regarding child development in contemporary developed populations is an understudied subject, and more studies are certainly needed for strong conclusions to be drawn.

Despite some uncertainties, the overall finding presented in this thesis is an interesting one. Regarding child quality, it is the allomothers within the nuclear family that seem to have the greatest influence. This is in contrast to high fertility, high mortality populations where father presence is often found to have minimal effects on child survival, while grandparent presence, especially maternal grandmother presence, is frequently found to have positive effects on child survival. What does this mean in terms of the childrearing system in the UK? Do humans still operate as cooperative breeders contemporary developed populations? In the coming final chapter, I address these questions and discuss the implications of my findings presented in this thesis.

Chapter 8: Discussion

8.1 Concluding Remarks

8.1.1 Overall Findings of the Thesis

Evolutionary anthropologists have argued that human mothers need assistance from allomothers for successful childrearing, leading some researchers to propose that humans are cooperative breeders. Cross-culturally, we see that mothers are often the primary caregiver for children with a network of allomothers assisting with direct care and provisioning. The network of allomothers seems to be most extensive in hunter-gatherer populations, where the provisioning of food and childcare is shared amongst camp members. It is important to note that the patterns of allomothering vary greatly between populations.

In the introduction, I discussed that the importance of individual allomothers may be linked to the dependency of mothers and children on their support, partially related to the availability of alternative allomothers. For instance, father presence in many high fertility/mortality populations are frequently found to have no significant influence on child survival, possibly as mothers are not particularly dependent on them for provisioning and childrearing support. In contrast, grandmother presence, particularly presence of maternal grandmothers, are more often than not found to have beneficial effects on child survival. If mothers are relatively self-sufficient, and other kin members such as grandparents are available for assistance, children without fathers may do just as well while children without grandparents are disadvantaged. In contrast, in environments where mothers are dependent on their partners for investments, and grandparent assistance is not readily available, father presence may have greater impact on children's outcomes while grandparent presence does not. In high-fertility, high-mortality populations, studies have shown that fathers generally have minimal effects on child survival, while grandmothers tend to have positive effects (Sear & Coall, 2011).

With this in mind, this thesis explored the importance of fathers, stepfathers and grandparents in a contemporary developed context, focusing on the UK. Unlike many traditional and developing populations, the societal context in the UK is defined by its smaller kin networks, longer lifespan, the neolocal and nuclear family norm, increasing female self-sufficiency, and some availability of state provisioning and childcare. The overarching aim was to investigate if and how different allomothers influenced child outcomes in the UK, which would contribute to our understanding of the UK childrearing

system. Ultimately, this contributes towards the debate on whether humans in contemporary developed contexts operate as cooperative breeders.

Contrasting scenarios were presented regarding the importance of different allomothers in the UK. First, for fathers and stepfathers, the financial dependence of mothers on male partners is unlikely to be obligatory due to increased female labour participation and the availability of welfare. At the same time, the smaller kin networks may mean that partner assistance is less substitutable. While financially independent mothers may not be reliant on their partners for resources, they may be dependent on them for direct investments due to the incompatibility between labour force participation and childcare. Second, for grandparents, the neolocal nuclear family norms and the availability of professional childcare/schooling may mean grandparental allomothering is neither readily available nor relied upon. At the same time, the high costs associated with raising children and the lack of other allomaternal kin may mean that mothers depend on grandparental provisioning and care for childrearing support.

In Part 1, I used the Avon Longitudinal Study of Parents and Children to explore if and how direct investments from fathers and stepfathers are associated with children's height, school test score and behavioural difficulty score. In Chapter 3, I outlined that, while the positive effect of paternal provisioning on child development has been well established, the effect of paternal direct investments on children has been less clear. Within my ALSPAC sample, I found paternal direct investments to be associated with positive effects on all child outcomes considered. Furthermore, the beneficial effect of paternal direct investments on test score was found to be stronger for boys than girls. In Chapter 4, I outlined that stepfather presence is often associated with detrimental effects on child development in contemporary developed populations. However, the association between direct investments within stepfather households and child development has not been extensively studied. Again, within my ALSPAC sample, I found that stepfather presence was associated with a negative effect on children's test score and behavioural difficulty score, and this was attributed to the lower levels of direct investments in stepfather households. Furthermore, the results suggested that stepfather direct investments have beneficial effects on children's test scores.

In Part 2, I used the Millennium Cohort Study to investigate if and how grandparental investments are associated with paternal direct investments and children's multiple development outcomes. In Chapter 6, I found that frequent contact with maternal and paternal grandmothers are associated with lower levels of breastfeeding, and financial assistance from paternal grandparents is associated with higher levels of paternal direct

investments. In Chapter 7, I found that grandparent investments have no significant association with child outcomes, apart from paternal grandparent financial help and test score. Paternal grandparent financial help was found to have a direct positive effect on test score, as well as an indirect positive effect mediated by father score.

Overall, this thesis provides evidence that children's cognitive development, represented by children's test scores, is influenced by fathers, stepfathers and paternal grandparents. In contrast, children's socio-emotional development, represented by behavioural difficulty score, is positively influenced by mothers, fathers and stepfathers. Children's physical development, represented by height, was weakly influenced by paternal direct investments, though the effects were small. In sum, in the majority of relevant analyses, paternal direct investments were found to have positive effects on child development outcomes. Stepfathers were also found to influence child outcomes, where presence had a negative impact, though stepfather direct investments themselves had a positive impact on test score. In contrast, I found no consistent and strong evidence that maternal direct investments or grandparent investments have significant impact on children's development.

