Essays in Applied and Development Economics

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I, Xiaoying Liu, 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.

26/09/2012

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献给我的祖父祖母

Abstract

This thesis contains three self-contained essays in development and applied economics.

Chapter 1 develops a new way to estimate the habit persistence coefficient of consumption using household panel data. In contrast to the traditional approach of estimating an approximate Euler equation, the identification comes from comparing the coevolution of income and consumption. Using Spanish data from 1985 to 1995, we estimate a joint model of habit formation and income variability. Under alternative preference specifications, we find habit persistence plays an important role in smoothing the impact of permanent income shocks on consumption. With our estimated parameters, we find habit persistence reduces the variance of consumption by 40% over the life-cycle. The presence of habits in consumption offers an explanation for the "excess smoothness of consumption" puzzle.

Chapter 2 examines the empirical link between inequality and common property resource extraction. Using a Tunisian data, we find groundwater table falls less in villages with higher land area inequality. We also design a choice experiment to elicit farmers' willingness to pay for a community-based management regime for groundwater use, and their demand for information sharing and accountability. We find farmers are inclined to cooperation and stabilizing water table level, and a majority demand a transparent system with independent monitoring, which is absent from the current management scheme. We further examine the effect of land inequality and heterogeneity on farmers' inclination.

Chapter 3 investigates the causal effect of father's labour migration on children's education in rural China. We employ two different empirical strategies which are compared and contrasted. The first strategy uses a fixed effect instrumental variable procedure. The second approach treats education and migration as duration processes using the multivariate duration framework developed by Abbring and van den Berg (2003). We find father's migration has no significant impact on child's lifetime education attainment.

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Introduction

This thesis contains three self-contained essays in development and applied economics. While covering a diverse range of topics, each of these three essays share an important common feature. In particular, all may be viewed as being concerned with the impacts associated with economic development, and the institutional causes that lie behind these. Often these impacts will be multidimensional and may include those which are economic, social, and environmental. While some of these impacts may be considered an inevitable part of the development process, often they may be the result of stagnant institutional arrangements (either formal or informal) which are usually characterized as "path dependency and stickiness" (North (1990)). If these arrangements are not addressed properly, then there is a concern that they may harm the sustainability of future development. For these reasons, this thesis is interested in studying the results of a combination of economic development and stagnant institutional change and how these interact with each other. Each self contained essay provides a quantitative evaluation of important economic issues using an array of different empirical approaches.

The first chapter, *Consumption Habit Formation and Income Variability*, focuses on the impact of income growth and uncertainty on consumption and savings behaviour. More precisely, it examines how the introduction of consumption habit formation in an otherwise standard life-cycle model affects household consumption and saving during periods of economic development. While there is a well documented positive correlation between savings and economic growth (Paxson (1996); Attanasio et al. (2000); Deaton and Paxson (2000)), we explore the mechanism through which economic development may foster high savings. Here, we treat habit persistence as an informal norm that is embedded in consumer's preferences. The precise form of habits that we consider are in the spirit of Becker (1992), who described such habitual behaviour as being "sensitive to choices in the more distant past – including sometimes choices made by parents and others in the past – because the effects of the past decay slowly". Consumption habit formation introduces dynamics in decision making not merely through intertemporal credit constraints but through the connection of past and future preferences. Inspired by Carroll et al. (2000), which provided a theoretical mechanism through which habit persistence can explain the link between high growth and high savings, I show how consumption habit functions like an insurance mechanism against unexpected income shocks and helps smooth consumption.

Based on this idea, this chapter develops a novel way to identify and estimate the habit persistence coefficient of consumption using household panel data. In contrast to the traditional approach of estimating an approximate Euler equation, the identification in this paper comes from the idea that habit is stagnant and helps consumers to smooth consumption against unpredictable income shocks. By comparing the co-evolution of income and consumption, we show how it is possible to identify the extent of habit persistence. As the model requires us to follow the same household for a long time period, a long panel data in both variables is essential for identification. For this purpose, we use Spanish Household Consumption and Income Panel Data from 1985–1995, in which each household is surveyed by up to eight quarters. I start with a dynamic household optimization problem with intertemporally non-separable preferences, and derive the associated Euler-equation of consumption. Instead of estimating the Euler equation directly, I connect the consumption innovation with income innovation through the budget constraint. This allows us to write the evolution of consumption as a function of the income innovation, which is assumed to include both permanent and transitory components.

I estimate a joint model of habit formation and income variability under alternative preference specifications (a baseline model with quadratic utility and additive habits, and an extended model with CRRA utility and multiplicative habits). Under both specifications, I find that habit persistence plays an important role in smoothing the impact of permanent income shocks on consumption. Quantitatively, I find that habit persistence can reduce the variance of consumption by 40% over the life-cycle. The presence of habits in consumption therefore offers an explanation for the "excess smoothness" puzzle in literature. Moreover, the same ideas are very relevant for understanding the experiences of fast developing economies, such as countries in East Asia. Indeed, the methods developed in this chapter, can be applied to data from these developing countries, giving us an opportunity to provide a quantitative assessment of the extent to which habits may be important for explaining the observed high savings and high growth rates in these countries.

The second chapter, *Inequality, Information and Groundwater Management: A Case Study in Rural Tunisia* (joint with Mare Sarr and Tim Swanson), explores the environmental impact of economic development. Instead of reviving the potential conflicts between economic development and the natural environment, this chapter focuses on the institutional settings and their impacts on common property resources management. To this end, it investigates a case study of groundwater management within villages in the Merguellil river basin in Tunisia. As we describe, water management in Tunisia has gone through several stages, from the traditional collective management of irrigation water at the tribe level, to the centralization control in 1950s, followed by the recent decentralization movement in which the Association of Collective Interest and Group of Collective Interests were formed to be responsible for water management at local level. Importantly, the new institution does not have the financial, technical and organizational capabilities to adequately fulfil its mission, and as a result farmers have little confidence in it. Water stealing and deepening wells are common, and consequently, scarce water resources are overexploited.

With this institutional background in mind, Chapter 2 of this thesis is dedicated to unearth the institutional factors that deter collective management of the common property resources. We first examine whether inequality (especially in land distribution) at the village level has any impact on resource use. Using unique data that we collected on water table levels and land distribution from 28 villages, we document an inverse relationship between inequality and water resource exploitation, which is in line with Olson (1965)'s argument on inequality and public goods provision. We further probe the institutional factors that are conducive to cooperation by conducting a choice experiment, in which farmers are asked to choose among a set of policy scenarios designed with an explicit trade-off. The quantitative analysis shows farmers are willing to pay a significant amount for a transparent management system with independent accountability, which is notably absent in the current institutional arrangement. In other words, asymmetric information and heterogeneity are the factors that hamper the formation of cooperation. At a policy level, making private water use information public through the "name and shame" strategy is a possible way to foster cooperation. We argue that as more government involvements try to be put in place to tackle the "common property tragedy", it's important to recognise that any intervention needs to remove the obstacles which impedes cooperation at local level in the first place.

The final chapter of this thesis, *The Effect of Labour Migration on Children's Education in Rural China*, examines the social impact of large scale internal labour migration in contemporary China. It is motivated by the concern over the welfare of those who are left behind by the inter-migration wave and the long-term debate on migrants' children's education outcome. With the unique Residence Registration System (*Hukou*) in China, children can only attend public school in the county where their *Hukou* were registered, which is most likely where they were born or where their parents resided before migrating. Since transferring *Hukou* is extremely difficult (especially from a rural one to an urban one), most migrants undertake migration work at cities where they don't have *Hukou* and therefore are not entitled to the local social welfare benefits or public services, such as children's schooling opportunities and medical insurance. As a result, it is very common to find "empty-nested" families in which children are left behind in their original villages, to live with grandparents or on their own, while their parents are doing year-long construction or manufacturing work in cities on east coast.

Given this institutional background, the problem at hand becomes prominent as rural parents on the one hand rely upon migration work for more income, while on the other hand have to leave their children at home without parents' supervision for schooling. The general impact of parents' migration on children is always in debate. The objective of this chapter is to investigate the causal effect of father's internal labour migration on children's education attainment in rural China. I employ two different empirical strategies which are compared and contrasted. The first approach uses a fixed effect instrumental variable procedure, instrumenting the migration decision by rainfall deviations. The second strategy I use treats education and migration as duration processes using the framework developed by Abbring and van den Berg (2003), and compares the education attainment between children whose fathers migrate during children's schooling years with those whose fathers who don't. By applying both empirical strategies to the same China Health and Nutrition Survey data, we find that on aggregate father's migration neither improves nor hinders the lifetime education attainment of the left-behind children in the long run.

Chapter 1

Consumption Habit Formation and Income Variability

> Árbol que nace torcido, jamás su tronco endereza (*A tree that is born twisted never grows straight*) — Spanish proverb.

1.1 Introduction

The past three decades have seen efforts to move away from the intertemporally separable preference model. Common ways to introduce intertemporal nonseparability in life cycle consumption models include habit formation (Constantinides, 1990) and the durability of consumption (Hayashi, 1985).[1] These mechanisms, in addition to the usual income and prices channels, can influence one's consumption in a fundamental way. In particular, with habit formation, current utility does not only depend on current consumption, but on past consumption in a form of habit stock. If habit plays an important role, then there can be much slower adjustments in consumption following shocks to income. Because of this important feature, habits have been proposed as an explanation for several apparent "puzzles" under the standard separable utility model. Examples include the excess sensitivity or excess smoothness of aggregate consumption (Deaton, 1992), the equity premium puzzle (Abel (1990); Campbell and Cochrane (1999); Constantinides (1990)), and the causal relationship between savings and economic growth (Carroll et al., 2000). Notwithstanding the great benefits of introducing habits into the utility function as well as the straightforward intuition it provides, the identification and estimation of the habit persistence has remained a very challenging problem. The objective of this paper is to develop a model that allows us to identify habit persistence in consumption, and then to empirically investigate the quantitative importance using Spanish Household Consumption and Income Panel (ECPF) data. By examining the coevolution of consumption and income inequality, we find that households' quarterly consumption displays a strong degree of habit persistence, with this persistence smoothing the impact of income shocks on consumption.

[1] The importance of habits in consumption have long been recognised. See Constantinides (1990) for a review on history of habit research.

Most previous attempts to identify habit persistence estimate Euler equation, i.e. the first order condition of the intertemporal maximization problem, exploring cross-sectional variations in consumption. Examples of this approach with additive habits[2] include Alessie and Lusardi (1997) and Dynan (2000). These models are then estimated using an GMM procedure with variables at lagged periods as instruments. These papers rely upon the use of a linearized Euler equation based on a Taylor series expansion, whose validity is the source of much disagreement (see the discussion between Carroll (2001) and Attanasio and Low (2004)). Carroll (2001), as well as Ludvigson and Paxson (2001), argues in estimating linearlized Euler equation, instruments (usually interest rates at lagged periods) are very likely to be correlated with the omitted higher-order approximation error. However, this argument has been refuted by Attanasio and Low (2004) who argue that it is the lack of cross-sectional variability in interest rates and lack of information on individual discount rates that contributes to the failure of sensable estimates of system parameters such as intertemporal elasticity of substitution. Instead, they show that using 'large-T' asymptotics instead of cross-sectional variation can produce unbiased estimates in simulation exercises unless discount rate is exceedingly and implausibly high, and hence log-linear approximation shouldn't be taken to account for the unreasonable estimates. This argument is joined by Yogo (2004) who particularly show weak instruments can explain the puzzle in estimating log-linearized Euler equation. Besides GMM-Euler equation approach, there exist other methods in literature to examine consumption habit. For example, Fuhrer (2000) considers a consumer model with multiplicative habits. He linearizes the Euler equation around steady state and estimates the model using maximum likelihood estimation. In contrast to Dynan (2000), which doesn't find evidence of habit persistence using household food consumption data from the Panel Study on Income Dynamics (PSID), Fuhrer (2000) finds habit formation is economically important using US quarterly aggregate consumption and income data. An alternative empirical approach is provided in Browning and Collado (2007). Here, the difference in additivity between different consumption goods is recognised, and Engel curve relationships are then estimated to test whether last period's budget share for a given good is correlated with this period's share. Meghir and Weber (1996) develop a structural model which is the first to disentangle dynamics in preferences (i.e. habit formation) from dynamics due to borrowing constraints – both features introduce dependence on variables in the information set of the consumer which invalidates the standard Euler equation. Although they reject intertemporal nonseparable preference over three types of nondurable goods using US Consumer Expenditure Survey, Carrasco et al. (2005) do find habit persistence by applying the same model to ECPF data and taking account of household fixed effects[3]. More recently, Crawford (2010) implements a nonparametric revealed preference test for habits using the same data set as we use in this study, and finds

[2]In additive habit model, habit stock enters utility function in a additive form to the current consumption; while in multiplicative habit model, habit stock enters utility function in a multiplicative form to the current consumption.

[3]They can't reject the absence of habit in consumption if they apply the exactly same Meghir and Weber (1996) method without household fixed effects to ECPF data.

evidence for habits in consumption. However, constrained by the methodologies used, most of these papers can't produce point estimation of structural parameters such as habit persistence coefficients.

This paper provides a new method to identify and estimate habits in consumption. It differs from much of the existing literature in that it examines the co-evolution of both income and consumption, and the identification comes from the comparison of variances and covariance between consumption and income. When the interest rate and the rate of time preference are similar, we demonstrate that intrinsic consumption (defined as the part of consumption that directly contributes to current utility), rather than consumption itself as under the permanent income hypothesis, should be a martingale. Moreover, the cross-sectional variance of intrinsic consumption should only reflect the variability of unexpected permanent income shocks. Faced with both income and consumption panel data at household level, the model allows us to identify the coefficient of habit persistence, together with the stochastic permanent and transitory income processes. By applying the model to the extensive Spanish Household Consumption and Income Panel data (covering the period 1985–1995), we find evidence for the presence of consumption habits and show that it plays an important role in smoothing out income shocks, especially the persistent permanent shocks, for Spanish Households. This finding is consistent with other papers that have tested habit persistence using the same data set (see Carrasco et al., 2005; Browning and Collado, 2007; Crawford, 2010), and more importantly, it identifies the quantitive scale of importance.

This paper not only contributes to the literature on consumption habit estimation, but also advances the research on the relationship between changes in income inequality and changes in consumption inequality. Blundell and Preston (1998) document the empirical divergence between consumption inequality and income inequality in the UK over 1980s, and relate this growth in income inequality primarily to growth in transitory income shocks, with permanent income shocks fully transmitted to changes in consumption. In a more recent paper Blundell et al. (2008b) provide a more detailed examination of the transmission of income shocks to consumption and develop a model which incorporates partial insurance (in terms of the degree of transmission from income shocks to consumption inequality). They provide the evidence to support partial insurance and emphasize the role of public transfers as well as heterogeneity in the ability of agents to self-insure. However, as they themselves say, they only provide "the 'structured facts' rather than a specific structural interpretation" about this insurance mechanism. This paper proceeds in a similar vein, and argues that besides precautionary saving, consumption habit persistence is also one of the mechanisms that can be thought of as self-insuring consumption against income shocks. This has important implication on welfare policy. As more and more researchers switch to consumption inequality from income inequality for welfare measure (for example,Cutler and Katz (1992), Deaton and Paxson (1994),Krueger and Perri (2006)), our findings suggest consumption inequality alone may not be an ample indicator if much smaller consumption inequality is attributed to habit persistence and combination of income and consumption inequality may be a more desirable indicator. Moreover, this paper also contributes to the research in explaining the "excess smoothness" of consumption to permanent income shocks (Campbell and Deaton (1989)) from the specification of utility function, following Fuhrer (2000). Although Quah (1990) shows that permanent income hypothesis can still predict excess smoothness of consumption when agents distinguish permanent and transitory movements in labour income, this paper shows that consumption can be further smoothed in the case of habit formation.

An understanding of consumers' habit persistence also helps us to shed light on a number of important policy questions. In particular, it helps us to understand why some countries have bigger saving rates than others. It is widely believed that being frugal is a cultural tradition in East Asian countries, and this argument has been used to explain the high saving rate in those countries despite prolonged periods of consistently high economic growth. However, no empirical studies have so far provided convincing evidence for this hypothesis. Carroll et al. (2000) provided theoretical foundations for this argument and present simulation exercises. Carroll's argument starts from the observation that fast growing countries in East Asia such as Japan, Korea, Hong Kong and Singapore all displayed a similar trend during their growth period – that is, the increases in growth preceded the rise in saving rate. The main mechanism, as he argues, is that habit formation prevents consumption from growing as fast as income in fast growing economies, so that savings accumulate. These arguments would be strengthened significantly if backed by robust empirical evidence. While looking at a somewhat different country from those considered by Carroll, one contribution of this paper is to document evidence of habits in consumption.

This chapter proceeds as follows. In Section 1.2, the baseline theoretical model is set up with an intertemporally nonseparable quadratic utility function, and the identification strategy for recovering the coefficient of habit persistence is discussed. Section 1.3 describes the data set that we use and presents the empirical results. Section 1.4 then extends the model to allow for a more general CRRA utility specification, and presents estimation results based upon this alternative specification. Section 1.5 shows some simulation exercises based on estimated parameters from the second model, before we conclude in section 1.6.

1.2 Model

The model in this paper builds on that developed in Blundell and Preston (1998), which under the hypothesis of the life cycle behaviour, uses the dynamics of consumption and income variances to identify the variances of permanent and transitory income shocks. In this section we extend their model to include habits (i.e. intertemporal non-separable utility), to examine how income shocks can be decomposed if consumption shows habit persistence, and more importantly, how we may identify the habit persistence of consumption.

We begin with consumers' intertemporal optimization problem by assuming a time-nonseparable utility function, with both current consumption and habit stock (defined below) as arguments. Each consumer chooses consumption at each period c_{it} to maximize the life-time utility function:

$$\max_{\{c_{it}\}} \mathbb{E}_t \left[\sum_{s=t}^{T} \left(\frac{1}{1+\delta} \right)^{s-t} u(c_{is}, h_{is}) \right],$$

where δ is discount rate and h_{it} is household i's habit stock at time t. The habit stock evolves according to: $h_{it} = h_{it-1} + \lambda(c_{it-1} - h_{it-1}) = (1-\lambda)h_{it-1} + \lambda c_{it-1}$. For simplicity, we assume that $\lambda = 1$, so that the habit stock is simply equal to last period's consumption: $h_{it} = c_{it-1}$[4].

Consumers maximize the above life-time utility function subject to the life time budget constraint:

$$\sum_{k=0}^{T-t-1} (1+r)^{-k} c_{it+k} = A_{it} + \sum_{k=0}^{R-t} (1+r)^{-k} y_{it+k},$$

where R is the retirement age, A_{it} are assets holding at time period t, and r is the risk-free interest rate. Note that the only source of uncertainty is from stochastic labour income process $y_{it+k,k\geq 0}$.

As demonstrated by Carroll (2000), the Euler equation for the simple case with $\lambda = 1$ can be written as:

$$\mathbb{E}_t \left[u_{c,t} + \frac{1}{1+\delta} u_{h,t+1} \right] = \frac{1+r}{1+\delta} \mathbb{E}_t \left[u_{c,t+1} + \frac{1}{1+\delta} u_{h,t+2} \right], \tag{1.1}$$

where u_{ct} and u_{ht} are the marginal utilities with respect to c_t and h_t respectively, and whose arguments have been suppressed for notational simplicity. The above Euler equation indicates the expected marginal utility by saving 1 unit of consumption today (LHS) should equal to the expected discounted marginal utility of $(1+r)$ units of consumption tomorrow (RHS). The second term on each side of the Euler equation is the marginal effect of current consumption on future utility that is carried over to the next period by habit persistence.