From this, we could infer that mothers and children in stable, two-parent families in the UK may rely on allomothers within the nuclear family as main sources of support. The childrearing system in the UK differs to most high fertility, high mortality populations where fathers are frequently found to have minimal effects on child survival, and, if any, the positive effects of fathers on offspring quality does not become important until adolescence and adulthood (e.g., Shenk & Scelza, 2012; Scelza, 2010). Perhaps, childrearing in the UK centres on the cooperation between mothers and their partners, and investments from non-nuclear kin members such as grandparents are not critical for successful childrearing. Providing for children in the UK is expensive: The estimated monetary costs of raising children in the UK have increased by 50% between 2003 and 2014, where raising a child from birth to age 21 following 2014 price levels are estimated to be £227,266 (LV=, 2014). This is almost 11.5 times the estimated average annual take-home pay (based on UK average hourly pre-tax earnings of £477 a week for June 2014, minus standard income tax and national insurance contributions; ONS, 2014b; HMRC, 2014a, 2014b). The high costs of childrearing, combined with nuclear family norms, may mean that mothers and their partners depend on each other to ease and juggle the clash between direct care and provisioning.

In relation to the high costs of childrearing, the current findings may be a reflection of the paternal investment strategy to optimise child quality over quantity. In high fertility,

high mortality populations, fathers may take a faster life history strategy by investing in mating effort and child quantity over child quality, leading to minimal impact of their presence on child survival. In contemporary developed contexts, fathers may take a slower life history strategy by investing in child quality where their investments have a positive impact on child development. This complements the evolutionary theories surrounding the demographic transition, where low fertility arguably stems the significant levels of parental investments into child quality over child quantity (Kaplan et al., 1995; Kaplan & Lancaster, 2000; Mace 2007). It seems that this societal shift to optimise child quality over quantity was accompanied by a shift in the childrearing system in contemporary developed populations such as the UK where mothers and fathers became the important caregivers, while grandparents now have minimal effects.

It is important to note that the sample of families throughout this thesis consists of stable, biparental households, and the current findings may not be applicable to families across the UK as a whole. In 2011, it was estimated that around 42% of marriages that took place will end in divorce (ONS, 2014c), and around 12% of families were single-parent families with dependent children (ONS, 2014d). The dynamics between maternal investments, allomaternal investments and child development may vary by household structure, with differences in investment trade-offs and life history strategies. In unstable households, for instance, parents may take investment strategies associated with a faster life history. If so, the allomothering system may be more similar to the patterns we generally find in traditional contexts, where fathers have minimal effects and grandmothers have positive effects on child quality. Furthermore, some evolutionary anthropologists have argued that stable partnerships between men and women are associated with complementary divisions of labour, where couples cooperate and coordinate their investment levels to increase economic and reproductive returns (Kaplan & Lancaster, 2003; Kaplan, Hooper & Gurven, 2009; Gurven et al., 2009). Mothers and their partners in the current sample may be particularly good at cooperating with each other in terms of childrearing, meaning they may be less reliant on grandparents as allomothers compared to other family types.

8.1.2 Conclusions and Implications of the Thesis Findings

Previous research within evolutionary anthropology surrounding allomothers and child outcomes have focused predominantly on high mortality, high fertility populations, examining the association between allomaternal kin presence and child survival. In the

current thesis, I extended this investigation into a contemporary developed population. Building on previous studies, I explored the effects of allomaternal investment behaviours on child development rather than presence. Furthermore, I included multiple types of commonly found allomothers, specifically fathers, stepfathers and grandparents. In all, this has allowed me to examine whether humans in developed contexts such as the UK operate as cooperative breeders.

The presented results provide evidence that certain allomothers in the UK are important regarding child quality, where mothers and children in stable biparental households benefit from allomaternal help. However, the most influential allomother seems to be the mother's male partner. This is in contrast to the breeding systems we observe in traditional and developing populations, where mothers rely on a large network of allomothers. With this, one could argue that people in the UK are not cooperative breeders. In fact, some researchers have questioned whether it is appropriate to categorise humans as cooperative breeders at all given the fact that our childrearing system often involves cooperation with unrelated individuals; a rare occurrence in typical cooperative and communal breeding species (Bogin, Bragg & Kuzawa, 2014). Bogin, Bragg & Kuzawa (2014) go onto argue that the human reproductive system is unique due to the existence of cultural norms and systems which prescribe and facilitate allomaternal investments from kin and non-kin. Such systems include "institutionalised allomothering" in contemporary developed populations, often available in the form of nurseries, schools, and welfare.

Whether or not you perceive humans to operate as cooperative breeders in contemporary developed populations may ultimately come down to semantics. In essence, institutionalised allomothering in the UK may be similar to many "cooperatively breeding" hunter-gatherers where a few individuals provide care to a group of young children while the adults are on hunting and foraging trips. One could argue, therefore, that humans in the UK do operate as cooperative breeders, though in a modified manner. The main difference may lie in the constitution of the allomaternal support networks rather than the breeding system itself, where families in contemporary developed populations rely heavily on allomaternal support from institutions, while families in traditional and developing populations rely on a network of family and friends. Whatever the stance on humans as cooperative breeders, the important fact remains that allomaternal help is required for successful childrearing in contemporary developed populations, be it from fathers, the state, or others. The variation in the sources of

allomaternal help across populations highlights the incredible flexibility of human behaviour, even when it comes to our childrearing system.

What are the implications of such conclusions? This clearly depends on the ultimate goal, but if we are to target children's development and wellbeing in the UK, findings from this thesis suggest that caregivers within the nuclear family are an important factor to consider. Children in stable, biparental households may benefit if direct investments from fathers and stepfathers were facilitated and encouraged. While it is beyond the scope of this thesis to assess the methods to encourage paternal and stepfather investments, minimising the barriers surrounding direct investments may be a good start. At a policy level, direct care from fathers could be encouraged through measures such as a longer period of ordinary paternity leave, which currently stands at 1 or 2 weeks. At a community level, simple measures could be taken, such as ensuring that parent-child groups and facilities are not solely oriented towards the mother. If direct investments from fathers and stepfathers are not available, then perhaps there is a need to make sure children are not disadvantaged by providing extra support.