1.2.1 Consumption Process

We begin our analysis by assuming that habits enter the utility function additively, with one period lagged consumption as the habit stock ($h_t = c_{t-1}$) unchanged, so that $u(c_t, h_t) = u(c_t - \gamma c_{t-1})$, and where γ is habit persistence coefficient. The parameter γ measures the strength of habit formation: when larger, the consumer receives less utility from a given amount of expenditure (Dynan, 2000). If there were positive habit persistence, γ should be in the range of $[0, 1]$. If $\gamma = 0$, then the model collapses to the standard intertemporally separable model, while $\gamma = 1$ means that only consumption growth matters for current utility. Alternatively, in the other case of intertemporal nonseparability – durability – γ could be less than zero, as past consumption brings satisfaction to the current time. To simplify the subsequent notation we denote $c^*_{it} \equiv c_{it} - \gamma c_{it-1}$.

For simplicity, we assume that the within period utility function is quadratic in c^*_{it}, so

[4] Using quarterly macro economic data, Fuhrer (2000) estimate a value of λ that is close to 1.

that marginal utility is simply linear in this term. Thus, the Euler equation in the presence of habits becomes:

$$\mathbb{E}_t\left[c^*_{it} - \frac{\gamma}{1+\delta}c^*_{it+1}\right] = \frac{1+r}{1+\delta}\mathbb{E}_t\left[c^*_{it+1} - \frac{\gamma}{1+\delta}c^*_{it+2}\right] \tag{1.2}$$

This Euler equation schedules the evolution of expected consumption from period t on. While as income provides the only uncertainty in this model, actual consumption will respond to the new income shocks correspondingly. In order to track how consumption evolves under uncertainty, we need to connect consumption to income innovations. This is done through the budget constraint, which by simple construction, may be written as:[5]

$$\begin{aligned}\sum_{k=0}^{T-t-1}(1+r)^{-k}c^*_{t+k} &= -\gamma c_{t-1} + \gamma(1+r)^{-(T-t)}c_{T-1} \\ &\quad + \left(1-\frac{\gamma}{1+r}\right)\left[A_t + \sum_{k=0}^{R-t}(1+r)^{-k}y_{t+k}\right], \end{aligned} \tag{1.3}$$

By simple rearrangement we also have:

$$\begin{aligned}\sum_{k=0}^{T-t-1}(1+r)^{-k}c^*_{t+k+1} &= -(1+r)c_t + (1+r)^{-(T-t-1)}c_T \\ &\quad + (1+r)\left(1-\frac{\gamma}{1+r}\right)\left[A_t + \sum_{k=0}^{R-t}(1+r)^{-k}y_{t+k}\right]. \end{aligned} \tag{1.4}$$

Subtracting equation (1.4) (multiplied by $\frac{\gamma}{1+\delta}$) from equation (1.3) gives us:

$$\begin{aligned}&\sum_{k=0}^{T-t-1}(1+r)^{-k}\left(c^*_{t+k} - \frac{\gamma}{1+\delta}c^*_{t+k+1}\right) \\ &\quad = \left(1-\gamma\frac{1+r}{1+\delta}\right)\left(1-\frac{\gamma}{1+r}\right)\left[A_t + \sum_{k=0}^{R-t}(1+r)^{-k}y_{t+k}\right] \\ &\quad - \gamma c_{t-1} + \gamma(1+r)^{-(T-t)}c_{T-1} + \gamma\frac{1+r}{1+\delta}c_t - \frac{\gamma}{1+\delta}(1+r)^{-(T-t-1)}c_T. \end{aligned} \tag{1.5}$$

Since the stock of assets evolving according to $A_t = (1+r)(A_{t-1} + y_{t-1} - c_{t-1})$ we may substitute this into equation (1.5) so that:

$$\begin{aligned}&\sum_{k=0}^{T-t-1}(1+r)^{-k}\left(c^*_{t+k} - \frac{\gamma}{1+\delta}c^*_{t+k+1}\right) = \\ &\left(1-\gamma\frac{1+r}{1+\delta}\right)\left(1-\frac{\gamma}{1+r}\right)\left[(1+r)A_{t-1} - (1+r)c_{t-1} + (1+r)\sum_{k=0}^{R-t+1}(1+r)^{-k}y_{t+k-1}\right] \\ &\quad - \gamma c_{t-1} + \gamma(1+r)^{-(T-t)}c_{T-1} + \gamma\frac{(1+r)}{1+\delta}c_t - \frac{\gamma}{1+\delta}(1+r)^{-(T-t-1)}c_T. \end{aligned} \tag{1.6}$$

[5] To simplify the notation, we have omitted the household specific subscript i.

By applying the period t expectations operator to both sides of equation (1.6), and subtracting the lagged version of equation (1.5) (with period $t-1$ expectations operator applied) we may cancel out the A_{t-1} term. Moreover, once we impose equality of the discount and interest rate, we obtain an expression for the evolution of the differenced term $c^*_{t+k} - \frac{\gamma}{1+\delta} c^*_{t+k+1}$:

$$\rho_t \left[\mathbb{E}_t \left(c^*_t - \frac{\gamma}{1+\delta} c^*_{t+1} \right) - \mathbb{E}_{t-1} \left(c^*_{t-1} - \frac{\gamma}{1+\delta} c^*_t \right) \right] = (1-\gamma)(1+r-\gamma)\eta_{it} \tag{1.7}$$

where $\rho_t = 1 - (1+r)^{-(T-t)}$ is an annuitization factor, and $\eta_t = r \times (1+r)^{-1} \sum_{k=0}^{R-t} (1+r)^{-k} (\mathbb{E}_t - \mathbb{E}_{t-1}) y_{t+k}$ is an income innovation term, or the annualized value of the expected difference of future income flows between the current and previous period.

The intuition for equation (1.7) is as follows: by taking into account the negative effect of current consumption on future utility, via habit persistence, the expected consumption change should only reflect a part of innovation to income at the current period. In other words, in the presence of habits, consumption should respond to income innovations more slowly. For a sufficiently small interest rate r, the multiplier on η_{it}– $(1-\gamma)(1+r-\gamma)$– is between 0 and 1. Stronger habit persistence (larger γ), reduces the multiplier, and therefore lowers the response of consumption to income shocks. Thus, habits introduce a form of inertia that prevent consumption from growing as fast when there is a positive income shock. Similarly, when there is a negative income shock it prevents consumption from decreasing as quickly.

1.2.2 From Income Change to Consumption Change

As in Blundell and Preston (1998) and Meghir and Pistaferri (2004), we assume a standard stochastic process determining the evolution of incomes y_{it}:

$$\begin{aligned} y_{it} &= y^P_{it} + u_{it} \\ y^P_{it} &= y^P_{it-1} + v_{it} \end{aligned} \tag{1.8}$$

where y^P_t is permanent income, and with period t changes in permanent income given by innovation term v_{it}. Similarly, transitory income shocks are given by u_{it} so that overall income evolves according to $\Delta y_{it} = \Delta u_{it} + v_{it}$. For now, we assume that permanent and transitory income shocks are independent from each other at all leads and lags, i.e. $u_{it} \perp v_{is}$, $\forall t, s$, although in the much of the later analysis we will assume that transitory shocks follow a MA(1) process. For now, we do not consider measurement error in either consumption or income.

Given the above income process, the income innovation term η_{it} can be decomposed into transitory and permanent innovations to income:

$$\eta_{it} = \rho_t v_{it} + \frac{r}{1+r} u_{it}. \tag{1.9}$$

Substitute (1.9) into (1.7) and remove the expectation operator from the LHS of equation

(1.7), we can rewrite this expression as:

$$\rho_t \left[(c_t^* - \frac{\gamma}{1+r} c_{t+1}^*) - (c_{t-1}^* - \frac{\gamma}{1+r} c_t^*) \right] = (1-\gamma)(1+r-\gamma)\eta_{it} + \rho_t \xi_{t+1} - \rho_t \xi_t \qquad (1.10)$$

where $\xi_{t+1} = -\frac{\gamma}{1+r}(c_{t+1} - \mathbb{E}_t c_{t+1})$ is the expectation error of consumption at period $t+1$, which includes information that only arrives at $t+1$, and $\xi_t = -\frac{\gamma}{1+r}(c_t - \mathbb{E}_{t-1} c_t)$ is similarly defined. Theoretically, the expectation error at time t will be a function of the income innovations u_{t+1} and v_{t+1} as it includes consumption shock in response to newly arrived information on income at $t+1$. For now, we treat these consumption expectation errors as unknown variables. Equation (1.10) implies that the growth in intrinsic consumption at time t, after removing the part which is carried over to the future period by habit persistence, can be decomposed into two parts: the corresponding annuitized income innovation at time t, and the difference between the expectation error of one-period forward consumption in the current period and that of the previous period.

For notational simplicity we define composite consumption $Q_t = c_t^* - \frac{\gamma}{1+r} c_{t+1}^*$ and $Q_{t-1} = c_{t-1}^* - \frac{\gamma}{1+r} c_t^*$. We refer to Q_t as *intrinsic consumption*, as it is the marginal current utility of current consumption with the effect on future utility (carried over by habit persistence) removed. So Equation (1.10) actually describes the martingale property of the *intrinsic consumption*. If we divide by the annuitization factor and take variances on both sides of equation (1.10) , we can obtain the following equation:

$$\Delta \text{var}(Q_{it}) = (1-\gamma)^2 (1+r-\gamma)^2 \left(\text{var}(v_{it}) + \frac{r^2}{(1+r)^2 \rho_t^2} \text{var}(u_{it}) \right) + \Delta \text{var}(\xi_{it+1})$$

For small enough interest rate r and sufficient long time horizon T, we obtain $\rho_t \to 1$ which allows us to derive an approximate version of the above equation:

$$\Delta \text{var}(Q_{it}) \simeq (1-\gamma)^2 (1+r-\gamma)^2 \text{var}(v_{it}) + \Delta \text{var}(\xi_{it+1}). \qquad (1.11)$$

To better understand the equation (1.11), we are comparing it with its counterpart in Blundell and Preston (1998):

$$\Delta \text{var}(c_{it}) \simeq \text{var}(v_{it}) \qquad (1.12)$$

As Blundell and Preston (1998) assume a life cycle model with a quadratic intertemporal separable utility function, equation (1.12) says the growth in consumption variance for each cohort should reflect the variance in permanent income shocks only at one to one ratio, with the effect of transitory income shocks being smoothed away. Similarly but differently, the moment condition Equation (1.11) in the case of habit persistence ($\gamma > 0$) states that, after being adjusted for the change in the variance of consumers' expectation error, the change in the variance of intrinsic consumption *which contributes to current utility* responds only to the permanent income innovation variance at a *discounted rate*. That is to say, consumers' habits act to passively smooth out income shocks. The permanent income hypothesis tells us how individuals use consumption to smooth out the impact of transitory income shocks on utility. While passively, habits provide some form of self-insurance against more persistent shocks, so that consumption responds even more gradually to income changes. As we now discuss, understanding this co-evolution of income and consumption is essential for empirically identifying the presence of habits.

1.2.3 Identification

Equation (1.11) suggests a method for estimating the coefficient of habit persistence γ. As in Blundell and Preston (1998), we can derive a set of moment conditions which will then allow us to separately identify the variance of permanent and transitory income innovations, as well as γ. We obtain:

$$\Delta\text{var}\left(c_t^* - \frac{\gamma}{1+r}c_{t+1}^*\right) \simeq \left[(1-\gamma)^2(1+r-\gamma)^2\right]\text{var}(v_t) + \Delta\text{var}(\xi_{t+1}) \tag{1.13}$$

$$\Delta\text{var}(y_t) - \frac{1}{(1-\gamma)^2(1+r-\gamma)^2}\Delta\text{var}\left(c_t^* - \frac{\gamma}{1+r}c_{t+1}^*\right) \simeq \Delta\text{var}(u_t) - \frac{1}{(1-\gamma)^2(1+r-\gamma)^2}\Delta\text{var}(\xi_{t+1}) \tag{1.14}$$

$$\frac{1}{(1-\gamma)(1+r-\gamma)}\Delta\text{cov}\left(c_t^* - \frac{\gamma}{1+r}c_{t+1}^*, y_t\right) \simeq \text{var}(v_t). \tag{1.15}$$

With $\gamma = 0$, these three equations collapse to the three moment conditions used in Blundell and Preston (1998):

$$\Delta\text{var}_k(c_t) \simeq \text{var}_k(v_t) \tag{1.16}$$

$$\Delta\text{var}_k(y_t) - \Delta\text{var}_k(c_t) \simeq \Delta\text{var}_k(u_t) \tag{1.17}$$

$$\Delta\text{var}_k(c_t, y_t) \simeq \text{var}_k(v_t) \tag{1.18}$$

Equation (1.13) is the first moment condition we derive in the last section. Equation (1.14) is analogous to (1.17) in which permanent shocks that is identified from (1.13) can be removed from change in variance of income to obtain change in transitory income shocks. The covariance between composite consumption and income also provides information on permanent income shocks (equation (1.15)). So far, for each period there are three parameters to be identified: $var(v_t)$, $\Delta var(u_t)$, $\Delta var(\xi_{t+1})$, plus a time-invariant γ, while we have only three moment conditions for each period as listed above. To obtain full identification of the whole model we proceed to use the income covariance conditions as presented in Meghir and Pistaferri (2004), which are sufficient to identify the variances of permanent income shocks:

$$\mathbb{E}\left[g_{it}\left(\sum_{j=-(1+q)}^{1+q} g_{it+j}\right)\right] = \mathbb{E}(v_{it}^2) = \text{var}(v_{it}), \tag{1.19}$$

where $g_{it} = \Delta y_{it} = \Delta u_{it} + v_{it}$ is stochastic income growth. q denotes the degree of moving average provess of transitory shock u_{it}. As we assume u_{it} is indepently distributed for the moment, $q = 0$.

The model moment conditions (equations (1.13)–(1.15) and (1.19)) use information on the relationship between income and consumption. While consumption habits can partly smooth out permanent shock of income, the covariance of the income series itself can reveal information about permanent income shocks. Furthermore, equation (1.15) and (1.19) allow us to identify habit persistence γ and variances of permanent shocks together, which when used with the other two conditions ((1.13) and (1.14)) allow us to identify the growth in variances of transitory shocks and prediction errors.

In the above model, we assumed that both u_{it} and v_{it} are independent from each other at all leads and lags. However, in reality, we may expect some form of correlation over time. Indeed, should transitory shocks follow MA(1) process, we set $q = 1$ in equation (1.19) and equation (1.15) is replaced by the following modified condition:

$$\Delta\text{cov}\left(c_{t+1}^* - \frac{\gamma}{1+r}c_{t+2}^*, y_t\right) = (1-\gamma)(1+r-\gamma)\text{var}(v_t) \tag{1.20}$$

It is important to note that, different from Blundell and Preston (1998) using repeated cross-sectional data in estimation, identification of this model requires at least 4 waves of panel data with both consumption and income in the presence of MA(0) transitory shocks as variance and covariance are not linear functions. And for the model with MA(1) transitory shocks, at least 6 waves then becomes necessary. The minimum number of waves required for identification in general is $4 + 2q$.

1.3 Data and initial results

We estimate the model using a detailed Spanish household panel data set (*Encuesta Continua de Presupuestos Familiares*, ECPF), 1985–1995. The ECPF has been used in several papers to test consumption intertemporal non-separability owing to the long panel that it covers (Carrasco et al., 2005; Browning and Collado, 2007; Crawford, 2010). Each household is surveyed for at most eight consecutive quarters, with one-eighth of the sample being rotated each wave. The sample size for each wave is around 3200 households. It provides detailed information on expenditure, income and demographics at the household level (see Browning and Collado, 2001, for a detailed description of the data set), with food and other non-durable goods consumption taken at weekly base, and durable goods consumption each quarter.

1.3.1 Sample selection and variable definition

We only consider families reporting complete information for at least 4 waves, and of couples with or without dependent children (34253 observations excluded from the original data). We also drop households if their household heads have changed over time (23 observations), those with at least one permanent guest (658 observations), or having household size changed by more than one person (2771 observations). We further drop those with age inconsistencies (1931 observations), or spouse's employment status changed (11,667 observations) to avoid spousal labour supply insurance which may confound our results. Finally, we dropped household observations with zero reported food consumption (204 observations). The final sample consists of 7,717 households (45,983 observations), with heads' age between 25 and 60 in the sample. For the detailed composition of sample, please see Table 1.5 in Appendix 1.A.

We define three categories of consumption and estimate our model with these alternative consumption definitions. Non-durable consumption and services is defined as the total household expenditure on food at home (including alcohol and tobacco), all kinds of services (including utility bills) and all the non-durable goods. We add semi-durable consumption (semi-durable household goods and clothes etc.) to non-durable consumption and services to form the second consumption category. The last category includes nearly all consumption items (including car purchasing and education payment for example), by adding durable goods consumption on top of the second category. Following Pijoan-Mas and Sánchez-Marcos (2010), we also try four measurements of income in estimation: net labour earnings (wages + 2/3 self employment earnings); net labour earnings plus private transfers; net income (all types of income, including wages, self-employed earning, capital income, and all private transfer); total net disposable income (net income plus public transfers such as pensions and unemployment benefit). We trim off the bottom and top 1% observations in consumption (the third definition) and income (the fourth definition) distribution in our estimation. Table 1.6 lists the mean and the variances of income and consumption under each definition.

To understand the movement of income and consumption shocks, the predictable part of real income and consumption (conditional on demographic characteristics) must first be removed. Following Blundell et al. (2008b), we run a simple linear regression:

$$\log Y_{it} = Z_{it}'\varphi_t + P_{it} + u_{it},$$

where P_{it} is i's permanent income at time t, and u_{it} is transitory income shock as before. Z_{it} is a set of household's (and head's) characteristics observable and known by consumers at time t. These include household demographics, head's education, head's job type, and seasonal effects. We allow these effects to interact with time or cohort. We also allow for general time

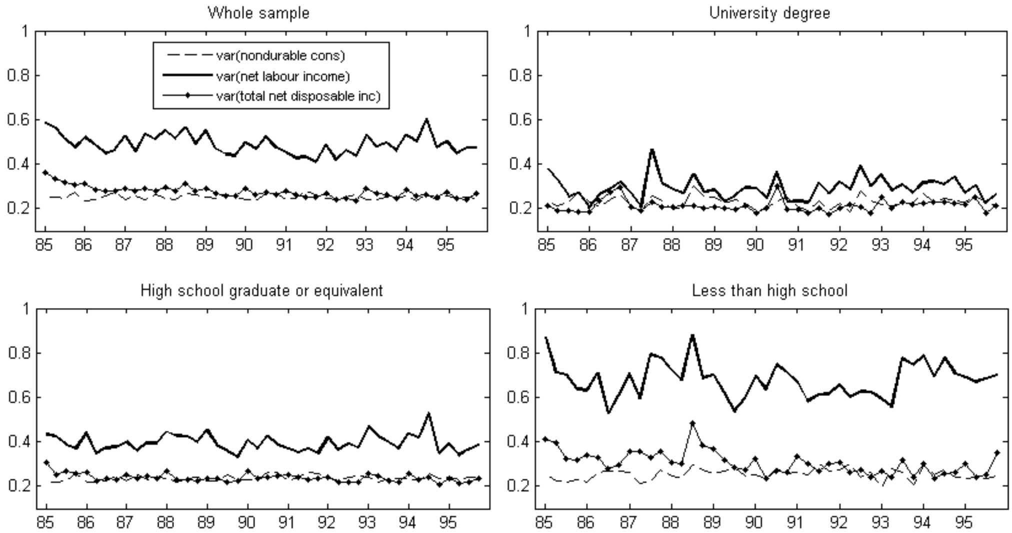


Figure 1.1: Evolution of Variance of Unpredicted Consumption and Income

trends[6] and cohort effects[7] in the intercept term. Both consumption and income are deflated by a Stone Price Index (which is the weighted price index with the household specific weights determined by each period's expenditure shares. Linear predictions are taken following these regressions; the distribution of residuals is presented in Figure 1.5 in the Appendix 1.A.

1.3.2 The autocovariance of consumption and income

Figure 1.1 plots the raw estimates of unexplained consumption and income variance, which are obtained after removing the predictable parts of income and consumption. The upper left panel is calculated using the entire estimation sample. It shows that income variance falls rapidly in the mid 1980s and then fluctuates around a steady level thereafter before rising again slowly in the last few quarters. Furthermore, the variance of consumption is much less variable and is around 0.15 throughout the sample period. Not surprisingly, the variance of total net disposable income is much lower than that of net labour income. Public and private transfers apparently work to lower the degree of inequality across population. The other three panels consider different (heads') education groups and show the trend of within-group variances over the same sample period. Households where the head has a university degree group shows a lower-than-average variance in incomes, while the lowest education group displays a much higher inequality, which drops by a large amount after taking account of transfers. These patterns are consistent with the conclusion of Pijoan-Mas and Sánchez-Marcos (2010) that "public transfers have played a crucial role in smoothing out the inequality arising in the labour market" during that period.

[6]We have experimented with two alternative types of time trend: an annual trend (one dummy for each year) and wave trend (one dummy for each wave). The main the empirical results are qualitatively similar for both types, and we present only those obtained using the annual trend.

[7]We adopt the same cohort definition as in Albarran et al. (2009): Cohort 1 – born between 1920 and 1934; Cohort 2 – born between 1935 and 1944; Cohort 3 – born between 1945 and 1954; Cohort 4 – born between 1955 and 1964.

Table 1.1: Estimated Habit Persistence (Quadratic preference)

	Income			
consumption	net labour earnings	net labour earnings + private transfer	net income	total net disposable income
nondurable	0.499 (0.056)	0.504 (0.053)	0.489 (0.051)	0.411 (0.049)
non+semi	0.459 (0.052)	0.462 (0.054)	0.452 (0.046)	0.415 (0.042)
all	0.433 (0.079)	0.446 (0.079)	0.449 (0.076)	0.415 (0.053)

Note: Bootstrapped standard errors are in parentheses.

For the auto-covariance between consumption and income, we calculate several moments of the income and consumption processes, as shown in Table (1.7). Estimates are reported for each wave. The table shows that there is a decrease in the variance of income growth in the second half of 1980s, while it increases slightly in the first part of 1990s. The first-order auto-covariances of income are of the expected sign ($-$) and show a slight increase over time in absolute value. Second- and higher- order auto-covariances are informative about the presence of serial correlation in the transitory income components (Blundell et al., 2008b). Second order auto-covariances are small economically and only statistically significant from zero in some time periods of the whole sample[8]. In the following analysis we assume the transitory income process as MA(1).

1.3.3 Results

1.3.3.1 Habit persistence

The above model has been estimated by minimum distance estimation. In estimation we allow the habit persistence coefficient γ to be negative. This therefore allows for both habit persistence ($\gamma > 0$) and durability of consumption ($\gamma < 0$) across time. Besides positive constraints on permanent income shock variances, no other linear nor non-linear constraints are imposed [9]. To obtain greater efficiency, we weight the moment conditions using the diagonal of their inverse variance matrix[10]. We also assume MA(1) structure of transitory income shocks. The results of this diagonally optimally weighted minimum distance estimation (DWMD) are presented in Table (1.1).

The table shows that the estimated habit persistence coefficients for non-durable and semi-durable goods consumption is positive and both economically and statistically significant (around 0.4–0.5). This means nearly half of the past consumption serves as baseline to which only the additional part of current consumption can be brought to current satis-

[8]However, the third-order auto-covariances of income are not small. In practice this data shows higher order auto-covariances are not necessarily small in size because of the quarterly data structure. To see how it works, look at $\text{cov}(\Delta y_{it}, \Delta y_{it+3}) = \text{cov}(y_{it} - y_{it-1}, y_{it+3} - y_{it+2})$, where $y_{it+3}$is the income in the same quarter exactly one year after when y_{it-1} is surveyed, which can be highly correlated, especially to seasonal job takers. This pattern exists even after we condition our incomes and consumptions on seasonal dummies. It's also important to notice the estimated standard errors don't take account of the fact that income data are the estimated residuals. Estimating the standard errors by bootstrapping may mitigate this problem. However, this is a data issue that seems hard to be completely resolved within the framework of this paper.

[9]We do not constrain $c_{it} - \gamma c_{it-1} \geq 0$ during estimation. However, *ex-post* we can easily verify whether this condition is violated in any t given our estimate of γ. We do not find any such violations.

[10]That is, the off diagonal elements are neglected. This treatment is to avoid the small sample bias of optimal minimum distance estimator (Altonji and Segal (1996)).

faction. The habit persistence coefficient decreases when we move from non-durable goods consumption to durable goods consumption, which reflects the fact that the identified coefficient captures both habit persistence and durability. When the degree of habit persistence is stronger than durability (for example in the case of non-durable goods consumption), the estimated coefficient tends to be positive and large. However, when the negative durability effect dominates the positive habit persistence (in the case of durable goods consumption) it is possible to obtain small or even be negative coefficients. Consistent with this intuition, when estimating the model with durable goods we obtain an estimate of γ that is significantly smaller than we obtained with non-durable goods (0.41–0.45), although economically this difference is not especially large. We also note that we find that the estimated habit persistence coefficient is much smaller when using total net disposable income, which is much less volatile than the other incomes without public transfers. This is consistent with our identification idea: given the same consumption variance, larger income variance implys larger habit persistence as habit works to smooth consumption in response to unexpected income shocks.

1.3.3.2 Income shocks

In Figure 1.2(a) we plot the variances of permanent income shocks (the solid line) and the change in variances of transitory shocks (the dashed line) over time to see how the income process in Spain has changed. These variances are decomposed from total net disposable incomes across the whole sample. The figure shows that there is much larger variation in transitory income shocks than in permanent income shocks, with a noticeable decline in these transitory income shock variances in the most sample periods (as the growth in this variable is negative in most periods), especially late 1980s. This decline suggests that it was a fall in variance of transitory income shocks that was responsible for decrease in overall income inequality seen in late 1980s. The variances of permanent income shocks are on the contrary quite stable and relatively small, at about 0.02 on average per quarter.

1.4 Incorporating precautionary saving

1.4.1 Habit persistence under CRRA utility

The model presented in Section 1.2 was based upon a life-cycle consumption model with a within-period quadratic utility function. Such a specification does not incorporate any precautionary savings motive. Precautionary saving provides another mechanism through which consumers may only partially adjust their consumption following a change in their permanent income. Ignoring it may confound our estimate of habit persistence coefficient. The main distinction between habit and precautionary saving lies in the fact that habit is formed before consumption (for example, it may be inherited from family) and therefore consumers are more unconscious of its effect; while precautionary saving is a conscious decision made by consumers, according to the predicted future income risk. This section extends

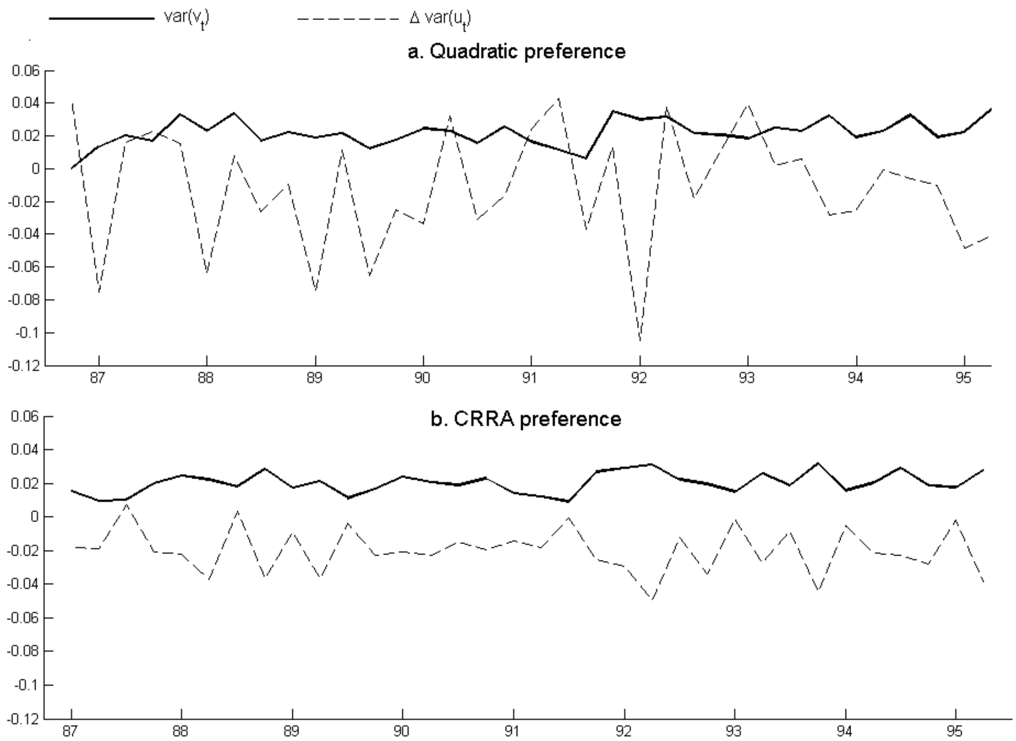


Figure 1.2: Variance of Income Shocks (total net disposable income)

the baseline model to allow for this property. Although we are not trying to disentangle the effects on consumption of habit persistence and precautionary saving, the model presented in the following does allow us to identify the coefficient of habit persistence in a framework in which precautionary saving is possible.

To incorporate precautionary saving, a utility function with convex marginal utility curve is necessary. We follow many papers that have incorporated habits, by using a constant relative risk aversion (CRRA) utility function. The setting is otherwise the same as in the quadratic utility case, and we continue to use last periods consumption as the habit stock. But in contrast to the quadratic case the stock of habits now enter the utility in multiplicative form, as in Carroll (2000). We therefore have the following within period utility function:

$$u(c_{it}, h_{it}) = u\left(\frac{c_{it}}{h_{it}^{\gamma}}\right) = \frac{1}{1-\sigma}\left(\frac{c_{it}}{h_{it}^{\gamma}}\right)^{1-\sigma},$$

with γ again used to denote the coefficient of habit persistence (although its scale is not comparable to the quadratic case). This coefficient should always be in the interval $[0, 1]$. A value $\gamma > 1$ would imply that steady-state utility is falling in consumption (Fuhrer, 2000). In contrast to the additive habit model, it is not the growth of consumption, but rather the *relative ratio* between consumption and the stock of habits that now matters for current utility. If $\gamma = 0$, this is simply the model without habits; while if $\gamma = 1$, only the ratio between current consumption and past consumption matters to the current utility; if it is between these values then both the consumption level and the ratio contribute to current utility, with γ determining the relative importance of each.

As before, we still assume expected utility framework, i.e. households choose consumption to maximize the sum of expected utility over time. If we substitute expressions for marginal utility, $u_{c,t} = (\frac{c_t}{h_t^\gamma})^{-\sigma}\frac{1}{h_t^\gamma}$ and $u_{h,t} = -\gamma\frac{c_t}{h_t}u_{c,t}$ into the generic Euler equation expression (Equation (1.1)) then we obtain:

$$\mathbb{E}_t\left[\frac{c_{it}^{-\sigma}}{h_{it}^{-\gamma\sigma+\gamma}} - \frac{\gamma}{1+\delta}\frac{c_{it+1}^{-\sigma+1}}{h_{it+1}^{-\gamma\sigma+\gamma+1}}\right] = \frac{1+r}{1+\delta}\mathbb{E}_t\left[\frac{c_{it+1}^{-\sigma}}{h_{it+1}^{-\gamma\sigma+\gamma}} - \frac{\gamma}{1+\delta}\frac{c_{it+2}^{-\sigma+1}}{h_{it+2}^{-\gamma\sigma+\gamma+1}}\right]. \tag{1.21}$$

This Euler equation again shows how consumption in the future should evolve over time. Theoretically it could be estimated by the usual Euler-equation GMM estimation method, with lagged variables as instruments. However, it is well known that estimating this non-linear Euler equation in the presence of measurement error with GMM generates inconsistent estimates (Amemiya (1985)). Therefore, log-linearization of the Euler equation is still necessary. Specifically we can show in the following how to remove the effect of measurement errors by log-linearization under standard assumptions of multiplicative measurement error. Following Carroll (2000), we write the above Euler equation as a function of c_{it}/h_{it} and linearize it around the steady state ratio c_0/h_0. As demonstrated in it, in the steady state of the model without stochastic shocks, the ratio between consumption and habit stock is equal to a constant: $c_0/h_0 = \chi$. Moreover, in the special case that $\lambda = 1$, as we examine here, the value of χ equals 1[11].

1.4.2 Linearization of Euler equation under CRRA utility

In a situation without uncertainty, the system reaches its steady state, in which the ratio between consumption and habit stock is a constant. As proved by Carroll (2000), this constant equals 1 if interest rate is the same as discount rate. We linearize the Euler equation around the log of this steady state ratio c_0/h_0. After removing the expectation terms, we obtain the following linearized Euler equation (see the Appendix 1.B for a proof):

$$\begin{aligned}
&\left(-\gamma - \frac{\sigma}{\sigma-1}(\gamma-1-r)\right)\triangle\ln c_{it+1} + \gamma(1+r)\triangle\ln c_{it} \\
&+\gamma(\triangle\ln c_{it+2} - \gamma\triangle\ln c_{it+1}) \\
&\simeq \left(-\gamma + \frac{\sigma}{\sigma-1}(\gamma-1-r)\right)\epsilon_{it+1} + \gamma(\xi_{it+2} - \epsilon_{it+1} - \gamma\epsilon_{it+1}) + \mathcal{O}(E_t\epsilon_{it+1}^2) + \mathcal{O}(E_t\xi_{it+2}^2) \\
&= \left(-\gamma + \frac{\sigma}{\sigma-1}(\gamma-1-r) - \gamma - \gamma^2\right)\epsilon_{it+1} + \gamma\xi_{it+2} + \mathcal{O}(E_t\epsilon_{it+1}^2) + \mathcal{O}(E_t\xi_{it+2}^2)
\end{aligned} \tag{1.22}$$

where $\epsilon_{it+1} = \ln c_{it+1} - \mathbb{E}_t \ln c_{it+1}$ and $\xi_{it+2} = \ln c_{it+2} - \mathbb{E}_t \ln c_{it+2}$ are the respective (one period and two periods) log consumption innovation. As in Blundell et al. (2008a), $\mathcal{O}(x)$

[11] Please refer to Carroll (2000) for derivation

denotes a term with the property that there exists a $K < \infty$ such that

$$| \mathcal{O}(x) | < K | x |$$

Based on the loglinearized budget constraint first used by Campbell (1993), Blundell et al. (2008a) has provided a way to connect this log consumption innovation with log income innovation. They show that $\epsilon_{it} = \pi_{it}(v_{it} + \alpha_t u_{it} + \Omega_t)$, where π_{it} is (roughly) the share of expected future labour income in current human and financial wealth, an idiosyncratic insurance coefficient against permanent income shocks, by for example precautionary saving; v_{it} and u_{it} are idiosyncratic permanent and transitory log income shocks at time t; Ω_t is the common income trend and doesn't vary across cohorts/population, and α_t can be seen as an annuitisation factor for income that is close to zero under a long time horizon. Similarly, it is easy to demonstrate that $\xi_{it+2} = \pi_{it+2}(v_{it+2} + \alpha_{t+2}u_{it+2} + (1-\alpha_{t+1})v_{it+1} + \alpha_{t+1}\alpha_{t+2}u_{it+1} + \Omega_{t+1} + \Omega_{t+2})$. As α_t is close to 0 for long T, the evolution of consumption can then be written as the following function of the income innovation:

$$\begin{aligned} &\left(-\gamma + \frac{\sigma}{\sigma-1}(\gamma-1-r)\right)\Delta\ln c_{it+1} + \gamma(1+r)\Delta\ln c_{it} + \gamma(\Delta\ln c_{it+2} - \gamma\Delta\ln c_{it+1}) \\ \simeq &\left(-\gamma + \frac{\sigma}{\sigma-1}(\gamma-1-r) - \gamma^2\right)\pi_{it}(v_{it+1} + \Omega_{t+1}) + \gamma\pi_{it+2}\left(v_{it+2} + \Omega_{t+2}\right) + \mathcal{O}_p(E_t||\nu_{it+1}^{R-1}||) \end{aligned}$$

where $\mathcal{O}_p(x)$ denotes a term with the property that for each $\kappa > 0$ there exists a $K < \infty$ such that

$$P(| \mathcal{O}_p(x) | > K | x |) < \kappa$$

For the purposes of estimation, we develop a similar set of moment conditions in the presence of MA(1) transitory shocks. We assume π_{it} is a constant across individuals and over time series. Defining $X_{it} \equiv (-\gamma + \frac{\sigma}{\sigma-1}(\gamma-1-r))\ln c_{it} + \gamma(1+r)\ln c_{it-1} + \gamma(\ln c_{it+1} - \gamma\ln c_{it})$, these may be written as:

$$\Delta\text{var}(X_{it+1}) = \left[-\gamma + \frac{\sigma}{\sigma-1}(\gamma-1-r) - \gamma^2 + \gamma\right]^2 \pi^2\text{var}(v_{it+1}) + \gamma^2\pi^2\Delta\text{var}(v_{it+2}) + \mathcal{O}(E_t\|\nu_{it+1}\|^3) \quad (1.23)$$

$$\Delta\text{var}(\ln y_{it}) = \text{var}(v_{it}) + \Delta\text{var}(u_{it}) \quad (1.24)$$

$$\Delta\text{cov}(X_{it+2}, \ln y_{it+1}) = \left[-\gamma + \frac{\sigma}{\sigma-1}(\gamma-1-r) - \gamma^2 + \gamma\right]\pi\text{var}(v_{it+1}) + \mathcal{O}(E_t\|\nu_{it+1}\|^3) \quad (1.25)$$

$$\mathbb{E}_{\mathbb{I}}\left[g_{it}\left(\sum_{j=-2}^{2} g_{it+j}\right)\right] = \text{var}(v_{it}) \quad (1.26)$$

These moment conditions are analogous to Equations (1.13)–(1.15) and (1.19). Up to a term which is $\mathcal{O}(E_t\|\nu_{it+1}\|^3)$, the growth of the intrinsic consumption variance responds to variances of unexpected permanent income shocks (Eq. (1.23))[12]. Although in reality we estimate the parameters all in one step, identification however can be considered as consisting of two steps: (i) decomposing variances of income shocks into permanent and transitory parts using (1.24) and (1.26); (ii) substituting the permanent income shock variances into (1.23) and (1.25) to back up the habit persistence coefficient γ and the coefficient of risk aversion σ. As 6 waves are required to identify one permanent income shock variance according to Equation (1.26), the variances of permanent income shocks are only identified starting from the fourth period till the last third period, i.e., $\text{var}(v_{i4})$,...,$\text{var}(v_{iT-2})$, and likewise for the change in variance of transitory income shocks.