8.1.3 Future Directions: Investigating Childrearing in Contemporary Developed Populations

Previous studies investigating allomothering and cooperative breeding in humans have generally been carried out in high-fertility, high-mortality populations. In the current thesis, I extended from previous studies by investigating the impact of allomothers on child quality in a contemporary developed population, thereby exploring the childrearing system in a low-fertility, low-mortality context. Following an evolutionary perspective, I investigated the potential impact of fathers, stepfathers and grandmothers on multiple child development outcomes. Studies on grandparents as allomothers in particular have been neglected in developed populations, perhaps due to the nuclear family norm that exists in these populations. While the current thesis provides fresh contributions to the existing literature, it is important to note that there are several limitations which should be highlighted and addressed in future work.

Firstly, the current thesis focused on stable, bi-parental families. As discussed previously, the childrearing system may differ within populations depending on individual family situations such as household stress and family type. For future work, it would be interesting to expand the current series of studies to include different family structures. For instance, are the important allomothers in single parent families the same as

biparental families? In single parent households, parents may be more dependent on grandparental investments for allomaternal support, and they may influence child outcomes to a greater degree. Furthermore, are investments from non-resident fathers as beneficial as investments from resident fathers? Do investments from non-resident fathers affect the association between stepfather presence, household direct investments and child outcomes? Due to constraints within the available data, I was unable to investigate these questions in the current project. However, given the relatively high rates of divorce and remarriage in the UK, these questions must be addressed for a comprehensive understanding of the UK childrearing system.

Secondly, the current thesis focused on fathers, stepfathers and grandmothers. The decision to focus on these allomothers stemmed from the fact that they are the most common allomother within the family children are likely to encounter in the UK (see Chapter 1). However, in a low-fertility society where our social networks predominantly consists of non-relatives, it would be interesting to explore the impact of non-kin allomothers such as friends and professional allomothers on child development outcomes. In future, rather than focusing on individual types of allomothers, it would be interesting to explore allomaternal networks as a whole, including kin, non-kin and professional childcare. Are there different classes of allomaternal networks in the UK, how do they map onto household characteristics, and what influences does it have on child outcomes? Are predominantly kin-based allomaternal networks more beneficial than predominantly non-kin networks?

Thirdly, this thesis focused on the impact of allomother investments on child development outcomes. It is not known whether the impact of allomothers differ by age of the offspring, and how the impact in childhood translates to adulthood. For instance, while grandparents had minimal impact on child development for children under 10, do grandparents have more impact for older children, perhaps when they become more independent? For future studies, it would be interesting to explore the longer-term impact of allomothers, such as adult quality and reproductive success, and combine it with the current findings.

Finally, this thesis focused on investigating the childrearing system in the UK due to the availability of suitable datasets and the familiarity of the societal context. However, to fully explore the childrearing system in contemporary developed populations there is a need to compare the importance and influences of allomaternal kin across the developed world. As discussed in the introduction, there are variations in the societal context regarding childcare even across developed populations. For instance, fathers in developed

Japan tend to spend much less time with children compared to fathers in the US (Makino, 1995), while kin networks are described to be extensive, stronger and more supportive in Mediterranean countries compared to the rest of Western Europe (Reher, 1998). Are paternal direct investments just as important for child development in Japan as it is in the UK? Are grandparents more important as sources of support in Mediterranean cultures?

This thesis has been a good starting point for examining childrearing systems in contemporary developed contexts, bringing insight into the importance of allomothers on child outcomes in the UK. Still, there is much to explore regarding childcare systems in the UK and other developed populations. My hope is that the investigation continues, integrating evolutionary theory into studies of families and children.

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Appendix

Table A1: Full result of the best fit BMI model based on AIC.

	BMI	
	Random Intercept Random Slope Regression	
	B	**SE**
†Birth Length (MC)	0.065***	0.014
†Gestation Length (MC)	-0.028	0.021
†Mother's Height (MC)	0.002	0.007
†Child's Age^2 (Months)	0.000	0.000
†Child's Age^3 (Months)	0.000***	0.000
Child's Age	-0.027***	0.002
Child's Sex:		
Male (ref)	-	-
Female	0.089	0.059
Child's Ethnicity:		
White (ref)	-	-
Other	-0.194	0.191
Number of Siblings	-0.103**	0.024
Weekly Income:		
<£200 p/wk (ref)	-	-
£200 to £399 p/wk	-0.117***	0.053
>£400 p/wk	-0.120***	0.057
Home Ownership:		
Renting (ref)	-	-
Own Home	0.030	0.077
Financial Difficulty	0.000	0.006
Mother's Age (MC)	-0.002	0.007
Mother's Employment Status:		
Unemployed (ref)	-	-
Employed	-0.034	0.031
Mother's Education:		
O-Level/Equiv.(ref)	-	-
A-Level	0.020	0.071
Degree	-0.161	0.097
Father's Employment Status:		
Unemployed (ref)	-	-
Employed	-0.228***	0.048
Father's Education:		
O-Level/Equiv.(ref)	-	-
A-Level	-0.005	0.071
Degree	0.018	0.091
Mother Score (MCO)	0.034*	0.015
Father Score (MCO)	-0.041***	0.013
Constant	18.199***	0.224
ψ_1 (intercept)	1.221	
ψ_2 (slope: Child's Age)	0.023	
θ	0.712	
N Observations	9442	
N Children	3293	
AIC	29890	
BIC	30076	

*P≤0.05 **P≤0.01 ***P≤0.001

(MC)=Mean Centred, (MCO)=Mean Centred at each measurement occasion.

Table A2: Key results for father-present and stepfather-present households and children's BMI.

N = 12895	Presence		Mother Score		Partner Score		Mother & Partner Score		Interactions	
	B	**se**	**B**	**se**	**B**	**se**	**B**	**se**	**B**	**se**
BMI										
Stepfather (ref: Father)	0.995	0.252	0.105	0.253	0.096	0.252	0.102	0.252	0.101	0.256
Mother Score	-	-	0.035	0.046	-	-	0.050	0.049	0.050	0.049
Partner Score	-	-	-	-	-0.026	0.029	-0.035	0.031	-0.034	0.031
Stepfather*Partner Score	-	-	-	-	-	-	-	-	-0.005	0.187

†$P \leq 0.10$ *$P \leq 0.05$, **$P \leq 0.01$, ***$P \leq 0.001$

Table A3: Full results of Interaction model for BMI

	BMI	
	B	**se**
Mother's Height (cm)	-0.000	0.006
Birth length (cm)	0.061***	0.016
Gestation length (weeks)	0.006	0.020
Child's age (months)	0.032*	0.015
Child's sex (ref: Male)		
Female	0.299***	0.070
Child's ethnicity (ref: White)		
Other	0.036	0.198
Number of siblings in household	-0.100*	0.046
Mother's age at birth (yrs)	0.003	0.009
Mother's education (ref: O-Level/Equiv.)		
A-Level	-0.094	0.094
Degree	-0.233*	0.117
Mother's employment (ref: Never)		
Some	0.009	0.112
Constant	0.089	0.104
Partner's employment (ref: Never)		
Some	-0.383	0.277
Constant	-0.203	0.249
Home Ownership (ref: Renting)		
Owned	-0.079	0.155
Financial Difficulty	-0.029	0.016
Average Weekly Income (ref: <£200p/wk)		
£200 to £399p/wk	-0.127	0.154
>£400p/wk	-0.237	0.173
Stepfather (ref: Father)		
Stepfather	0.101	0.256
Mother Score	0.050	0.049
Partner Score	-0.035	0.031
Stepfather*Partner Score	-0.005	0.187
Constant	16.494***	0.269

†$P \leq 0.10$ *$P \leq 0.05$, **$P \leq 0.01$, ***$P \leq 0.001$

Table A4: Best fit AIC model for breastfeeding initiation.

N=11471 ***Breastfeeding Initiation***	**OR**	**95%CI**
Birth Weight (kg) (mc)	1.185***	1.074, 1.307
Gestation Length (wks) (mc)	0.980	0.953, 1.008
Mother's Age (yrs) (mc)	1.020***	1.010, 1.031
Country		
England (ref)	-	-
Wales	0.798***	0.703, 0.907
Scotland	0.675***	0.588, 0.775
Northern Ireland	0.553***	0.475, 0.645
Mother Employed	0.963	0.866, 1.072
Father Employed	0.998	0.847, 1.175
Household Income		
Top 25% (ref)	-	-
Middle 50%	1.130	0.970, 1.317
Bottom 25%	1.305**	1.065, 1.600
IMD	1.056***	1.036, 1.076
Financial Difficulty		
Living comfortably (ref)	-	-
Doing alright	1.054	0.934, 1.188
Just about getting by	1.153*	1.007, 1.320
Finding it quite difficult	1.244*	1.015, 1.524
Finding it very difficult	1.720**	1.219, 2.426
Home Ownership		
Renting (ref)	-	-
Own Home	1.239***	1.092, 1.405
Other	1.853**	1.208, 2.843

*$P \leq 0.05$ **$P \leq 0.01$ ***$P \leq 0.001$

Table A4: Best fit AIC model for breastfeeding initiation, continued.

Maternal Education		
O-Level (ref)	-	-
A-Level	1.451***	1.271, 1.657
Degree	2.593***	2.280, 2.951
Overseas	1.097	0.794, 1.515
None	0.708***	0.607, 0.826
Paternal Education		
O-Level (ref)	-	-
A-Level	1.258***	1.102, 1.437
Degree	1.577***	1.387, 1.793
Overseas	0.859	0.664, 1.110
None	0.825**	0.714, 0.953
Child's Ethnicity		
White (ref)	-	-
South Asian	3.413***	2.660, 4.380
Black	6.334***	3.524, 11.387
Other	3.558***	2.420, 5.231
Sex of Child		
Male (ref)	-	-
Female	0.980	0.894, 1.074
Number of Sibs in Household	0.780***	0.742, 0.820
Father Score	0.985*	0.971, 0.999
MGM Contact		
Every Day (ref)	-	-
Weekly	1.414***	1.238, 1.615
Monthly	2.018***	1.626, 2.505
Every Few Months	1.814***	1.438, 2.287
Yearly or Less	2.644***	1.944, 3.597
Never	1.463***	1.218, 1.757

*$P \leq 0.05$ **$P \leq 0.01$ ***$P \leq 0.001$

Table A4: Best fit AIC model for breastfeeding initiation, continued.

MGF Contact		
Every Day (ref)	-	-
Weekly	0.959	0.812, 1.134
Monthly	1.120	0.896, 1.400
Every Few Months	1.746***	1.365, 2.234
Yearly or Less	0.968	0.744, 1.259
Never	1.058	0.892, 1.125
PGM Contact		
Every Day (ref)	-	-
Weekly	1.213*	1.039, 1.417
Monthly	1.480***	1.223, 1.791
Every Few Months	1.677***	1.351, 2.080
Yearly or Less	1.680***	1.311, 2.152
Never	1.306**	1.083, 1.575
AIC	11695	
BIC	11923	

*$P \leq 0.05$ **$P \leq 0.01$ ***$P \leq 0.001$

Table A5: Best fit AIC model for breastfeeding duration.