Measurement errors

So far we have not discussed the possible measurement errors in consumption and income. In the case of multiplicative measurement errors (i.e., $\tilde{q}_t = q_t \varepsilon_t^q$, where q_t denotes the true value of consumption or income , $\tilde{q}_t$ for the observed value, and ε_t^q as measurement error on q_t), if we make the following assumption:

> **Assumption** *Measurement errors in consumption and income are stationary and independent of each other and other variables in the model, and also serially uncorrelated.*

then the estimation of the parameters in interest (γ, σ) is robust to the presence of measurement errors. We can see this point clearly from the first moment condition Eq. (1.23), as we take the growth in variances of intrinsic consumption which is a linear function of log consumption, as long as measurement errors in consumption are stationary and independent from all consumptions and other parameters, the variance of measurement error in consumption would disappear by taking the first difference. Estimation of permanent income shocks is also robust to the presence of measurement error in income. In the last moment condition Eq. (1.26), if we use the observed income data with measurement errors we can get LHS as:

$$
\begin{aligned}
&\mathbb{E}_{\mathbb{I}}\left[\Delta \ln \tilde{y}_{it} \cdot \left(\Delta \ln \tilde{y}_{it+2} + \Delta \ln \tilde{y}_{it+1} + \Delta \ln \tilde{y}_{it} + \Delta \ln \tilde{y}_{it-1} + \Delta \ln \tilde{y}_{it-2}\right)\right] \\
=&\mathbb{E}_{\mathbb{I}}\left[\left(\Delta \ln y_{it} + \Delta \varepsilon_{it}\right)\left(\ln y_{it+2} + \varepsilon_{it+2} - \ln y_{it-3} - \varepsilon_{it-3}\right)\right] \\
=&\mathbb{E}_{\mathbb{I}}\left[\left(\Delta \ln y_{it}\right)\left(\ln y_{it+2} - \ln y_{it-3}\right)\right]
\end{aligned}
$$

i.e., the result is the same as using the true value. Again, here we just use the assumption that measurement error is multiplicative and serially uncorrelated. It's also easy to see that this robustness maintains in the other two moment conditions as long as the above assumption holds. This feature of the model makes it superior to the Euler equation approach as estimating nonlinear Euler equation (especially in the habit model) using GMM yields inconsistent estimates in the presence of measurement error (Amemiya (1985)).

[12]Blundell et al. (2008a) shows by Monte-Carlo experiment approximation omitting $\mathcal{O}(E_t\|\nu_{it+1}\|^3)$ doesn't bias estimates.

Table 1.2: Estimated Habit Persistence (CRRA preference)

		Income			
	consumption	net labour earnings	net labour earnings + private transfer	net income	total net disposable income
habit persistence γ	nondurable	0.761 (0.395)	0.742 (0.338)	0.752 (0.377)	0.647 (0.398)
	non+semi	0.835 (0.328)	0.792 (0.306)	0.832 (0.233)	0.853 (0.290)
	all	0.708 (0.320)	0.497 (0.281)	0.656 (0.292)	0.801 (0.347)
coef risk aversion σ	nondurable	0.696 (0.417)	0.665 (0.381)	0.683 (0.395)	0.541 (0.408)
	non+semi	0.812 (0.415)	0.743 (0.419)	0.801 (0.404)	0.836 (0.424)
	all	0.656 (0.380)	0.349 (0.357)	0.561 (0.385)	0.770 (0.420)
income transmission ω^2	nondurable	1.40E-003	3.67E-004	9.60E-004	1.08E-003
	non+semi	2.10E-002	3.74E-003	1.03E-002	3.03E-002
	all	1.28E-002	1.59E-003	2.28E-003	1.52E-002
Sample size			4649		

Note: Bootstrapped standard errors are in parentheses.

As consumption and income data are in log form, this model actually identifies growth in variances of *proportionate* transitory and permanent shocks, and habit persistence as the relative importance of consumption change to current consumption level in the current satisfaction of consumption. Again when $\gamma = 0$, the model collapses to the basic model (with c_{it} replaced by lnc_{it}). In this case, the coefficient of risk aversion σ is not identified as it would be cancelled out in log-linearization. The income transmission term $\omega^2 = \left[\frac{\sigma}{\sigma-1}(\gamma - 1 - r) - \gamma^2\right]^2$ contains information of both risk aversion (and hence precautionary saving) as well as habit persistence. If it is less than 1 in value, then the influence of current permanent income shocks on consumption is dulled by a combination of these effects.

All $(2T - 8)$ parameters $(\text{var}(v_4)...\text{var}(v_{T-2}),\Delta\text{var}(u_4)...\Delta\text{var}(u_{T-2}),\gamma,\sigma)$ are estimated jointly using DWMD with the inverse of the variance of the empirical moments as weights. π is set to be fixed at 0.85. The point estimate results of γ and σ are presented in Table 1.2. The habit persistence coefficient γ is around 0.75–0.85 for non-durable or semi-durable consumption, while it is generally lower for the broader consumption category. This is in line with our earlier empirical findings, and is consistent with the hypothesis that the durability of consumption goods counteracts the influence of habit persistence, resulting in a smaller estimated γ. As the income and consumption are in log forms, the habit persistence in this model shows the relative importance of the consumption growth ratio in utility function. Higher this coefficient, more important the consumption growth relative to the absolute size of consumption in current satisfaction, and therefore smoother consumption change. Although the estimated coefficients of risk aversion are smaller than the usual range used in the literature (around 1.5), they are not significantly different from 1, which is in line with some studies (Chetty (2006)). The size of the coefficient of risk aversion is in general smaller for consumption measures which include durable goods than those without, consistent with the finding that households display a high degree of risk aversion with respect to consumption of basic goods compared to luxury goods (AIT-SAHALIA et al. (2004)).

We can calculate the income transmission coefficient ω using the estimated values of γ and σ. The results are presented in the bottom panel in Table 1.2, and show that this coefficient is well below 1, or very close to 0 in value. This suggests that the combination of both habit persistence and precautionary saving leads to intrinsic consumption adjusting mainly to the growth in variance of permanent income shocks in the next period (with coefficient $\gamma^2 \simeq 0.6$ for nondurable consumption), which makes consumption adjustment a much smoother process. The identified income shocks are depicted in panel (b) in Figure 1.2. The variance of permanent income shocks display a slight increasing trend, while the variance of transitory shocks show a continual decline over the same period.

Table 1.3 presents the estimation results with a smaller sample by removing the seasonal workers and employers (mainly in the agricultural sector) from the original sample to mitigate the seasonal effect in income process. Both estimated coefficients of habit persistence and relative risk aversion are slightly bigger than the ones in Table 1.2, and the general patterns described above still maintain. Again, the estimated coefficients of relative risk aversion are smaller than, but not significantly different from 1. These results are improved version of the model estimates because of the following reasons: 1) the new sample is more homogeneous than the original one, and therefore households are more likely to face the same income shocks; 2) seasonal pattern is less likely to be present in the new sample data, especially the income data.

Table 1.3: Estimated Habit Persistence (CRRA preference w/o seasonal inc earners)

		Income			
	consumption	net labour earnings	net labour earnings + private transfer	net income	total net disposable income
habit persistence γ	nondurable	0.897 (0.396)	0.896 (0.373)	0.903 (0.407)	0.902 (0.452)
	non+semi	0.909 (0.308)	0.915 (0.260)	0.920 (0.245)	0.919 (0.200)
	all	0.861 (0.214)	0.861 (0.192)	0.882 (0.227)	0.885 (0.232)
coef risk aversion σ	nondurable	0.885 (0.447)	0.881 (0.447)	0.893 (0.444)	0.892 (0.444)
	non+semi	0.909 (0.432)	0.916 (0.433)	0.922 (0.422)	0.922 (0.427)
	all	0.847 (0.425)	0.844 (0.419)	0.871 (0.421)	0.875 (0.413)
income transmission ω^2	nondurable	4.88E-002	3.65E-002	6.06E-002	6.14E-002
	non+semi	1.46E-001	1.74E-001	2.14E-001	2.25E-001
	all	3.83E-002	3.09E-002	4.97E-002	5.58E-002
Sample size			3705		

Note: Bootstrapped standard errors are in parentheses.

1.4.3 Further into the past?

In the last section, habit stock is assumed being equal to last period's consumption, i.e. $\lambda = 1$. A natural question follows: what if habit has longer memory? After all, habit is not built in a day. It could be resourced back to early life, or even past generations. For this purpose, we extend the above model to the case with more two lags in habit stock equation[13].

[13]Theoretically, we could have extended analysis to more lags. While the empirical extension would be constrained by the data set available as long panel data would be required for long memory.

Habit stock evolves according to $h_{it} = (1-\lambda)h_{it-1} + \lambda c_{it-1}$, where $\lambda \in [0,1]$ describing the speed of habit catching up with consumption. As λ approaches to 1, recent consumptions become more important in habit stock. In the extreme case with $\lambda = 1$, only last period's consumption is enough to represent one's habit stock. While when $0 < \lambda < 1$, we can repeatedly iterate substitution and get the evolution of habit as:

$$h_{it} = (1-\lambda)^s h_{it-s} + \lambda \sum_{k=1}^{s} (1-\lambda)^{k-1} c_{it-k}$$

If $\lambda \to 1$, $(1-\lambda)^n \to 0$, for $n > 1$. Therefore we can truncate the higher orders and approximate the habit stock as:

$$h_{it} \simeq (1-\lambda)\lambda c_{it-2} + \lambda c_{it-1}$$

With two lags of consumption in habit stock, we log-linearize Euler equation (1.21) around steady state as follows (See Appendix 1.B for proof). Keep in mind that with assumption that interest rate equal to the discount rate, the steady state ratio $\frac{c_t^s}{h_t^s} = 1$ and $\frac{c_t^s}{c_{t-1}^s} = 1$ still hold.

$$E_t \left[-\sigma \Delta \ln c^*_{it+1} + (\gamma\sigma - \gamma)\Delta \ln h^*_{it+1} - \frac{\gamma}{1+\delta}\Delta \ln c_{it+2} + \frac{\gamma}{1+\delta}\Delta \ln h_{it+2} \right] = 0$$

where, $\ln c^*_{it} = \ln c_{it} - \frac{\gamma}{1+\delta}\ln c_{it+1}$, $\ln h^*_{it} = \ln h_{it} - \frac{\gamma}{1+\delta}\ln h_{it+1}$.

If we define $\Xi_{it+1} = -\sigma \ln c^*_{it+1} + (\gamma\sigma - \gamma)\ln h^*_{it+1} - \frac{\gamma}{1+\delta}\ln c_{it+2} + \frac{\gamma}{1+\delta}\ln h_{it+2}$, Euler equation can be written as the following martingale form:

$$E_t \Xi_{it+1} = E_t \Xi_{it}$$

Remove expectation, we can again write the consumption composite growth as the function of consumption innovations:

$$\begin{aligned}
\Delta \Xi_{it+1} &= -\sigma(\epsilon_{it+1} - \frac{\gamma}{1+\delta}\xi_{it+2} + \frac{\gamma}{1+\delta}\epsilon_{it+1}) - (\gamma\sigma - \gamma)\frac{\gamma}{1+\delta}\epsilon_{it+1} \\
&\quad - \frac{\gamma}{1+\delta}(\xi_{it+2} - \epsilon_{it+1}) + \frac{\gamma}{1+\delta}\epsilon_{it+1} \\
&= (-\sigma - \frac{\sigma\gamma}{1+\delta} - \frac{\gamma^2(\sigma-1)}{1+\delta} + \frac{2\gamma}{1+\delta})\epsilon_{it+1} + (\gamma\frac{\sigma-1}{1+\delta})\xi_{it+2}
\end{aligned}$$

Call $A = -\sigma - \frac{\sigma\gamma}{1+\delta} - \frac{\gamma^2(\sigma-1)}{1+\delta} + \frac{2\gamma}{1+\delta}$, $B = \gamma\frac{\sigma-1}{1+\delta}$, the above function can be simplified as:

$$\begin{aligned}\Delta\Xi_{it+1} &= A\epsilon_{it+1} + B\xi_{it+2} \\ &= A\pi_{it+1}v_{it+1} + B\pi_{it+2}(v_{it+2} + v_{it+1})\end{aligned}$$

Substitute the consumption innovation with income innovations, we can again relate consumption change with income innovations, and therefore form the moment conditions as follows:

$$\begin{aligned}\Delta\text{var}(\Xi_{it+1}) &= (A+2B)^2\pi^2\text{var}(v_{it+1}) + B^2\pi^2\Delta\text{var}(v_{it+2}) \\ \Delta\text{var}(\ln y_{it}) &= \text{var}(v_{it}) + \Delta\text{var}(u_{it}) \\ \Delta\text{cov}(\Xi_{it+2}, \ln y_{it+1}) &= (A+2B)\pi\text{var}(v_{it+1}) \\ \Delta\text{cov}(\Xi_{it+2}, \ln y_{it+2}) &= (A+2B)\pi\text{var}(v_{it+2}) \\ \mathbb{E}_{\mathbb{I}}\left[g_{it}\left(\sum_{j=-2}^{2} g_{it+j}\right)\right] &= \text{var}(v_{it})\end{aligned}$$

As the moment conditions involve $\{C_{it-2}, C_{it-1}, C_{it}, C_{it+1}, C_{it+2}, C_{it+3}\}$ for each $3 \leq t \leq T-3$, 6 waves panel is again necessary and sufficient to identify $2T-7$ parameters, including all the income shocks as well as γ, σ and λ.

This model is brought to nondurable goods consumption and all income categories. The results are shown as follows:

Table 1.4: Estimated Parameters for Habits with Longer Memories

	Income			
	net labour earnings	net labour earnings + private transfer	net income	total net disposable income
habit persistence γ	0.841 (0.098)	0.831 (0.106)	0.836 (0.099)	0.807 (0.126)
coef risk aversion σ	0.792 (0.072)	0.780 (0.073)	0.786 (0.078)	0.757 (0.073)
habit evolution rate λ	0.923 (0.053)	0.928 (0.055)	0.940 (0.056)	0.930 (0.055)
Sample size	4649			

Note: Consumption variable is nondurable goods consumption. Bootstrapped standard errors are in parentheses.

1.5 Simulation

In order to give a more intuitive demonstration of the effect of habit persistence on consumption, I have done two types of simulations. The first one examines the life cycle evolution of consumption inequality, and the second one shows whether the prediction from our model can replicate the original data set. As variances of income shocks can be identified using income information alone, we generate a series of normal distributed idiosyncratic permanent

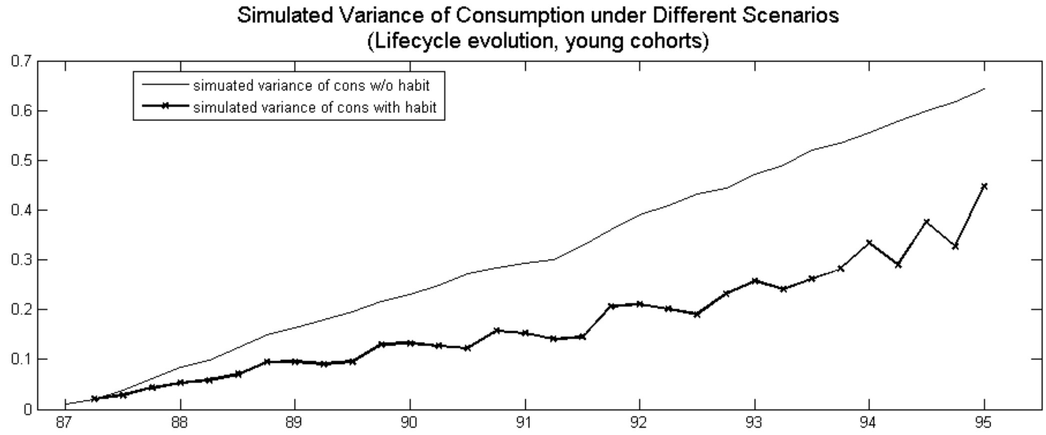


Figure 1.3: Simulated Variance of Consumption I

income shocks using the multi-year average of the identified variance of income shock and the assumption of mean zero of the shocks. For the first simulation, we focus on young cohorts as it is generally believed that consumption inequality increases over life time (Deaton and Paxson (1994)) and therefore by conditioning on cohorts we can exclude cohort effects from the age effect. We assume all the households start with a mean nondurable consumption (i.e. variance is zero) in the initial period(s)[14], and simulate their consumption series in the future periods given the randomly assigned idiosyncratic permanent income shocks, under two scenarios: without habit and with habit identified in the previous section. We then plot the variances of consumption series in Figure 1.3. As permanent income shocks have strong persistence, it is not surprising to find that inequality in consumption increases over time given a series of persistent shocks. Moreover, although the variances of consumption increase under both scenarios, the one with habit persistence increases however much more slowly than the one without habit persistence. More specifically, given the income shocks identified from our model, the variance of nondurable consumption increases from 0 to 0.65 during the period 1987-1995, by on average 0.08 each year, or 0.02 each quarter, which is exactly the variance of quarterly permanent shock. As in CRRA model this variance is in proportional term, in other words, the variance of consumption would be increasing by 8% every year in the absence of habit persistence. However, this level is nearly halved by the presence of consumption habit, i.e. by increasing around 5% each year. That is to say, consumption habit can help smooth consumption even further compared to the one predicted by permanent income hypothesis in response to persistence income shocks, which confirms our argument that habit is an insurance mechanism for consumers to smooth their consumption.

The second simulation shows whether our model can replicate the original data trend. We again focus on youngest cohort. Since the data set is an unbalanced panel data, we use the actual data as initial values and only predict the future value under each scenario if there has

[14]For non-habit case, only one initial period is necessary to generate future consumption series by random walk; while multi-periods are required in the habit model.

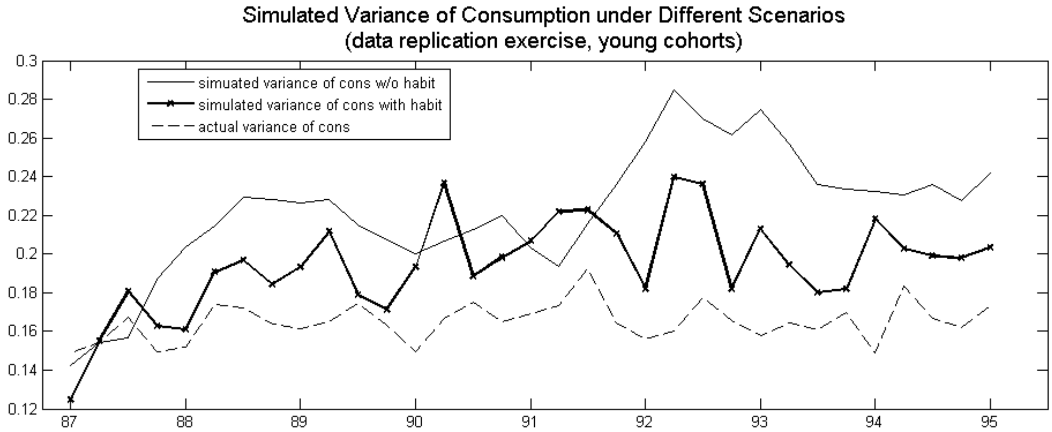


Figure 1.4: Simulated Variance of Consumption II

been an observation in the corresponding period for the household. The permanent shocks are generated according to the actual variances identified from the previous section (instead of the multi-year average as in the first simulation). We then calculate the variances of consumption for each period and plot them along with the variance of consumption from the real data in Figure 1.4. It is not difficult to see that the predicted trend by the habit model match the real data more closely, with variance of consumption lower than the result predicted by the model without habit, which leads to less volatile consumption.

In summary, the above two simulations show that habit model in general predict the data much better than its intertemporal separable alternative, and reconciles the "excess smoothness" puzzle of consumption.

1.6 Conclusion

This paper has provided a new way to estimate the habit persistence coefficient in a life-cycle consumption model. This is achieved by examining the evolution of cross-sectional variances and covariances of consumption and income, so that we can back up the scale of habit persistence coefficient. The identification strategy comes from the fact that with habit formation, consumers not only smooth consumption, but also the rate of consumption change, and therefore it can introduce sluggish response of consumption to unexpected income shocks, especially the permanent ones. This information is correspondingly reflected in variances of consumption and income. Using an extensive Spanish household panel data set, we find evidence to support the existence of habits in consumption, with our results both economically and statistically significant. In our baseline model with quadratic utility and additive habits we obtain habit coefficients in the range 0.4–0.5, while in our extended model with CRRA utility with multiplicative habits we obtain consumption habit coefficient is about 0.75-0.85, although the scale of coefficients are not comparable across specifications. The scale of habit persistence coefficient in CRRA framework fits the size which can explain most of empirical puzzles (Deaton (1988); Carroll et al. (2000); Constantinides (1990)). We also estimate the coefficient of relative risk aversion (RRA) in the second model, as about 0.8-0.9, and not significantly different from 1. We show in simulation exercises that habit model can reconcile the "excess smoothness" of consumption.

By combining two important strands of literature, this paper has shown how habit persistence can be identified by exploring the co-evolution of income and consumption. In doing so it avoids estimating (log) linearized approximate Euler equation whose validity hinges upon the ability to find suitable instruments (mainly lagged variables) which has enough variation and does not correlate to the approximation error. Within our framework, the presence of habits means that the consumption which contributes to the current utility is, to some extent, insulated from permanent income shocks. Therefore, while income information alone can be used to identify income shocks, its combination with consumption data can provide a way to identify habit persistence as well as other parameters. As predicted by theory, our results also suggest that consumers have stronger habit persistence when considering non-durable goods rather than durable goods.

Our analysis is not without its limitations. First, quarterly income data displays different patterns of auto-covariation from annual data due to seasonal correlation. This may invalidate the assumption of an MA(1) structure of transitory shocks and therefore the identification of permanent income shocks. This is however, a data rather than a conceptual challenge. Annual panel data (at least 6 years panel for income and 3 years panel for consumption), or quarterly consumption excluding seasonal goods in this sense would be more desirable. Second, in the current paper we assume the whole population face the same uncertainty. However, estimation distinguishing cohorts and education group should be implemented given a larger data set. Different cohorts and education groups are supposed to face income shocks at different level and persistence. Thirdly, credit constraints are not considered in the current model while they may also have the effect of delaying consumption to later periods. Meghir and Weber (1996) disaggreate intertemporal nonseparability from borrowing constraints by comparing the intertemporal substitution of consumer goods with the intratemporal one, as the latter should be immune to the borrowing constraints but still affected by intertemporal nonseparability. Although Carrasco et al. (2005) apply this method to ECPF data and do find the existence of habit persistence with consideration of borrowing constraints, this paper however can't disentangle two effects and therefore the quantitative scale of the habit persistence coefficient.

Nonetheless, our results have important implications for both public and macro economic policy. In particular, understanding the quantitative importance of habits can help researchers better understand how households smooth consumption in different economic environments, and how they respond to redistributive policies. More broadly, the results also shed important insight into how fast growing countries accumulate saving and design the optimal fiscal policy.

Chapter 1 Appendix

1.A Statistics

In Figure 1.5 we show the distribution of regression residuals of consumption and income using data from 1985Q1, 1990Q1 and 1995Q1. In Table 1.5 we show the composition of our sample; summary statistics are presented in Table 1.6. Finally, in Table 1.7 we show the autocovariance matrix of total net disposable income growth. The reader should refer to the main text for further details and discussion of these.

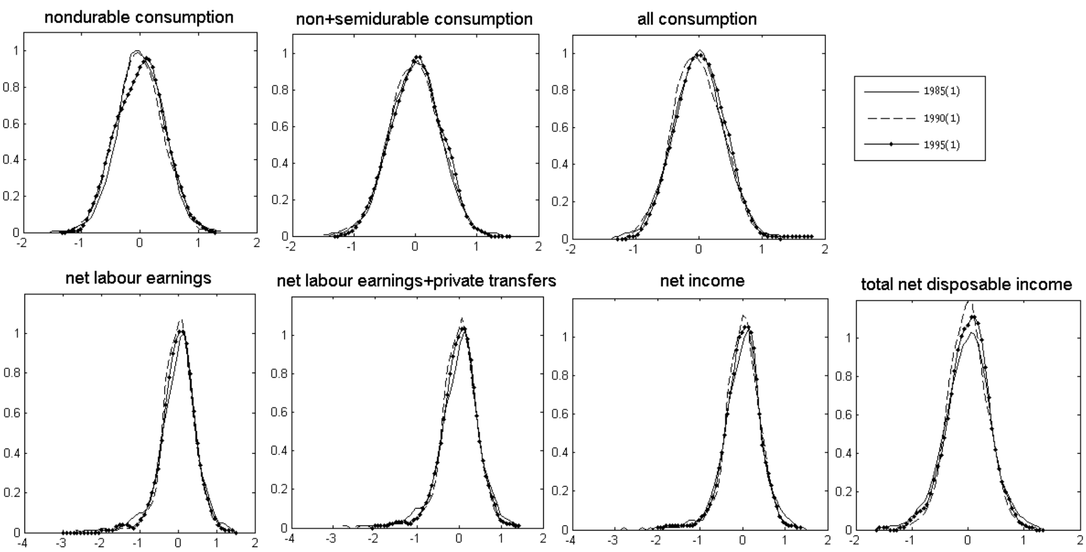


Figure 1.5: Residuals of (log) Consumption and Income.

Table 1.5: Sample Definition

year	quarter	Born ¡1935	1935-44	1945-54	1955-1964	1965-1970
1985	1	303	338	303	90	**1**
1985	2	330	363	325	97	**1**
1985	3	341	372	340	101	**1**
1985	4	334	376	343	105	**1**
1986	1	310	348	311	117	**1**
1986	2	267	324	297	104	**0**
1986	3	256	318	297	116	**2**
1986	4	269	315	314	136	**2**
1987	1	261	333	336	138	**3**
1987	2	274	339	332	147	**3**
1987	3	280	349	333	158	**4**
1987	4	265	343	330	180	**4**
1988	1	237	340	321	188	**4**
1988	2	229	332	313	184	**2**
1988	3	221	347	312	183	**3**
1988	4	228	339	317	176	**3**
1989	1	221	343	337	187	**4**
1989	2	201	345	354	194	**4**
1989	3	185	342	340	203	**5**
1989	4	189	358	352	207	**7**
1990	1	178	353	375	204	**6**
1990	2	178	345	361	205	**8**
1990	3	171	340	350	228	**8**
1990	4	163	357	341	227	**9**
1991	1	142	361	337	242	**9**
1991	2	153	360	337	243	**11**
1991	3	140	354	352	250	**13**
1991	4	134	358	345	264	**12**
1992	1	121	332	330	264	**19**
1992	2	109	338	350	265	**21**
1992	3	102	324	344	270	**24**
1992	4	264	317	369	268	**27**
1993	1	272	299	372	265	**29**
1993	2	259	287	370	264	**28**
1993	3	245	288	356	264	**31**
1993	4	240	282	363	295	**35**
1994	1	**230**	311	354	303	**32**
1994	2	**227**	304	352	320	**39**
1994	3	**223**	310	350	325	**37**
1994	4	**211**	305	352	337	**46**
1995	1	**209**	301	364	327	**50**
1995	2	**208**	301	345	343	**50**
1995	3	**194**	292	340	334	**54**
1995	4	**189**	295	347	332	**51**

Note: Figures in bold are not included in the constructed sample. See the discussion in Section 3.1.

Table 1.6: ECPF Data: Summary Statistics

year	quarter	nondurable consumption **(C1)**	non+semidurable consumption **(C2)**	total consumption **(C3)**	net labour earnings **(Y1)**	net labour earnings + private transfer **(Y2)**	net income **(Y3)**	total net disposable income **(Y4)**	sample size
1985	1	1320.99	1809.63	2357.23	1594.39	1609.73	1718.46	1875.65	1158
		(579.132)	(847.323)	(1088.050)	(928.094)	(942.043)	(944.202)	(963.160)	
1985	2	1318.79	1834.78	2396.53	1426.92	1440.41	1548.26	1704.97	1254
		(618.920)	(899.545)	(1165.731)	(821.473)	(829.881)	(837.588)	(843.149)	
1985	3	1347.25	1848.12	2461.33	1604.68	1613.96	1726.82	1904.93	1295
		(637.729)	(894.692)	(1190.585)	(939.637)	(945.378)	(946.166)	(960.058)	
1985	4	1379.61	1954.73	2610.51	1584.84	1593.61	1708.61	1866.41	1306
		(690.741)	(1025.871)	(1341.694)	(896.879)	(895.365)	(903.448)	(922.470)	
1986	1	1369.59	1950.84	2514.75	1777.39	1786.41	1914.55	2098.29	1218
		(624.827)	(976.524)	(1233.149)	(1014.591)	(1017.604)	(1041.173)	(1059.751)	
1986	2	1393.34	1981.61	2536.48	1585.36	1596.36	1722.92	1890.07	1112
		(648.617)	(993.117)	(1240.274)	(894.089)	(897.073)	(914.135)	(913.723)	
1986	3	1490.82	2060.17	2745.83	1805.42	1810.51	1954.41	2126.28	1108
		(740.642)	(1071.997)	(1502.027)	(976.649)	(976.064)	(1005.951)	(1023.837)	
1986	4	1516.55	2158.4	2843.53	1745.49	1752.46	1900.29	2082.52	1175
		(812.741)	(1132.277)	(1455.733)	(950.768)	(948.554)	(976.773)	(975.864)	
1987	1	1465.1	2126.01	2772.79	1927.97	1939.75	2091.7	2307.08	1232
		(706.627)	(1071.125)	(1394.999)	(1101.011)	(1103.550)	(1134.200)	(1115.424)	
1987	2	1498.32	2124.6	2784.2	1768.05	1779.79	1919.5	2099.17	1268
		(751.429)	(1110.633)	(1430.329)	(976.641)	(978.918)	(1006.587)	(993.953)	
1987	3	1488.4	2100.48	2820.75	1941.48	1952.76	2098	2307.07	1304
		(711.550)	(1058.589)	(1530.836)	(1127.575)	(1122.798)	(1133.119)	(1134.125)	
1987	4	1551.19	2243.28	3038.25	1908.68	1924.03	2067.23	2276.56	1305
		(827.701)	(1200.032)	(1635.361)	(1065.964)	(1073.872)	(1095.317)	(1080.893)	
1988	1	1461.35	2150.51	2808.58	2118.92	2129.1	2271.3	2505.69	1272
		(677.264)	(1065.570)	(1389.228)	(1226.073)	(1224.764)	(1237.256)	(1228.666)	
1988	2	1510.8	2183.48	2884.18	1928.81	1943.75	2079.95	2304.25	1250
		(715.424)	(1111.523)	(1477.988)	(1075.293)	(1083.274)	(1089.498)	(1068.645)	
1988	3	1594.67	2272.12	3071.09	2125.39	2143.82	2295.08	2529.5	1251
		(805.768)	(1175.247)	(1591.611)	(1223.643)	(1228.007)	(1228.051)	(1200.874)	
1988	4	1633.76	2399.92	3276.09	2120.48	2136.13	2297.32	2532.6	1257
		(821.421)	(1289.946)	(1722.825)	(1203.451)	(1206.061)	(1226.648)	(1217.128)	

Table 1.6: ECPF Data: Summary Statistics (continued)

year	quarter	nondurable consumption **(C1)**	non+semidurable consumption **(C2)**	total consumption **(C3)**	net labour earnings **(Y1)**	net labour earnings + private transfer **(Y2)**	net income **(Y3)**	total net disposable income **(Y4)**	sample size
1989	1	1674.4	2467.63	3305.07	2368.16	2381.05	2553.01	2842.89	1291
		(838.033)	(1303.184)	(1727.533)	(1416.631)	(1416.956)	(1415.753)	(1385.849)	
1989	2	1689.72	2438.93	3297.87	2174.58	2184.72	2349.91	2594.89	1291
		(827.150)	(1253.950)	(1748.116)	(1246.669)	(1249.581)	(1272.099)	(1239.681)	
1989	3	1761.92	2547.64	3433.08	2416.65	2428.73	2608.52	2874.91	1258
		(885.882)	(1301.634)	(1701.433)	(1387.908)	(1390.056)	(1411.637)	(1395.595)	
1989	4	1818.92	2730.46	3820.28	2388.34	2408.17	2584.43	2847.48	1302
		(937.461)	(1501.936)	(2130.427)	(1340.862)	(1350.082)	(1365.434)	(1339.079)	
1990	1	1812.24	2707.56	3653.01	2686.23	2705.31	2899.21	3218.48	1306
		(866.798)	(1340.651)	(1805.938)	(1556.923)	(1560.867)	(1578.985)	(1581.389)	
1990	2	1834.1	2668.2	3646.92	2427.82	2447.14	2638.89	2922.69	1279
		(844.161)	(1332.315)	(1790.719)	(1353.000)	(1354.015)	(1382.933)	(1348.162)	
1990	3	1916.41	2814.23	3867.47	2594.44	2606.77	2805.24	3168.14	1295
		(1036.993)	(1550.455)	(2126.157)	(1544.739)	(1544.347)	(1564.841)	(1549.346)	
1990	4	1992.3	2931.91	4065.75	2520.06	2537.3	2734.42	3068.33	1287
		(1048.225)	(1535.371)	(2056.914)	(1434.624)	(1434.546)	(1462.484)	(1439.447)	
1991	1	1954.37	2935.55	4023.86	2844.18	2868.72	3075.2	3447.84	1273
		(975.072)	(1491.759)	(2044.595)	(1635.652)	(1643.580)	(1664.795)	(1648.015)	
1991	2	1958.82	2857.13	3991.11	2580.38	2602.95	2813.98	3134.07	1281
		(987.936)	(1455.971)	(2046.992)	(1443.764)	(1459.538)	(1498.125)	(1486.466)	
1991	3	2019.01	2943.32	4229.01	2875.87	2896.21	3107.92	3468.62	1289
		(1058.247)	(1569.987)	(2320.009)	(1640.034)	(1648.760)	(1666.327)	(1663.597)	
1991	4	2081.96	3098.8	4368.51	2728.14	2750.32	2965.65	3295.4	1295
		(1125.345)	(1643.530)	(2248.970)	(1473.339)	(1482.421)	(1513.527)	(1492.689)	
1992	1	2093.15	3149.02	4364.91	3098.43	3117.4	3324.27	3715.21	1259
		(997.780)	(1538.894)	(2205.812)	(1766.427)	(1775.723)	(1784.555)	(1765.037)	
1992	2	2120.62	3091.2	4318.72	2895.26	2913.7	3129.99	3474.67	1291
		(1073.158)	(1598.569)	(2185.200)	(1579.433)	(1579.015)	(1606.721)	(1586.087)	
1992	3	2132.22	3092.19	4443.44	3066.95	3087.31	3315.25	3714.46	1260
		(1038.815)	(1544.378)	(2225.012)	(1678.235)	(1683.071)	(1699.722)	(1692.071)	
1992	4	2226.73	3288.91	4746.97	2982.05	3004.29	3243.95	3646.72	1271
		(1181.963)	(1745.019)	(2419.797)	(1606.484)	(1611.998)	(1662.123)	(1627.570)	

Table 1.6: ECPF Data: Summary Statistics (continued)

year	quarter	nondurable consumption **(C1)**	non+semidurable consumption **(C2)**	total consumption **(C3)**	net labour earnings **(Y1)**	net labour earnings + private transfer **(Y2)**	net income **(Y3)**	total net disposable income **(Y4)**	sample size
1993	1	2199.73	3277.25	4641.59	3238.17	3272.55	3518.76	4004.93	1267
		(1089.344)	(1665.512)	(2321.466)	(1903.820)	(1918.559)	(1932.430)	(1904.915)	
1993	2	2199.92	3131.24	4448.36	2911.21	2938	3186.66	3636.71	1232
		(1063.095)	(1544.565)	(2140.136)	(1675.443)	(1677.418)	(1712.250)	(1678.836)	
1993	3	2257.52	3225.32	4719.99	3147.47	3195.99	3452.01	3914.05	1205
		(1186.025)	(1722.989)	(2463.118)	(1851.530)	(1882.414)	(1918.455)	(1886.294)	
1993	4	2244.53	3207.64	4667.56	2986.2	3002.49	3251.67	3689.51	1233
		(1113.501)	(1645.881)	(2227.750)	(1700.002)	(1695.369)	(1731.203)	(1703.828)	
1994	1	2327.73	3369.97	4724.4	3365.25	3392.41	3667.78	4156.63	1251
		(1138.526)	(1677.397)	(2233.649)	(2012.802)	(2001.703)	(2034.004)	(2009.605)	
1994	2	2284.98	3177.4	4577.45	2985.13	3012.34	3273.84	3716.81	1258
		(1098.063)	(1586.736)	(2241.830)	(1726.282)	(1737.002)	(1776.764)	(1721.684)	
1994	3	2345.58	3287.55	4735.78	3196.99	3228.19	3497.74	3986.37	1268
		(1186.643)	(1671.898)	(2308.432)	(1862.473)	(1863.768)	(1892.104)	(1860.583)	
1994	4	2289.96	3255.5	4800.72	3099.66	3120.21	3381.23	3831.9	1275
		(1155.471)	(1685.155)	(2401.195)	(1783.736)	(1786.494)	(1849.819)	(1797.378)	
1995	1	2375.77	3409.29	4845.4	3504.12	3530.71	3787.01	4320.26	1277
		(1178.026)	(1697.196)	(2288.778)	(2069.848)	(2068.632)	(2103.438)	(2057.182)	
1995	2	2358.17	3273.13	4639.14	3153.18	3173.17	3436.83	3900.81	1274
		(1163.001)	(1636.623)	(2218.555)	(1813.545)	(1802.403)	(1861.624)	(1786.658)	
1995	3	2363.48	3360.1	4824.02	3438.23	3459.84	3728.57	4233.79	1241
		(1131.388)	(1665.030)	(2272.167)	(1964.000)	(1956.943)	(1976.884)	(1923.829)	
1995	4	2453.21	3449.88	5074.45	3327.95	3356.06	3607.31	4060.61	1239
		(1205.719)	(1796.566)	(2557.670)	(1869.011)	(1863.289)	(1888.808)	(1850.307)	