N=36604 ***Breastfeeding Duration***	**OR**	**95%CI**
Occasion		
1 (ref)	-	-
2	0.726***	0.665, 0.791
3	0.696***	0.633, 0.764
4	0.789***	0.716, 0.870
5	0.976	0.883, 1.078
6	0.695***	0.617, 0.782
7	1.044	0.9322, 1.170
8	0.756***	0.661, 0.864
Birth Weight (kg) (mc)	0.955	0.897, 1.017
Gestation Length (wks) (mc)	0.957***	0.941, 0.974
Mother's Age (yrs) (mc)	0.962***	0.956, 0.969
Country		
England (ref)	-	-
Wales	1.079	0.992, 1.173
Scotland	0.954	0.872, 1.043
Northern Ireland	1.559***	1.396, 1.740
Mother Employed	1.228***	1.150, 1.312
Father Employed	0.938	0.836, 1.052
Household Income		
Top 25% (ref)	-	-
Middle 50%	0.995	0.891, 1.110
Bottom 25%	1.140*	1.000, 1.300
IMD	0.984**	0.973, 0.995
Financial Difficulty		
Living comfortably (ref)	-	-
Doing alright	0.984	0.916, 1.056
Just about getting by	1.071	0.984, 1.165
Finding it quite difficult	0.972	0.855, 1.106
Finding it very difficult	0.945	0.769, 1.162

*$P \leq 0.05$ **$P \leq 0.01$ ***$P \leq 0.001$

Table A5: Best fit AIC model for breastfeeding duration, continued.

Home Ownership		
Renting (ref)	-	-
Own Home	0.915*	0.840, 0.996
Other	0.738**	0.587, 0.927
Maternal Education		
O-Level (ref)	-	-
A-Level	0.759***	0.695, 0.829
Degree	0.647***	0.601, 0.698
Overseas	0.686***	0.562, 0.836
None	1.101	0.972, 1.332
Paternal Education		
O-Level (ref)	-	-
A-Level	0.889**	0.815, 0.969
Degree	0.757***	0.702, 0.817
Overseas	0.898	0.754, 1.070
None	1.072	0.960, 1.196
Child's Ethnicity		
White (ref)	-	-
South Asian	0.826**	0.724, 0.941
Black	0.610***	0.491, 0.759
Other	0.691***	0.589, 0.811
Sex of Child		
Male (ref)	-	-
Female	0.953	0.901, 1.009
Number of Sibs in Household		
Father Score	1.033***	1.024, 1.042
MGM Contact		
Every Day (ref)	-	-
Weekly	0.956	0.882, 1.035
Monthly	0.812***	0.730, 0.904
Every Few Months	0.806***	0.723, 0.897
Yearly or Less	0.655***	0.568, 0.756
Never	0.924	0.822, 1.039

*$P \leq 0.05$ **$P \leq 0.01$ ***$P \leq 0.001$

Table A5: Best fit AIC model for breastfeeding duration, continued.

PGM Contact		
Every Day (ref)	-	-
Weekly	0.784***	0.680, 0.903
Monthly	0.836*	0.711, 0.982
Every Few Months	0.702***	0.592, 0.833
Yearly or Less	0.833	0.692, 1.003
Never	0.766***	0.657, 0.893
PGF Contact		
Every Day (ref)	-	-
Weekly	1.217*	1.045, 1.418
Monthly	1.082	0.912, 1.285
Every Few Months	1.033	0.863, 1.236
Yearly or Less	1.075	0.890, 1.299
Never	1.146	0.986, 1.332
AIC	32043	
BIC	32502	

*$P \leq 0.05$ **$P \leq 0.01$ ***$P \leq 0.001$

Table A6: Best fit AIC model for mother score.

N Obs=22320 N Mothers=11592 ***Mother Score***	**B**	**SE**
Measurement Occasion (years since birth)	-0.255***	0.006
Mother's Age (yrs) (mc)	-0.000	0.003
Country		
England (ref)	-	-
Wales	0.048	0.043
Scotland	0.052	0.046
Northern Ireland	-0.107*	0.054
Mother Employed	-0.291***	0.032
Father Employed	0.409***	0.056
Household Income		
Top 25% (ref)	-	-
Middle 50%	0.011	0.044
Bottom 25%	-0.112*	0.056
IMD	0.018**	0.006
Financial Difficulty		
Living comfortably (ref)	-	-
Doing alright	0.053	0.034
Just about getting by	0.014	0.040
Finding it quite difficult	0.127*	0.063
Finding it very difficult	0.052	0.106
Home Ownership		
Renting (ref)	-	-
Own Home	-0.005	0.044
Other	0.094	0.127
Maternal Education		
O-Level (ref)	-	-
A-Level	0.142**	0.046
Degree	0.180***	0.039
Overseas	-0.079	0.109
None	-0.250***	0.060

*$P \leq 0.05$ **$P \leq 0.01$ ***$P \leq 0.001$

Table A6: Best fit AIC model for mother score, continued.

Paternal Education		
O-Level (ref)	-	-
A-Level	-0.073	0.045
Degree	0.001	0.040
Overseas	-0.213*	0.092
None	-0.149**	0.055
Child's Ethnicity		
White (ref)	-	-
South Asian	-0.605***	0.072
Black	-0.254*	0.130
Other	0.059	0.094
Sex of Child		
Male (ref)	-	-
Female	0.036	0.030
Number of Sibs in Household	-0.025	0.016
Father Score	0.319***	0.005
PGF Contact		
Every Day (ref)	-	-
Weekly	0.208***	0.065
Monthly	0.214**	0.072
Every Few Months	0.255***	0.075
Yearly or Less	0.276***	0.082
Never	0.215***	0.066
ψ_1 **(intercept)**	1.549	
ψ_2 **(slope: Occasion)**	0.377	
θ	1.462	
AIC	93656	
BIC	93977	

*$P \leq 0.05$ **$P \leq 0.01$ ***$P \leq 0.001$

Table A7: Best fit AIC model for father score.