Table 1.7: The Autocovariance Matrix of Total net Disposable Income Growth

year	quarter	$var(\triangle y_t)$	$cov(\triangle y_t,\triangle y_{t-1})$	$cov(\triangle y_t,\triangle y_{t-2})$	$cov(\triangle y_t,\triangle y_{t-3})$
1985	1				
1985	2	0.093 (0.007)			
1985	3	0.082 (0.007)	-0.029 (0.004)		
1985	4	0.076 (0.005)	-0.033 (0.004)	0.004 (0.003)	
1986	1	0.102 (0.008)	-0.039 (0.005)	0.011 (0.004)	-0.015 (0.006)
1986	2	0.065 (0.006)	-0.039 (0.007)	0.007 (0.004)	-0.003 (0.004)
1986	3	0.070 (0.009)	-0.026 (0.004)	0.008 (0.005)	-0.016 (0.006)
1986	4	0.079 (0.008)	-0.031 (0.004)	-0.001 (0.005)	n.a
1987	1	0.065 (0.004)	-0.039 (0.006)	0.006 (0.004)	0.001 (0.010)
1987	2	0.065 (0.006)	-0.024 (0.003)	0.006 (0.004)	-0.010 (0.004)
1987	3	0.071 (0.007)	-0.024 (0.004)	0.006 (0.003)	-0.013 (0.006)
1987	4	0.080 (0.006)	-0.039 (0.005)	0.006 (0.004)	-0.014 (0.004)
1988	1	0.080 (0.007)	-0.037 (0.006)	0.007 (0.004)	-0.008 (0.004)
1988	2	0.069 (0.007)	-0.033 (0.005)	0.011 (0.005)	-0.008 (0.006)
1988	3	0.085 (0.008)	-0.023 (0.004)	0.003 (0.003)	-0.023 (0.004)
1988	4	0.077 (0.006)	-0.046 (0.006)	0.009 (0.004)	-0.010 (0.005)
1989	1	0.066 (0.005)	-0.026 (0.004)	0.006 (0.005)	-0.014 (0.003)
1989	2	0.060 (0.005)	-0.033 (0.004)	0.008 (0.005)	-0.008 (0.006)
1989	3	0.069 (0.006)	-0.023 (0.003)	0.010 (0.003)	-0.029 (0.005)
1989	4	0.075 (0.006)	-0.038 (0.004)	0.003 (0.003)	-0.008 (0.003)
1990	1	0.062 (0.005)	-0.031 (0.003)	0.008 (0.003)	-0.008 (0.004)
1990	2	0.053 (0.003)	-0.024 (0.003)	0.011 (0.003)	-0.011 (0.003)
1990	3	0.071 (0.006)	-0.029 (0.003)	0.008 (0.004)	-0.015 (0.004)
1990	4	0.072 (0.007)	-0.044 (0.007)	0.016 (0.003)	-0.015 (0.005)

Table 1.7: The Autocovariance Matrix of Total net Disposable Income Growth(continued)

year	quarter	$var(\triangle y_t)$	$cov(\triangle y_t, \triangle y_{t-1})$	$cov(\triangle y_t, \triangle y_{t-2})$	$cov(\triangle y_t, \triangle y_{t-3})$
1991	1	0.062 (0.005)	-0.034 (0.005)	0.009 (0.003)	-0.015 (0.003)
1991	2	0.055 (0.004)	-0.026 (0.003)	0.008 (0.003)	-0.012 (0.003)
1991	3	0.060 (0.004)	-0.030 (0.004)	0.004 (0.003)	-0.014 (0.003)
1991	4	0.074 (0.006)	-0.030 (0.003)	0.007 (0.003)	-0.011 (0.003)
1992	1	0.073 (0.006)	-0.040 (0.005)	0.010 (0.002)	-0.011 (0.003)
1992	2	0.066 (0.006)	-0.033 (0.004)	0.016 (0.004)	-0.005 (0.005)
1992	3	0.065 (0.005)	-0.033 (0.004)	0.017 (0.004)	-0.023 (0.005)
1992	4	0.070 (0.006)	-0.034 (0.004)	0.015 (0.003)	-0.020 (0.006)
1993	1	0.069 (0.006)	-0.034 (0.004)	0.014 (0.003)	-0.018 (0.004)
1993	2	0.081 (0.008)	-0.039 (0.005)	0.012 (0.003)	-0.021 (0.004)
1993	3	0.082 (0.008)	-0.041 (0.005)	0.014 (0.004)	-0.013 (0.004)
1993	4	0.089 (0.008)	-0.047 (0.007)	0.015 (0.005)	-0.013 (0.004)
1994	1	0.063 (0.004)	-0.039 (0.004)	0.009 (0.004)	-0.013 (0.006)
1994	2	0.070 (0.006)	-0.037 (0.005)	0.023 (0.005)	-0.018 (0.005)
1994	3	0.073 (0.005)	-0.032 (0.003)	0.013 (0.003)	-0.028 (0.006)
1994	4	0.071 (0.006)	-0.038 (0.004)	0.008 (0.003)	-0.010 (0.004)
1995	1	0.081 (0.006)	-0.035 (0.004)	0.010 (0.004)	-0.012 (0.004)
1995	2	0.069 (0.005)	-0.041 (0.004)	0.015 (0.004)	-0.017 (0.005)
1995	3	0.071 (0.006)	-0.031 (0.004)	0.009 (0.003)	-0.019 (0.007)
1995	4	0.078 (0.005)	-0.040 (0.004)	0.013 (0.003)	-0.017 (0.004)

1.B Proof of model

Proof of equation (1.11) in quadratic utility model

The LHS of equation 1.10 after taking variance:

$$\begin{aligned}
& \text{var}(Q_t - Q_{t-1}) \\
= \; & \text{var}(Q_t) + \text{var}(Q_{t-1}) - 2\text{cov}(Q_{t-1}, Q_t) \\
= \; & \text{var}(Q_t) + \text{var}(Q_{t-1}) - 2\text{cov}\left(Q_{t-1} + \frac{(1-\gamma)(1+r-\gamma)}{\rho_t}\eta_{it} + \xi_{t+1} - \xi_t, Q_{t-1}\right) \\
= \; & \Delta\text{var}(Q_t) - 2\text{cov}\left(\frac{(1-\gamma)(1+r-\gamma)}{\rho_t}\eta_{it} + \xi_{t+1} - \xi_t, c^*_{t-1} - \frac{\gamma}{1+r}c^*_t\right) \\
= \; & \Delta\text{var}(Q_t) - 2\text{cov}\left(\frac{(1-\gamma)(1+r-\gamma)}{\rho_t}\eta_{it} + \xi_{t+1} - \xi_t, -\frac{\gamma}{1+r}(c_t - \gamma c_{t-1})\right) \\
= \; & \Delta\text{var}(Q_t) - 2\text{cov}\left(\frac{(1-\gamma)(1+r-\gamma)}{\rho_t}\eta_{it} + \xi_{t+1} - \xi_t, -\frac{\gamma}{1+r}\mathbb{E}_{t-1}c_t + \xi_t\right) \\
= \; & \Delta\text{var}(Q_t) - 2\text{cov}\left(\frac{(1-\gamma)(1+r-\gamma)}{\rho_t}\eta_{it} + \xi_{t+1} - \xi_t, \xi_t\right) \\
= \; & \Delta\text{var}(Q_t) - 2\text{cov}\left((1-\gamma)(1+r-\gamma)\left(v_{it} + \frac{r}{(1+r)\rho_t}u_{it}\right), \xi_t\right) + 2\text{var}(\xi_t)
\end{aligned}$$

Where the second equation is achieved by applying equation (1.10). While on the RHS, we have

$$\begin{aligned}
& \text{var}\left((1-\gamma)(1+r-\gamma)\frac{\eta_{it}}{\rho_t} + \xi_{it+1} - \xi_{it}\right) \\
= & \text{var}\left((1-\gamma)(1+r-\gamma)\frac{\eta_{it}}{\rho_t}\right) + var\left(\xi_{t+1} - \xi_t\right) \\
& + 2\text{cov}\left((1-\gamma)(1+r-\gamma)\frac{\eta_{it}}{\rho_t}, \xi_{t+1} - \xi_t\right) \\
= & (1-\gamma)^2(1+r-\gamma)^2\left(\text{var}(v_{it}) + \frac{r^2}{(1+r)^2\rho_t^2}\text{var}(u_{it})\right) \\
& + \text{var}(\xi_{t+1}) + \text{var}(\xi_t) \\
& - 2\text{cov}\left((1-\gamma)(1+r-\gamma)(v_{it} + \frac{r}{(1+r)\rho_t}u_{it}), \xi_t\right)
\end{aligned}$$

For small enough r and sufficently long T, the equation may be simplified as follows:

$$\begin{aligned}
\Delta\text{var}(Q_t) \; = \; & (1-\gamma)^2(1+r-\gamma)^2\left(\text{var}(v_{it}) + \frac{r^2}{(1+r)^2\rho_t^2}\text{var}(u_{it})\right) + \text{var}(\xi_{t+1}) \\
& + \text{var}(\xi_t) - 2\text{var}(\xi_t) \\
= \; & (1-\gamma)^2(1+r-\gamma)^2\left(\text{var}(v_{it}) + \frac{r^2}{(1+r)^2\rho_t^2}\text{var}(u_{it})\right) + \Delta\text{var}(\xi_{t+1}) \\
\simeq \; & (1-\gamma)^2(1+r-\gamma)^2\text{var}(v_{it}) + \Delta\text{var}(\xi_{t+1})
\end{aligned}$$

Proof of equation (1.15) in quadratic utility model

$$\begin{aligned}
\Delta\text{cov}(Q_t, y_t) &= \text{cov}(Q_t, y_t) - \text{cov}(Q_{t-1}, y_{t-1}) \\
&= \text{cov}(Q_{t-1} + \Delta Q_t, y_{t-1} + \Delta y_t) - \text{cov}(Q_{t-1}, y_{t-1}) \\
&= \text{cov}(\Delta Q_t, \Delta y_t) + \text{cov}(Q_{t-1}, \Delta y_t) \\
&= \text{cov}(\Delta Q_t, \Delta y_t) + \text{cov}(Q_{t-2} + \Delta Q_{t-1}, \Delta y_t) \\
&= \text{cov}(\Delta Q_t + \Delta Q_{t-1}, \Delta y_t) + \text{cov}(Q_{t-3} + \Delta Q_{t-2}, \Delta y_t) \\
&= \text{cov}(\Delta Q_t + \Delta Q_{t-1} + \Delta Q_{t-2}, \Delta y_t) + \text{cov}(Q_{t-3}, \Delta y_t)
\end{aligned}$$

where $\text{cov}(Q_{t-3}, \Delta y_t) = 0$ if the transitory shock u_{it} is i.i.d. Since we also have:

$$\Delta Q_t = Rv_{it} + R\frac{r}{(1+r)\rho_t}u_{it} + \xi_{t+1} - \xi_t,$$

with $R = (1-\gamma)(1+r-\gamma)$, and $\Delta y_{it} = \Delta u_{it} + v_{it}$, the difference of the covariance then becomes:

$$\begin{aligned}
\Delta\text{cov}(Q_t, y_t) &= \text{cov}\left(Rv_{it} + R\frac{r}{(1+r)\rho_t}u_{it} + \xi_{t+1} - \xi_t\right. \\
&\quad +Rv_{it-1} + R\frac{r}{(1+r)\rho_{t-1}}u_{it-1} + \xi_t - \xi_{t-1} \\
&\quad \left. +Rv_{it-2} + R\frac{r}{(1+r)\rho_{t-2}}u_{it-2} + \xi_{t-1} - \xi_{t-2}, \Delta u_{it} + v_{it}\right) \\
&= R \cdot var(v_{it}) + R\frac{r}{1+r}\Delta\frac{1}{\rho_t}var(u_{it}) \\
&\approx R \cdot var(v_{it})
\end{aligned}$$

with the approximation holding for small r and large t.

If we assume instead assume an MA(1) structure for transitory shocks, then we can derive the following condition:

$$\begin{aligned}
\Delta\text{cov}(Q_{t+1}, y_t) &= \text{cov}(\Delta Q_{t+1} + \Delta Q_t + \Delta Q_{t-1} + \Delta Q_{t-2} + \Delta Q_{t-3}, \Delta y_t) + \text{cov}(Q_{t-4}, \Delta y_t) \\
&= \text{cov}(\Delta Q_{t+1} + \Delta Q_t + \Delta Q_{t-1} + \Delta Q_{t-2} + \Delta Q_{t-3}, \Delta y_t) \\
&= R \cdot \text{var}(v_{it}) + R\frac{r}{1+r}\text{var}(\epsilon)\left(\frac{\theta}{\rho_{t+1}} + \frac{\theta^2 - \theta + 1}{\rho_t} + \frac{\theta - 1 - \theta^2}{\rho_{t-1}} - \frac{\theta}{\rho_{t-2}}\right) \\
&\approx R \cdot \text{var}(v_{it})
\end{aligned}$$

where, we assume $u_{it} = \epsilon_t - \theta\epsilon_{t-1}$, and ϵ_t is i.i.d with mean 0 and constant $\text{var}(\epsilon)$

The same method applies for the last equation in model 3.

$$\begin{aligned}
\Delta \text{cov}(c_{t+1}^*, y_t) &= \text{cov}(c_{t+1}^*, y_t) - \text{cov}(c_t^*, y_{t-1}) \\
&= \text{cov}(c_t^* + (1-\frac{\gamma}{1+r})v_{t+1} + (1-\frac{\gamma}{1+r})\frac{r}{(1+r)\rho_{t+1}}u_{t+1}, y_{t-1} + \Delta u_t + v_t) \\
&- \text{cov}(c_t^*, y_{t-1}) \\
&= \text{cov}(c_t^*, \Delta u_t + v_t) + (1-\frac{\gamma}{1+r})\text{cov}(v_{t+1} + \frac{r}{(1+r)\rho_{t+1}}u_{t+1}, \Delta u_t + v_t) \\
&+ (1-\frac{\gamma}{1+r})\text{cov}(v_{t+1} + \frac{r}{(1+r)\rho_{t+1}}u_{t+1}, y_{t-1}) \\
&= cov\left(c_{t-3}^* + (1-\frac{\gamma}{1+r})v_{t-2} + (1-\frac{\gamma}{1+r})\frac{r}{(1+r)\rho_{t-2}}u_{t-2} + (1-\frac{\gamma}{1+r})v_{t-1}\right. \\
&+ \left.(1-\frac{\gamma}{1+r})\frac{r}{(1+r)\rho_{t-1}}u_{t-1} + (1-\frac{\gamma}{1+r})v_t + (1-\frac{\gamma}{1+r})\frac{r}{(1+r)\rho_t}u_t, \Delta u_t + v_t)\right) \\
&+ \frac{r}{(1+r)\rho_{t+1}}cov(u_{t+1}, \Delta u_t) \\
&= (1-\frac{\gamma}{1+r})var(v_t) \\
&+ (1-\frac{\gamma}{1+r})\frac{r}{(1+r)}cov(\frac{1}{\rho_{t-2}}u_{t-2} + \frac{1}{\rho_{t-1}}u_{t-1} + \frac{1}{\rho_t}u_t + \frac{1}{\rho_{t+1}}u_{t+1}, \Delta u_t)
\end{aligned}$$

Again, if we assume MA(1) structure for transitory shock, i.e. $u_{it} = \epsilon_t - \theta\epsilon_{t-1}$, and ϵ_t is i.i.d with mean 0 and constant var(ϵ), we can write the above equation into

$$\begin{aligned}
\Delta cov(c_{t+1}^*, y_t) &= (1-\frac{\gamma}{1+r})var(v_t) \\
&+ (1-\frac{\gamma}{1+r})\frac{r}{(1+r)}cov\left(\frac{1}{\rho_{t-2}}(\epsilon_{t-2} - \theta\epsilon_{t-3}) + \frac{1}{\rho_{t-1}}(\epsilon_{t-1} - \theta\epsilon_{t-2}) + \frac{1}{\rho_t}(\epsilon_t - \theta\epsilon_{t-1})\right. \\
&+ \left.\frac{1}{\rho_{t+1}}(\epsilon_{t+1} - \theta\epsilon_t), (\epsilon_t - \theta\epsilon_{t-1} - \epsilon_{t-1} + \theta\epsilon_{t-2})\right) \\
&= (1-\frac{\gamma}{1+r})var(v_t) \\
&+ (1-\frac{\gamma}{1+r})\frac{r}{1+r}var(\epsilon)\left[-\frac{\theta}{\rho_{t+1}} + \frac{\theta}{\rho_{t-2}} - \frac{1+\theta+\theta^2}{\rho_{t-1}} + \frac{\theta^2+\theta+1}{\rho_t}\right] \\
&\approx (1-\frac{\gamma}{1+r})var(v_t)
\end{aligned}$$

approximation holds for small r and big $T - t$.

Proof of linearization equation in CRRA model

This proof borrows heavily from Carroll (2000).