N Obs=22320 N Mothers=11592 ***Father Score***	**B**	**SE**
Measurement Occasion (years since birth)	0.096***	0.007
Mother's Age (yrs) (mc)	-0.015***	0.004
Country		
England (ref)	-	-
Wales	0.104	0.055
Scotland	0.350***	0.060
Northern Ireland	0.317***	0.069
Mother Employed	0.642***	0.039
Father Employed	-0.928***	0.069
Household Income	-0.140***	0.020
Top 25% (ref)	-	-
Middle 50%	0.049	0.039
Bottom 25%	0.093	0.069
IMD	-0.018**	0.007
Financial Difficulty		
Living comfortably (ref)	-	-
Doing alright	0.075	0.040
Just about getting by	0.025	0.048
Finding it quite difficult	0.044	0.076
Finding it very difficult	0.282	0.127
Home Ownership		
Renting (ref)	-	-
Own Home	-0.089	0.055
Other	-0.325*	0.159
Maternal Education		
O-Level (ref)	-	-
A-Level	0.108	0.060
Degree	0.148**	0.050
Overseas	-0.076	0.141
None	0.067	0.078

*$P \leq 0.05$ **$P \leq 0.01$ ***$P \leq 0.001$

Table A7: Best fit AIC model for father score, continued.

Paternal Education		
O-Level (ref)	-	-
A-Level	0.184**	0.059
Degree	0.211***	0.051
Overseas	-0.318**	0.120
None	-0.437***	0.072
Child's Ethnicity		
White (ref)	-	-
South Asian	-0.571***	0.091
Black	0.502**	0.168
Other	-0.150	0.123
Sex of Child		
Male (ref)	-	-
Female	-0.225***	0.038
Number of Sibs in Household	-0.140***	0.020
Mother Score	0.408***	0.007
PG Financial Help		
No (ref)	-	-
Yes	0.140***	0.037
ψ_1 **(intercept)**	2.668	
ψ_2 **(slope: Occasion)**	0.463	
θ	1.546	
AIC	102250	
BIC	102539	

*$P \leq 0.05$ **$P \leq 0.01$ ***$P \leq 0.001$

Table A8: Full model for height.

N Obs=18745 N Children=8541 ***Height (cm)***	**B**	**SE**
Child's Age (yrs)	8.914***	0.062
Child's Age ^2 (yrs)	-0.212***	0.006
Mother's Age (yrs) (mc)	-0.000	0.010
Country		
England (ref)	-	-
Wales	-0.189	0.127
Scotland	-0.045	0.136
Northern Ireland	-0.025	0.164
Mother Employed	0.057	0.056
Father Employed	0.106	0.106
Household Income		
Top 25% (ref)	-	-
Middle 50%	-0.036	0.063
Bottom 25%	-0.131	0.082
IMD	0.037*	0.015
Financial Difficulty		
Living comfortably (ref)	-	-
Doing alright	0.021	0.050
Just about getting by	-0.008	0.063
Finding it quite difficult	0.094	0.102
Finding it very difficult	0.072	0.171
Home Ownership		
Renting (ref)	-	-
Own Home	0.088	0.105
Other	0.370	0.234
Maternal Education		
O-Level (ref)	-	-
A-Level	0.136	0.140
Degree	0.036	0.117
Overseas	0.374	0.337
None	0.064	0.193

*$P \leq 0.05$ **$P \leq 0.01$ ***$P \leq 0.001$

Table A8: Full model for height, continued.

Paternal Education		
O-Level (ref)	-	-
A-Level	-0.119	0.138
Degree	0.093	0.120
Overseas	-0.334	0.290
None	-0.110	0.174
Child's Ethnicity		
White (ref)	-	-
South Asian	3.242***	0.221
Black	3.175***	0.416
Other	0.541	0.296
Sex of Child		
Male (ref)	-	-
Female	-0.983***	0.091
Number of Sibs in Household	-0.240***	0.039
Birth Weight (kg) (mc)	1.965***	0.100
Gestation Length (wks) (mc)	-0.155***	0.029
Mother's Height (cm) (mc)	0.188***	0.007
Mother Score	0.007	0.011
Father Score	-0.010	0.009
MGM Contact		
Every Day (ref)	-	-
Weekly	0.030	0.095
Monthly	0.019	0.139
Every Few Months	0.086	0.155
Yearly or Less	0.159	0.204
Never	-0.026	0.156
MGF Contact		
Every Day (ref)	-	-
Weekly	-0.221	0.121
Monthly	-0.190	0.153
Every Few Months	-0.363*	0.166
Yearly or Less	-0.113	0.193
Never	0.050	0.141

*$P \leq 0.05$ **$P \leq 0.01$ ***$P \leq 0.001$

Table A8: Full model for height, continued.

PGM Contact		
Every Day (ref)	-	-
Weekly	-0.586***	0.149
Monthly	-0.757***	0.172
Every Few Months	-0.733***	0.187
Yearly or Less	-0.896***	0.215
Never	-0.573***	0.180
PGF Contact		
Every Day (ref)	-	-
Weekly	0.081	0.161
Monthly	0.097	0.184
Every Few Months	0.129	0.198
Yearly or Less	0.170	0.216
Never	0.276	0.173
MG Financial Help		
No (ref)	-	-
Yes	0.037	0.055
PG Financial Help		
No (ref)	-	-
Yes	0.052	0.051
ψ_1 **(intercept)**	4.775	
ψ_2 **(slope: Child Age)**	0.808	
θ	1.424	
AIC	97397	
BIC	97883	

*$P \leq 0.05$ **$P \leq 0.01$ ***$P \leq 0.001$

Table A9: Full model for BMI.