Linearize the Euler equation (1.21) around steady state ratio (c_0/h_0):

$$\mathbb{E}_t\left[\frac{c_{it}^{-\sigma}}{h_{it}^{-\gamma\sigma+\gamma}} - \frac{\gamma}{1+\delta}\frac{c_{it+1}^{-\sigma+1}}{h_{it+1}^{-\gamma\sigma+\gamma+1}}\right] = \frac{1+r}{1+\delta}\mathbb{E}_t\left[\frac{c_{it+1}^{-\sigma}}{h_{it+1}^{-\gamma\sigma+\gamma}} - \frac{\gamma}{1+\delta}\frac{c_{it+2}^{-\sigma+1}}{h_{it+2}^{-\gamma\sigma+\gamma+1}}\right]$$

Divide both sides of the Euler equation by the first ratio on LHS:

$$\mathbb{E}_t\left[1 - \frac{\gamma}{1+\delta}\frac{c_{it+1}^{-\sigma}}{c_{it}^{-\sigma}}\frac{h_{it}^{-\gamma\sigma+\gamma}}{h_{it+1}^{-\gamma\sigma+\gamma}}\frac{c_{it+1}}{h_{it+1}}\right] = \frac{1+r}{1+\delta}\mathbb{E}_t\left[\frac{c_{it+1}^{-\sigma}}{c_{it}^{-\sigma}}\frac{h_{it}^{-\gamma\sigma+\gamma}}{h_{it+1}^{-\gamma\sigma+\gamma}} - \frac{\gamma}{1+\delta}\frac{c_{it+2}^{-\sigma}}{c_{it+1}^{-\sigma}}\frac{c_{it+1}^{-\sigma}}{c_{it}^{-\sigma}}\frac{h_{it}^{-\gamma\sigma+\gamma}}{h_{it+2}^{-\gamma\sigma+\gamma}}\frac{c_{it+2}}{h_{it+2}}\right]$$

Define $\psi_t = c_t/c_{t-1}$, $\chi_t = c_t/h_t$, and remember $h_{it+1} = c_{it}$, the above equation can be written as:

$$\mathbb{E}_t\left[1-\frac{\gamma}{1+\delta}\psi_{it+1}^{-\sigma}\chi_{it}^{\gamma(\sigma-1)}\chi_{it+1}\right]=\frac{1+r}{1+\delta}\mathbb{E}_t\left[\psi_{it+1}^{-\sigma}\chi_{it}^{\gamma(\sigma-1)}-\frac{\gamma}{1+\delta}\psi_{it+2}^{-\sigma}\psi_{it+1}^{-\sigma}\chi_{it}^{\gamma(\sigma-1)}\chi_{it+1}^{\gamma(\sigma-1)}\chi_{it+2}\right]$$

Multiply both sides by $\psi_{it+1}^{\sigma}\chi_{it}^{\gamma(1-\sigma)}$

$$1=\mathbb{E}_t\left[\frac{1+\delta}{1+r}\left(\psi_{it+1}^{\sigma}\chi_{it}^{\gamma(1-\sigma)}-\frac{\gamma}{1+\delta}\chi_{it+1}\right)+\frac{\gamma}{1+\delta}\psi_{it+2}^{-\sigma}\chi_{it+1}^{\gamma(\sigma-1)}\chi_{it+2}\right]$$

Linearize the above equation around the steady state ratio $ln\psi_0$and $ln\chi_0$:

$$\begin{aligned}1 \quad = \quad & \mathbb{E}_t\Bigg[\frac{1+\delta}{1+r}\left(\psi_0^{\sigma}\chi_0^{\gamma(1-\sigma)}+\sigma\psi_0^{\sigma}\chi_0^{\gamma(1-\sigma)}(ln\psi_{it+1}-ln\psi_0)+\gamma(1-\sigma)\psi_0^{\sigma}\chi_0^{\gamma(1-\sigma)}(ln\chi_{it}-ln\chi_0)+\mathcal{O}(n)\right)\\ & -\frac{1+\delta}{1+r}\frac{\gamma}{1+\delta}\left(\chi_0+\chi_0(ln\chi_{it+1}-ln\chi_0)+\mathcal{O}(n)\right)+\frac{\gamma}{1+\delta}\psi_0^{-\sigma}\chi_0^{\gamma(\sigma-1)}\chi_0\\ & +\frac{\gamma}{1+\delta}\left(-\sigma\psi_0^{-\sigma}\chi_0^{\gamma(\sigma-1)}\chi_0(ln\psi_{it+2}-ln\psi_0)+\gamma(\sigma-1)\psi_0^{-\sigma}\chi_0^{\gamma(\sigma-1)}\chi_0(ln\chi_{it+1}-ln\chi_0)\right)\\ & +\frac{\gamma}{1+\delta}\psi_0^{-\sigma}\chi_0^{\gamma(\sigma-1)}\chi_0(ln\chi_{it+2}-ln\chi_0)+\mathcal{O}(n)\Bigg]\end{aligned}$$

Use the fact that $\chi_t=\psi_t$ as we assume $h_t=c_{t-1}$ for simplicity and assume $r\simeq\delta$,therefore $\psi_0\simeq 1$, we can simplify above linear equation into:

$$\begin{aligned}0 \quad = \quad & \mathbb{E}_t\Bigg[\sigma ln\psi_{it+1}+\gamma(1-\sigma)ln\chi_{it}-\frac{\gamma}{1+r}ln\chi_{it+1}-\frac{\gamma\sigma}{1+r}ln\psi_{it+2}\\ & +\frac{\gamma}{1+r}\left(\gamma(\sigma-1)ln\chi_{it+1}+ln\chi_{it+2}+\mathcal{O}(n)\right)\Bigg]\end{aligned}$$

$$\begin{aligned}0 \quad = \quad & \mathbb{E}_t\Bigg[\sigma ln\psi_{it+1}+\gamma(1-\sigma)ln\psi_{it}-\frac{\gamma}{1+r}ln\psi_{it+1}-\frac{\gamma\sigma}{1+r}ln\psi_{it+2}\\ & +\frac{\gamma}{1+r}\left(\gamma(\sigma-1)ln\psi_{it+1}+ln\psi_{it+2}+\mathcal{O}(n)\right)\Bigg]\end{aligned}$$

Substitute $ln\psi_t=\ln c_t-\ln c_{t-1}$ and rearrange,

$$\mathbb{E}_t\left[(\sigma-\frac{\gamma}{1+r})\Delta\ln c_{it+1}-\gamma(\sigma-1)\Delta\ln c_{it}-\frac{\gamma(\sigma-1)}{1+r}(\Delta\ln c_{it+2}-\gamma\Delta\ln c_{it+1})+\mathcal{O}(n)\right]=0$$

where, $\mathcal{O}(n)$ includes the second and higher order term of linearization approximation error, which is approching to zero as $(ln\psi_{it}-ln\psi_0)$approaches to zero.

Multiply both sides by $(1+r)$ and dividing by $(\sigma-1)$, it becomes:

$$\mathbb{E}_t\left[\left(\frac{\sigma}{\sigma-1}(1+r)-\frac{\gamma}{\sigma-1}\right)\Delta\ln c_{it+1}-\gamma(1+r)\Delta\ln c_{it}-\gamma\left(\Delta\ln c_{it+2}-\gamma\Delta\ln c_{it+1}\right)+\mathcal{O}(n)\right]=0$$

Remove expectation and define $\epsilon_{it+1} = \ln c_{it+1} - \mathbb{E}_t \ln c_{it+1}$ and $\xi_{it+2} = \ln c_{it+2} - \mathbb{E}_t \ln c_{it+2}$, we can get equation (1.22) after simple rearrangement.

Proof of linearization equation in CRRA model with two lags:

The Euler Equation with habit is:

$$\mathbb{E}_t\left[1-\frac{\gamma}{1+\delta}\frac{c_{it+1}^{-\sigma}}{c_{it}^{-\sigma}}\frac{h_{it}^{-\gamma\sigma+\gamma}}{h_{it+1}^{-\gamma\sigma+\gamma}}\frac{c_{it+1}}{h_{it+1}}\right]=\frac{1+r}{1+\delta}\mathbb{E}_t\left[\frac{c_{it+1}^{-\sigma}}{c_{it}^{-\sigma}}\frac{h_{it}^{-\gamma\sigma+\gamma}}{h_{it+1}^{-\gamma\sigma+\gamma}}-\frac{\gamma}{1+\delta}\frac{c_{it+2}^{-\sigma}}{c_{it+1}^{-\sigma}}\frac{c_{it+1}^{-\sigma}}{c_{it}^{-\sigma}}\frac{h_{it}^{-\gamma\sigma+\gamma}}{h_{it+2}^{-\gamma\sigma+\gamma}}\frac{c_{it+2}}{h_{it+2}}\right]$$

In order to linearize around the steady state ratio, we need to write it in terms of the rate of consumption over habit:

$$\begin{aligned}E_t\left[1-\frac{\gamma}{1+\delta}\frac{c_{it+1}^{-\sigma}}{c_{it}^{-\sigma}}\frac{h_{it}^{-\gamma\sigma+\gamma}}{c_{it}^{-\gamma\sigma+\gamma}}\frac{c_{it}^{-\gamma\sigma+\gamma}}{c_{it+1}^{-\gamma\sigma+\gamma}}\frac{c_{it+1}^{-\gamma\sigma+\gamma}}{h_{it+1}^{-\gamma\sigma+\gamma}}\frac{c_{it+1}}{h_{it+1}}\right]&=\frac{1+r}{1+\delta}E_t\left[\frac{c_{it+1}^{-\sigma}}{c_{it}^{-\sigma}}\frac{h_{it}^{-\gamma\sigma+\gamma}}{c_{it}^{-\gamma\sigma+\gamma}}\frac{c_{it}^{-\gamma\sigma+\gamma}}{c_{it+1}^{-\gamma\sigma+\gamma}}\frac{c_{it+1}^{-\gamma\sigma+\gamma}}{h_{it+1}^{-\gamma\sigma+\gamma}}\right.\\&\left.-\frac{\gamma}{1+\delta}\frac{c_{it+2}^{-\sigma}}{c_{it+1}^{-\sigma}}\frac{c_{it+1}^{-\sigma}}{c_{it}^{-\sigma}}\frac{h_{it}^{-\gamma\sigma+\gamma}}{c_{it}^{-\gamma\sigma+\gamma}}\frac{c_{it}^{-\gamma\sigma+\gamma}}{c_{it+1}^{-\gamma\sigma+\gamma}}\frac{c_{it+1}^{-\gamma\sigma+\gamma}}{h_{it+1}^{-\gamma\sigma+\gamma}}\frac{h_{it+1}^{-\gamma\sigma+\gamma}}{c_{it+1}^{-\gamma\sigma+\gamma}}\frac{c_{it+1}^{-\gamma\sigma+\gamma}}{c_{it+2}^{-\gamma\sigma+\gamma}}\frac{c_{it+2}^{-\gamma\sigma+\gamma}}{h_{it+2}^{-\gamma\sigma+\gamma}}\frac{c_{it+2}}{h_{it+2}}\right]\end{aligned}$$

Define $\psi_{it} \equiv \frac{c_{it}}{c_{it-1}}$ and $\chi_{it} \equiv \frac{c_{it}}{h_{it}}$, we then have:

$$\begin{aligned}E_t\left[1-\frac{\gamma}{1+\delta}\psi_{it+1}^{-\sigma}\chi_{it}^{\gamma\sigma-\gamma}\psi_{it+1}^{\gamma\sigma-\gamma}\chi_{it+1}^{-\gamma\sigma+\gamma}\chi_{it+1}\right]&=\frac{1+r}{1+\delta}E_t\left[\psi_{it+1}^{-\sigma}\chi_{it}^{\gamma\sigma-\gamma}\psi_{it+1}^{\gamma\sigma-\gamma}\chi_{it+1}^{-\gamma\sigma+\gamma}\right.\\&\left.-\frac{\gamma}{1+\delta}\psi_{it+2}^{-\sigma}\psi_{it+1}^{-\sigma}\chi_{it}^{\gamma\sigma-\gamma}\psi_{it+1}^{\gamma\sigma-\gamma}\chi_{it+1}^{-\gamma\sigma+\gamma}\chi_{it+1}^{\gamma\sigma-\gamma}\psi_{it+2}^{\gamma\sigma-\gamma}\chi_{it+2}^{-\gamma\sigma+\gamma}\chi_{it+2}\right]\end{aligned}$$

Or

$$\begin{aligned}E_t\left[1-\frac{\gamma}{1+\delta}\psi_{it+1}^{\gamma\sigma-\gamma-\sigma}\chi_{it}^{\gamma\sigma-\gamma}\chi_{it+1}^{-\gamma\sigma+\gamma+1}\right]&=\frac{1+r}{1+\delta}E_t\left[\psi_{it+1}^{\gamma\sigma-\gamma-\sigma}\chi_{it}^{\gamma\sigma-\gamma}\chi_{it+1}^{-\gamma\sigma+\gamma}\right.\\&\left.-\frac{\gamma}{1+\delta}\psi_{it+1}^{\gamma\sigma-\gamma-\sigma}\psi_{it+2}^{\gamma\sigma-\gamma-\sigma}\chi_{it}^{\gamma\sigma-\gamma}\chi_{it+2}^{-\gamma\sigma+\gamma+1}\right]\end{aligned}$$

Move the second term on LHS to RHS and linearize around steady state $\ln\chi_0$, $\ln\psi_0$:

$$\begin{aligned}1=E_t&\left[\frac{\gamma}{1+\delta}\psi_0^{\gamma\sigma-\gamma-\sigma}\chi_0+\frac{\gamma}{1+\delta}(\gamma\sigma-\gamma-\sigma)\psi_0^{\gamma\sigma-\gamma-\sigma}(\ln\psi_{it+1}-\ln\psi_0)\chi_0\right.\\&\left.+\frac{\gamma}{1+\delta}\psi_0^{\gamma\sigma-\gamma-\sigma}\chi_0\left((\gamma\sigma-\gamma)(\ln\chi_{it}-\ln\chi_0)+(-\gamma\sigma+\gamma+1)(\ln\chi_{it+1}-\ln\chi_0)\right)\right]\\&+\frac{1+r}{1+\delta}E_t\left[\psi_0^{\gamma\sigma-\gamma-\sigma}+(\gamma\sigma-\gamma-\sigma)\psi_0^{\gamma\sigma-\gamma-\sigma}(\ln\psi_{it+1}-\ln\psi_0)\right.\\&+\psi_0^{\gamma\sigma-\gamma-\sigma}\left((\gamma\sigma-\gamma)(\ln\chi_{it}-\ln\chi_0)+(-\gamma\sigma+\gamma)(\ln\chi_{it+1}-\ln\chi_0)\right)\\&-\frac{\gamma}{1+\delta}\psi_0^{2\gamma\sigma-2\gamma-2\sigma}\chi_0-\frac{\gamma}{1+\delta}(\gamma\sigma-\gamma-\sigma)\psi_0^{2\gamma\sigma-2\gamma-2\sigma}\chi_0\left((\ln\psi_{it+1}-\ln\psi_0)+(\ln\psi_{it+2}-\ln\psi_0)\right)\\&\left.-\frac{\gamma}{1+\delta}\psi_0^{2\gamma\sigma-2\gamma-2\sigma}\chi_0\left((\gamma\sigma-\gamma)(\ln\chi_{it}-\ln\chi_0)+(-\gamma\sigma+\gamma+1)(\ln\chi_{it+2}-\ln\chi_0)\right)\right]\end{aligned}$$

As proved by Carroll (2000), $\chi_0 = 1$, $\psi_0 = 1$ if $r = \delta$. Substitute into the above equation:

$$
\begin{aligned}
1 = & E_t\left[\frac{\gamma}{1+\delta}\left(1+(\gamma\sigma-\gamma-\sigma)\ln\psi_{it+1}+(\gamma\sigma-\gamma)\ln\chi_{it}+(-\gamma\sigma+\gamma+1)\ln\chi_{it+1}\right)\right] \\
& + E_t\left[1+(\gamma\sigma-\gamma-\sigma)\ln\psi_{it+1}+(\gamma\sigma-\gamma)\ln\chi_{it}+(-\gamma\sigma+\gamma)\ln\chi_{it+1}\right. \\
& \left. -\frac{\gamma}{1+\delta}\left(1+(\gamma\sigma-\gamma-\sigma)(\ln\psi_{it+1}+\ln\psi_{it+2})+(\gamma\sigma-\gamma)\ln\chi_{it}+(-\gamma\sigma+\gamma+1)\ln\chi_{it+2}\right)\right]
\end{aligned}
$$

by rearrangement,

$$
\begin{aligned}
0 = & E_t\left[\frac{\gamma}{1+\delta}(-\gamma\sigma+\gamma+1)\ln\chi_{it+1}+(\gamma\sigma-\gamma-\sigma)\ln\psi_{it+1}+(\gamma\sigma-\gamma)\ln\chi_{it}+(-\gamma\sigma+\gamma)\ln\chi_{it+1}\right] \\
& - E_t\left[\frac{\gamma}{1+\delta}(\gamma\sigma-\gamma-\sigma)\ln\psi_{it+2}+\frac{\gamma}{1+\delta}(-\gamma\sigma+\gamma+1)\ln\chi_{it+2}\right]
\end{aligned}
$$

Replace back the definition of $\chi_{it}=\frac{c_{it}}{h_{it}}$and $\psi_{it}=\frac{c_{it}}{c_{it-1}}$,

$$
\begin{aligned}
& E_t\left[-\frac{\gamma}{1+\delta}(\gamma\sigma-\gamma-1)(\ln c_{it+1}-\ln h_{it+1})+(\gamma\sigma-\gamma-\sigma)(\ln c_{it+1}-\ln c_{it})\right. \\
& \left.+(\gamma\sigma-\gamma)(\ln c_{it}-\ln h_{it})-(\gamma\sigma-\gamma)(\ln c_{it+1}-\ln h_{it+1})\right] \\
= & E_t\left[\frac{\gamma}{1+\delta}(\gamma\sigma-\gamma-\sigma)(\ln c_{it+2}-\ln c_{it+1})-\frac{\gamma}{1+\delta}(\gamma\sigma-\gamma-1)(\ln c_{it+2}-\ln h_{it+2})\right]
\end{aligned}
$$

or it can be written as,

$$
\begin{aligned}
& E_t\left[(\gamma\sigma-\gamma-\sigma)\left((\ln c_{it+1}-\frac{\gamma}{1+\delta}\ln c_{it+2})-(\ln c_{it}-\frac{\gamma}{1+\delta}\ln c_{it+1})\right)\right. \\
& +(\gamma\sigma-\gamma)\left((\ln c_{it}-\frac{\gamma}{1+\delta}\ln c_{it+1})-(\ln h_{it}-\frac{\gamma}{1+\delta}\ln h_{it+1})\right) \\
& -(\gamma\sigma-\gamma)\left((\ln c_{it+1}-\frac{\gamma}{1+\delta}\ln c_{it+2})-(\ln h_{it+1}-\frac{\gamma}{1+\delta}\ln h_{it+2})\right) \\
& \left.+\frac{\gamma}{1+\delta}(\ln c_{it+1}-\ln h_{it+1})-\frac{\gamma}{1+\delta}(\ln c_{it+2}-\ln h_{it+2})\right] \\
= & 0
\end{aligned}
$$

Define $\ln c^*_{it}\equiv\ln c_{it}-\frac{\gamma}{1+\delta}\ln c_{it+1}$, $\ln h^*_{it}\equiv\ln h_{it}-\frac{\gamma}{1+\delta}\ln h_{it+1}$,

$$
E_t\left[-\sigma\Delta\ln c^*_{it+1}+(\gamma\sigma-\gamma)\Delta\ln h^*_{it+1}-\frac{\gamma}{1+\delta}\Delta\ln c_{it+2}+\frac{\gamma}{1+\delta}\Delta\ln h_{it+2}\right]=0
$$

Or if we define $\Xi_{it+1}=-\sigma\ln c^*_{it+1}+(\gamma\sigma-\gamma)\ln h^*_{it+1}-\frac{\gamma}{1+\delta}\ln c_{it+2}+\frac{\gamma}{1+\delta}\ln h_{it+2}$, we can simply write the above as:

$$
E_t\Xi_{it+1}=E_t\Xi_{it}
$$

Chapter 2

Inequality, Information and Groundwater Management: A Case Study in Rural Tunisia[1]

2.1 Introduction

Around the globe, depletion of aquifers caused by over-extraction of groundwater has become a major threat to freshwater ecosystems especially in arid and semi-arid regions. The agricultural sector is a major culprit as farmers often rely on groundwater as a major source of abundant renewable resource extracted at a fairly low cost. Oftentimes, groundwater constitutes *de facto* an unregulated common property resource (CPR for abbreviation). Once a farmer has invested in wells or boreholes, excluding him from extracting water out of the aquifer is either impossible or highly costly. However, each farmer's withdrawal has an impact on all the farmers who share the same aquifer by affecting future levels of the water table as well as water quality. Thus, groundwater is often exploited beyond its optimal level due to the presence of externalities. The existence of these externalities that are hard to internalize accelerates the depletion of water resource and drives the demand for collective action at community level during last two decades. However, the widespread failure to provide collective action in reality leads us to ask a question: what factors are more conducive to successful collective actions and what other factors impede cooperation. To find the answer for this question is the main objective of this paper. In the paper, we exploit the groundwater management experience in Merguellil river basin in Tunisia and identify inequality and asymmetric information as the two main factors that prevent cooperation.