N Obs=10979 N Children=6302 ***BMI***	**B**	**SE**
Child's Age (yrs)	0.010	0.012
Mother's Age (yrs) (mc)	0.005	0.005
Country		
England (ref)	-	-
Wales	0.158*	0.062
Scotland	0.079	0.069
Northern Ireland	0.133	0.081
Mother Employed	0.068	0.043
Father Employed	-0.105	0.083
Household Income		
Top 25% (ref)	-	-
Middle 50%	0.096	0.056
Bottom 25%	0.074	0.260
IMD	-0.032***	0.081
Financial Difficulty		
Living comfortably (ref)	-	-
Doing alright	0.043	0.042
Just about getting by	0.071	0.051
Finding it quite difficult	0.133	0.081
Finding it very difficult	0.330	0.138
Home Ownership		
Renting (ref)	-	-
Own Home	-0.166*	0.069
Other	0.333	0.184
Maternal Education		
O-Level (ref)	-	-
A-Level	-0.086	0.067
Degree	-0.058	0.056
Overseas	-0.131	0.172
None	-0.059	0.100

*$P \leq 0.05$ **$P \leq 0.01$ ***$P \leq 0.001$

Table A9: Full model for BMI, continued.

Paternal Education		
O-Level (ref)	-	-
A-Level	-0.012	0.066
Degree	-0.123*	0.058
Overseas	0.256	0.147
None	0.189*	0.089
Child's Ethnicity		
White (ref)	-	-
South Asian	-0.379***	0.116
Black	0.728***	0.058
Other	0.060	0.150
Sex of Child		
Male (ref)	-	-
Female	-0.019	0.044
Number of Sibs in Household	-0.075***	0.024
Birth Weight (kg) (mc)	0.721***	0.048
Gestation Length (wks) (mc)	-0.079***	0.014
Mother's Height (cm) (mc)	-0.010	0.003
Mother Score	-0.005	0.008
Father Score	-0.003	0.006
MGM Contact		
Every Day (ref)	-	-
Weekly	-0.184*	0.077
Monthly	-0.233*	0.104
Every Few Months	-0.344***	0.108
Yearly or Less	-0.461***	0.138
Never	-0.283**	0.098
MGF Contact		
Every Day (ref)	-	-
Weekly	0.185	0.099
Monthly	0.038	0.118
Every Few Months	0.150	0.122
Yearly or Less	0.123	0.137
Never	0.161	0.099

*$P \leq 0.05$ **$P \leq 0.01$ ***$P \leq 0.001$

Table A9: Full model for BMI, continued.

PGM Contact		
Every Day (ref)	-	-
Weekly	-0.212	0.120
Monthly	-0.349**	0.132
Every Few Months	-0.297*	0.136
Yearly or Less	-0.258	0.154
Never	-0.188	0.127
PGF Contact		
Every Day (ref)	-	-
Weekly	0.159	0.128
Monthly	0.192	0.141
Every Few Months	0.248	0.143
Yearly or Less	0.116	0.156
Never	0.106	0.125
MG Financial Help		
No (ref)	-	-
Yes	0.018	0.046
PG Financial Help		
No (ref)	-	-
Yes	-0.054	0.042
ψ_1 **(intercept)**	17.004	
ψ_2 **(slope: Child Age)**	0.018	
θ	1.219	
AIC	43096	
BIC	43541	

*$P \leq 0.05$ **$P \leq 0.01$ ***$P \leq 0.001$

Table A10: Full model for test score.

N = 5191 ***Test Score***	**B**	**SE**
Child's Age (yrs) (mc)	2.546***	0.205
Mother's Age (yrs) (mc)	-0.012	0.011
Country		
England (ref)	-	-
Wales	-0.689***	0.143
Scotland	-0.352*	0.157
Northern Ireland	-0.478**	0.185
Mother Employed	0.134	0.123
Father Employed	0.120	0.246
Household Income		
Top 25% (ref)	-	-
Middle 50%	0.213	0.151
Bottom 25%	0.517***	0.190
IMD	0.072***	0.020
Financial Difficulty		
Living comfortably (ref)	-	-
Doing alright	-0.284*	0.126
Just about getting by	-0.470***	0.146
Finding it quite difficult	-0.657**	0.232
Finding it very difficult	-0.820*	0.388
Home Ownership		
Renting (ref)	-	-
Own Home	0.513**	0.177
Other	0.726	0.594
Maternal Education		
O-Level (ref)	-	-
A-Level	0.450**	0.154
Degree	0.796***	0.128
Overseas	-0.849*	0.396
None	-0.884***	0.234

*$P \leq 0.05$ **$P \leq 0.01$ ***$P \leq 0.001$

Table A10: Full model for test score, continued.

Paternal Education		
O-Level (ref)	-	-
A-Level	0.624***	0.151
Degree	0.974***	0.133
Overseas	-0.173	0.352
None	-0.396	0.207
Child's Ethnicity		
White (ref)	-	-
South Asian	0.420	0.286
Black	-0.075	0.500
Other	0.335	0.344
Sex of Child		
Male (ref)	-	-
Female	0.301**	0.098
Number of Sibs in Household	-0.066	0.057
Mother Score	-0.017	0.025
Father Score	0.087***	0.024
MGM Contact		
Every Day (ref)	-	-
Weekly	0.152	0.179
Monthly	0.498*	0.239
Every Few Months	0.121	0.250
Yearly or Less	0.435	0.326
Never	0.114	0.233
MGF Contact		
Every Day (ref)	-	-
Weekly	-0.031	0.232
Monthly	-0.199	0.274
Every Few Months	0.260	0.285
Yearly or Less	0.049	0.323
Never	-0.034	0.233

*$P \leq 0.05$ **$P \leq 0.01$ ***$P \leq 0.001$

Table A10: Full model for test score, continued.

PGM Contact		
Every Day (ref)	-	-
Weekly	0.302	0.289
Monthly	0.398	0.316
Every Few Months	0.404	0.325
Yearly or Less	0.812*	0.373
Never	0.611*	0.312
PGF Contact		
Every Day (ref)	-	-
Weekly	0.094	0.301
Monthly	0.080	0.328
Every Few Months	-0.019	0.333
Yearly or Less	-0.156	0.366
Never	-0.039	0.296
MG Financial Help		
No (ref)	-	-
Yes	0.192	0.138
PG Financial Help		
No (ref)	-	-
Yes	0.259	0.133
AIC	27804	
BIC	28158	

*$P \leq 0.05$ **$P \leq 0.01$ ***$P \leq 0.001$

Table A11: Partial mediation path analysis model for father score and test score.

N = 6131 ***Test Score***	**B**	**SE**
Father Score←		
Mother Score	0.289***	0.126
PG Financial Help (yes)	0.275***	0.061
Sex of Child (female)	-0.253***	0.053
Mother Employed (yes)	0.168**	0.062
Number of Siblings	-0.225***	0.029
Constant	0.137	0.091
Test Score←		
Father Score	0.091***	0.021
PG Financial Help (yes)	0.484***	0.112
MG Financial Help (yes)	0.397***	0.119
MGM Weekly Contact (yes)	-0.522***	0.099
PGM Weekly Contact (yes)	0.359***	0.093
Sex of Child (female)	-0.492***	0.099
IMD	0.187***	0.017
Mother Employed (yes)	0.448***	0.109
Financial Difficulty	-0.449***	0.050
Number of Siblings	-0.213***	0.052
Child Age (yrs) (mc)	2.356***	0.191
Constant	14.362	0.227
$X^2(7)$	10.22	
CFI	0.998	
RMSEA	0.009	
AIC	195170	
BIC	195305	
R^2	0.195	

*$P \leq 0.05$ **$P \leq 0.01$ ***$P \leq 0.001$

Table A12: Full model for behavioural difficulty score.

N Obs=17951 N Children=8268 ***BDS***	**IRR**	**95% CI**
Child's Age (yrs)	0.898***	0.893,0.902
Mother's Age (yrs) (mc)	0.992***	0.990,0.994
Country		
England (ref)	-	-
Wales	0.994	0.967,1.022
Scotland	0.998	0.969,1.028
Northern Ireland	0.974	0.939,1.009
Mother Employed	0.970***	0.952,0.987
Father Employed	0.978	0.945,1.012
Household Income		
Top 25% (ref)	-	-
Middle 50%	0.973*	0.952,0.996
Bottom 25%	0.947***	0.920,0.975
IMD	0.989***	0.985,0.993
Financial Difficulty		
Living comfortably (ref)	-	-
Doing alright	1.017	0.999,1.036
Just about getting by	1.066***	1.043,1.090
Finding it quite difficult	1.092***	1.054,1.132
Finding it very difficult	1.189***	1.122,1.260
Home Ownership		
Renting (ref)	-	-
Own Home	0.937***	0.911,0.963
Other	0.976	0.910,1.046
Maternal Education		
O-Level (ref)	-	-
A-Level	0.956**	0.928,0.985
Degree	0.913***	0.891,0.937
Overseas	1.039	0.964,1.119
None	1.113***	1.068,1.160

*$P \leq 0.05$ **$P \leq 0.01$ ***$P \leq 0.001$

Table A12: Full model for behavioural difficulty score, continued.

Paternal Education		
O-Level (ref)	-	-
A-Level	0.996	0.968,1.026
Degree	0.978	0.953,1.004
Overseas	1.020	0.959,1.085
None	1.061**	1.023,1.101
Child's Ethnicity		
White (ref)	-	-
South Asian	1.143***	1.085,1.204
Black	0.938	0.852,1.032
Other	1.016	0.952,1.084
Sex of Child		
Male (ref)	-	-
Female	0.922***	0.904,0.940
Number of Sibs in Household		
Mother Score	1.003	0.999,1.007
Father Score	0.998	0.996,1.001
MGM Contact		
Every Day (ref)	-	-
Weekly	0.991	0.965,1.019
Monthly	0.991	0.953,1.030
Every Few Months	1.003	0.962,1.046
Yearly or Less	0.966	0.911,1.025
Never	1.005	0.966,1.047
MGF Contact		
Every Day (ref)	-	-
Weekly	1.012	0.977,1.048
Monthly	1.010	0.968,1.056
Every Few Months	1.003	0.958,1.050
Yearly or Less	1.028	0.974,1.085
Never	1.022	0.984,1.060

*$P \leq 0.05$ **$P \leq 0.01$ ***$P \leq 0.001$

Table A12: Full model for behavioural difficulty score, continued.

PGM Contact		
Every Day (ref)	-	-
Weekly	0.974	0.933,1.016
Monthly	0.961	0.916,1.009
Every Few Months	0.958	0.910,1.009
Yearly or Less	0.978	0.920,1.038
Never	0.983	0.937,1.032
PGF Contact		
Every Day (ref)	-	-
Weekly	0.987	0.943,1.033
Monthly	0.990	0.941,1.042
Every Few Months	0.999	0.946,1.054
Yearly or Less	0.988	0.932,1.050
Never	0.996	0.952,1.044
MG Financial Help		
No (ref)	-	-
Yes	1.010	0.990,1.031
PG Financial Help		
No (ref)	-	-
Yes	0.997	0.978,1.015
ψ_1 **(intercept)**		0.282
ψ_2 **(slope: Child Age)**		0.085
AIC		93886
BIC		94330

*$P \leq 0.05$ **$P \leq 0.01$ ***$P \leq 0.001$