A large literature has developed attempting to identify conditions that are conducive to collective action and sustainable management of common property resources. An important issue relates to the manner in which the inefficiencies due to the very nature of common property resources ought to be addressed. A number of studies have highlighted the design of rules by local communities to manage common resources. Ostrom (2000) provides a body

[1] This chapter is based on conjoint work with Mare Sarr and Timothy Swanson.

of evidence based on a number of case studies where such regulations were instrumental in the successful management of common resources. Typically local management of commons may succeed when 1) access is limited to a well defined group of users who abide by specific rules set by the community; and 2) users are responsible for monitoring and enforcement, and punish non-compliance according to the severity of the offense. However, Baland and Platteau (2003) draw the attention to the fact that rules devised by communities to manage local common property resources do not necessarily aim to improve the efficiency of the use of resources unlike what a number of analyses have argued. Rather those rules often have a distributive motive as they serve the purpose of regulating the access to the resources.

Two features of community-based management of common property resources may matter for efficiency. The first is group size and the second is group heterogeneity. While there seems to be some consensus that small group sizes tend to help efficiency (Sandler (1992); Baland and Platteau (1996)), the effect of group heterogeneity on the efficiency of the management of common property resources remains an open question. In an influential contribution, Olson (1965) argues that if a public good is productivity-enhancing and wealthier agents derive a larger benefit from the public good than their less wealthy counterparts, then the richer agents may have incentive to provide it and bear all the costs involved even if the poorer agents may free-ride in their contributions. Thus, according to Olson, inequality may foster the provision of a public good.

In the context of common property resource extraction, Baland and Platteau (1997) argue that increased inequality or a disequalizing transfer from a poor and constrained user of a common resource to a rich and unconstrained user can be efficiency enhancing. In their model, the reduction in effort (e.g. resource extraction) resulting from the poor agent dominates the increase in effort induced by the rich user so that the aggregate effort level decreases with higher inequality. However, they also recognize that the existence of exit option may also give incentive to the rich users to accelerate the extraction of the resource. Therefore, the effect of inequality on resource extraction becomes less clear under these two counteracting forces. In a similar setting with inequality in the appropriation constraints, but a two-agent two-stage fishing model, Dayton-Johnson and Bardhan (2002) show that the relationship between inequality and economic efficiency is U–shaped. Their intuition is that at perfect equality conservation is Nash Equilibrium, while mean-preserving spreads of wealth distribution will reduce one's wealth to a point where his claim on the final-period resource stock provides insufficient incentive to conserve. And as inequality becomes even more unequal, conservation becomes the dominant strategy of the wealthier resource user so that efficiency increases with inequality when it is beyond a threshold. In a more specific setting of groundwater exploitation, Aggarwal and Narayan (2004) also demonstrate that efficiency and inequality are likely to be related in a non-linear fashion. Similar to Dayton-Johnson and Bardhan (2002), Aggarwal and Narayan (2004) also consider a two-stage model of groundwater extraction. But instead of extracting at both stages, farmers invest in capacity (well depth) at the first stage and decide the level of water extraction at the second stage. The inequality considered in their paper is in the ability to make investment. By endogenizing investment in wells, farmers end up competing by over-investing in capacity under open access. This fierce competition is the main factor responsible for groundwater over-exploitation. In addition they show that there is a U-shaped relationship between inequality and efficiency in the use of groundwater. When inequality (in terms of access to credit to dig wells) is low, the usual Nash equilibrium under open access obtains. However when inequality becomes moderate the stock of groundwater drops substantially before increasing again with higher levels of inequality. Although different in many settings, these three papers share the same feature, that is inequality in study is in the constraints of appropriation effort (or investment) and profit is only function of the resource in concern. However, there is another kind of inequality that is not considered in these papers: that is, inequality in an input that is complementary to the common property resource in production function. This type of inequality is common if the resource in study is water while land as another important input in production is usually distributed unequally. How is land inequality affects the efficiency in use of water is the question that we are going to examine in this paper. Bardhan et al. (2007) has studied this problem in a general theoretical framework, from contribution to public goods to extraction of common-property resources. While as they focus on finding out the joint profit maximizing inequality level, we are interested in studying how the existing heterogeneity affects the use of groundwater and users' willingness to take collective action, and more importantly how to induce resource users to cooperate in resource use at the presence of land inequality.

In addition, all the above analysis remain at a theoretical level, and there have been very few works studying this problem empirically. The main constraint we believe lies in the difficulty in obtaining appropriate data. Yet, some studies have addressed this problem using experimental data collected in the laboratory (Cardenas (2003)), while others study the relationship between inequality and group participation in contributions to public or common goods rather than exploitation of common property resources with real data collected from the field (Molinas (1998); Bardhan (2000); Alesina and Ferrara (2000); La Ferrara (2002); Alix-Garcia and Harris (2011)). A few exceptions include the papers by Libecap and his coauthors (Johnson and Libecap (1982); Libecap and Wiggins (1985)) who emphasize the role of asymmetric information and heterogeneity in common property resources exploitation.

Our paper contributes to the literature by providing new evidence on CPR exploitation using the real data collected from the field. In particular, we examine the empirical relationship between inequality in land distribution within villages and the fall in groundwater level using a unique data set collected from Tunisia. In addition, we investigate the willingness of Tunisian farmers to engage in collective action and stabilizing the watertable level in the face of the current over-exploitation of groundwater resources in the Merguellil Valley, where farmers rely on groundwater as an abundant source of low cost water and keep digging wells and boreholes without any regard to the law restricting such investment. As a result, the water table level keeps falling: it has decreased over the past 20 years from -42 meters in 1986 to -52 meters in 2006 and is expected to reach nearly -60 meters in the next 10 years.

This is a typical illustration of the tragedy of the commons where individual rationality conflicts with collective rationality: each farmer seeking his own self-interest makes eventually the community worse off. As a result, farmers have to dig deeper every year to get enough water for their crops and therefore incur increasing pumping costs. Water policy makers are concerned about the current unsustainable path. The question they have to address is: given the over-exploitation of the resources and the low enforcement of the legislation on unlicensed sources of water, how can farmers be led to internalize the externalities that they impose upon one another and society at large (costly pumping, water quality, etc.).

The application of Folk Theorem in CPR management implies that long-term repetition of the same game may foster cooperation. While if resource use is private information and asymmetric among heterogeneous resource users, cooperation is susceptible to deceit or deviation from cooperative rule and hard to form (Libecap and Wiggins (1984, 1985)). Since most groundwater extraction in the study area is from private wells and water stealing is common, how to foster cooperation becomes particularly challenging. To address this issue we design a choice experiment to ask for the farmers' willingness to pay to shift to a collective action equilibrium in which water extraction will be restricted and paid for. We pay special attention to the role of information and monitoring in farmers' decision making, and correspondingly include *transparency* and *accountability* as two important policy attributes. If it is heterogeneity and asymmetric information that deters cooperation, enhanced information sharing and accountability would be preferred by most farmers and strengthen their preferences for collective action. Any policy intervention that tries to induce cooperation but ignores this point wouldn't be able to solve the overextraction problem. Therefore, our purpose in conducting the choice experiment is to elicit farmers' preferences for information sharing and accountability and identify the factors that restrain resource users from using water more sustainably.

Our formal analysis begins with a theoretical model of heterogeneous farmers exploiting groundwater resources in Section 2.2. We analyse the effect of enhanced inequality on water extraction under both baseline model and an extended model where differentiated market price is considered. We also model farmers' decision making in choosing management regime and examine the impact of inequality and heterogeneity. Section 2.3 introduces the survey area and its water management institutional design. It later introduces the design and implementation of the choice experiment. Section 2.4 displays the results of empirical analysis, which includes two parts: empirical test of the relationship between inequality and water extraction at village level and the analysis of choice experiment at individual level. The paper concludes in Section 2.5.

2.2 Theoretical Model

In this section, we develop a simple model with the view of highlighting some of the key features we set out to investigate empirically. We build our model based on the generalized framework provided by Bardhan et al. (2007), which studies the effect of inequality on a range of collective actions, from the provision of pure public goods to the extraction of common property resources, in a situation where the unequally distributed private input and the collective good input are complements in the production function.

2.2.1 Baseline model

Although extraction of common property resources is a dynamic process, our model abstracts from the dynamic externality [2] and simplifies the problem into a static one. Following Bardhan et al. (2007), we assume a concave production function with one private input (land l_i) and a common property resource (groundwater w_i). We assume both inputs are complements, and groundwater is shared by n resource users[3]. In the unregulated situation, each farmer chooses extraction effort e_i to maximize individual profit:

$$\pi_i = f(l_i, w_i) - e_i$$

where e_i is the extraction effort of groundwater, and is assumed to be linear with extraction cost.

Both static and dynamic externality are captured in the production function through the common property input, $w_i = be_i + cE$, where $b > 0$ is constant production efficiency coefficient, and E is the total extraction effort by all the resource users who share the same aquifer, i.e., $E = \sum_{i=1}^{n} e_i$. The constant $c < 0$ captures the negative externality of other farmers' extraction on the available groundwater.

Following Bardhan et al. (2007) we make the following 4 assumptions:

Assumption 1. The production function $f(l_i, w_i)$ is strictly increasing and concave function and twice differentiable on $\mathbb{R}^2_+$ with respect to both inputs, $f_{12} > 0$, $\lim_{l \to 0} f_2 = 0$, and f satisfies the Inada endpoint conditions.

Assumption 2. $b \geq 0$ and $b + cn > 0$ to ensure positive total extraction.

Assumption 3. The marginal return of the collective input $h(l_i, w_i) \equiv f_2(l_i, w_i)$ is quasi-concave.

Assumption 4. The function h has property: $h_{22} > 0$ and $h_{12} < 0$.

[2] In literature, there are three types of externality in groundwater use: *(i)* stock externality: exploitation of a stock of groundwater; *(ii)* pumping cost externality: increase in extraction and pumping cost due to the water table declines; and *(iii)* risk externality: inherent value of groundwater as a substitute source of water in times of surface water shortage (Provencher and Oscar (1993), Karousakis and Koundouri (2006)). We mainly focus on the first two types in this paper.

[3] Theoretically groundwater is shared by the whole watershed, we assume in the empirical analysis that each village shares certain amount of groundwater independently.

Note that Assumptions 1, 3 and 4 are all satisfied by the Cobb-Douglas production function.

Farmer's problem is to choose the level of extraction effort e_i that maximizes his profit taking the other farmers' extraction efforts as given. i.e., the solution is noncooperative Nash Equilibrium. By standard Kuhn-Tucker conditions, we obtain:

$$f_2(l_i, be_i + cE) = \frac{1}{b+c} \tag{2.1}$$

Define function $g(l_i) > 0$ as the solution to $f_2(l_i, g(l_i)) = \frac{1}{b+c}$, we can draw its property into Lemma 1:

Lemma 1: $g(l_i) > 0$, $g'(l_i) = -\frac{h_1}{h_2} > 0$ and $g''(l_i) \leq 0$ for any $l_i > 0$

Proof: See Appendix 2.B.

By Lemma 1, we establish that the response curve of common property input (water) to private input (land) is concave if and only if the marginal return of common property input is quasi-concave. That is, water extraction increases with land endowment at a decreasing rate. Intuitively, the monotonicity result indicates that, with mean-spreading land distribution, big farmers would increase their water extraction while the small farmers would decrease theirs. However, the relative size of these two opposing effects depends on the curvature of the above response curve. Concavity of the response curve guarantees the decreased water input by small farmers is bigger than the increased level by big farmers.

Therefore, we can examine how land distribution affects water stock change $\Delta X = R - W$, where R is regeneration of groundwater (assumed exogenous), and total water extraction $W = \sum_{i=1}^{n} w_i$.

Following Persson and Tabellini (1994), we measure each farmer's land area as a distance deviated from the mean in the whole distribution, i.e. $l_i = a + \sigma\varepsilon_i$, where a is average of land endowment, and $\sigma\varepsilon_i$ is individual-specific land endowment with zero mean. In particular, an increase in the mean-preserving spread σ captures the idea of increase in inequality.

Proposition 1: *Suppose Assumption 1-4 are satisfied, the fall in stock of groundwater decreases with enhanced land inequality, i.e.* $\frac{d \mid \Delta X \mid}{d\sigma} < 0$.

Proof: Take derivative of W with respect to σ gives,

$$\frac{d \mid \Delta X \mid}{d\sigma} = \frac{dW}{d\sigma} = \sum_{i=1}^{n} g'(l_i)\varepsilon_i$$

The sign of the derivative depends on the sign of the weighted sum of the slope of response curve $g(l_i)$. If we sort farmers according to their land endowment from the minimum to the maximum such that $\varepsilon_1 < \cdots < \varepsilon_{k-1} < 0 < \varepsilon_k < \cdots < \varepsilon_n$, we then have

$$
\begin{aligned}
\sum_{i=1}^{n} g'(l_i)\varepsilon_i &= \sum_{i=1}^{k-1} g'(l_i)\varepsilon_i + \sum_{i=k}^{n} g'(l_i)\varepsilon_i \\
&< \sum_{i=1}^{k-1} g'(l_k)\varepsilon_i + \sum_{i=k}^{n} g'(l_k)\varepsilon_i \\
&= g'(l_k)\sum_{i=1}^{n} \varepsilon_i = 0
\end{aligned}
$$

The inequality condition follows directly from Lemma 1 that $g'(l_i)$ is a decreasing function. ■

This theoretical result is consistent with Olson (1965)'s argument about the positive monotonic relationship between inequality and public goods provision. However, this result has been challenged by both Dayton-Johnson and Bardhan (2002) and Aggarwal and Narayan (2004) who show the relationship could theoretically describe an inverted U-shape in the case of CPR extraction. While both papers consider a two-stage dynamic model, in next section we show it is also possible to derive a non-monotonic relationship with an extension of the above model by introducing market imperfection.

2.2.2 Differentiated market prices

In the baseline model, it is implicitly assumed that all farmers face the same price for their produce and this price is normalized at $\delta = 1$. In reality, there is evidence of market imperfection in the marketing of agricultural products in Tunisia in general and in the Merguellil in particular[4]. Due to market imperfection, farmers no longer face the same unique price, but a differentiated price according to their land endowment $\delta(l_i)$. This heterogeneity in price leads to difference in payoffs of the *inside options* for water users. We assume that bigger farmers (those with larger land endowment l_i) have better opportunities to sell their products at higher prices, i.e. $\delta'(l_i) > 0$. Accordingly, the profit function now takes the form:

$$\pi_i = \delta(l_i) f(l_i, w_i) - e_i$$

Assumption 5. $\delta'(l_i) > 0$, $\lim_{l_i \to 0} \delta(l_i) = 1$ and $\lim_{l_i \to \infty} \delta(l_i) < \infty$.

The first order condition of the above optimization problem shows marginal product of water input is now amplified by a factor $\delta(l_i)$. As big farmers have bigger amplifier, they can use water till a level where marginal product of water is well below the marginal cost,

[4] Albouchi (2006) in his PhD thesis mentions that due to credit constraints, small farmers (who either cannot afford to have their own means of transport or rent vehicles) are forced to sell their products to intermediaries who collect harvests directly from the farms. By doing so, they give up an important part of the margin to these intermediaries who, in turn, will sell the products in wholesale markets in Kairouan and Tunis. On the other hand, big farmers often have their own vehicles (ISUZU) or are able to rent trucks to transport their large quantities of products to the major wholesale markets. In addition, big farmers tend to have better information about prices in the various wholesale market and are therefore able to choose the right time to sell their products.

according to

$$\delta(l_i) f_2(l_i, be_i^n + cE^n) = \frac{1}{b+c} \tag{2.2}$$

Lemma 2:

Define $\phi(l_i)$ so that $\delta(l_i) f_2(l_i, \phi(l_i)) = \frac{1}{b+c}$. In the presence of differentiated prices, the response curve of the collective input (water) to the private input (land) is positive and increasing:

a) $\phi(l_i) > 0$ for any $l_i > 0$

b) $\phi(l_i) > g(l_i)$ for any $l_i > 0$

c) $\phi'(l_i) = -\frac{h_1}{h_2} - \frac{h}{h_2}\frac{\delta_i'}{\delta_i} > 0$

d) The sign of $\phi''(l_i)$ is ambiguous, depending on the shape of $\delta(l_i)$. In the following, we consider two types of functions:

1. *Concave Inside Option*: If we impose the restriction that $\delta(l_i)$ is a concave function, i.e., δ increases with land area at a decreasing speed, or $\delta''(l_i) < 0$, we have $\phi''(l_i) < 0$.
2. *Convex Inside Option*: In this case δ increases with land area at an increasing speed, or $\delta''(l_i) > 0$. If the curvature is big enough, we may have $\phi''(l_i) > 0$. Otherwise, we have $\phi''(l_i) < 0$. The sign may also change with l_i. $\phi''(l_i)$ could be positive at low values of l_i and turn negative at high values of l_i.

Proof: See Appendix 2.B.

We recall from the baseline model that the effect of inequality on resource extraction depends on the weighted sum of response curve slope. Under differentiated market, we have $\frac{dW}{d\sigma} = \sum_{i=1}^{n} \phi'(l_i)\varepsilon_i$, which sign is further determined by the curvature of $\phi(l_i)$. When we have a mean-preserving spread of land distribution, big farms would increase water use but small farms would decrease since water response curve to land is up-sloping. Then the marginal effect depends on the relative size of the rise from the big farms versus the cut from small farmers. If the response curve $\phi(l_i)$ is concave, the rise from the big farmers is smaller than the cut from small farmers, so that the total marginal effect is negative. However, the sign would be opposite if $\phi''(l_i)$ is positive. This happens if the increasing speed of $\delta'(l_i)$ is bigger than the decreasing speed of $g'(l_i)$ in the case without differentiated market. In other words, when big farmers increase water use faster than small farmers decrease their water use with a mean-preserving spread of land distribution, the total water extraction increases with inequality. By Lemma 2, $\phi''(l_i)$ can be always negative or positive or be positive for small l_i but negative with big l_i, depending on the curvature of the inside option. If $\phi(l_i)$ is concave throughout, the sign of the weighted sum is negative, i.e., higher inequality in land distribution leads to lower total water extraction. This is same as in the baseline model. However, if $\phi'(l_i)$ is convex at low l_i and concave at high l_i, total water extraction may increase with inequality first and decrease later, i.e., a U-shaped relationship between water conservation and inequality in land. In the end, a mean-preserving spread in land distribution may affect water extraction in a non-monotonic way. We make the following proposition:

Proposition 2: *Given Assumption 1-5, in the case with differentiated market where profit function is amplified by a factor $\delta(l_i)$, the fall in the stock of groundwater may increase or decrease with enhanced land inequality, where the former can only happen if there is a nonconcave inside option.*

More intuitively, the effect of inequality on water extraction with convex inside options depends on two opposite effects: the negative effect of concave water response (without differentiated market) versus the positive effect of convex inside option. For example, when we move from pure equality to medium inequality at which the latter effect is so big that may dominate the former effect, the total extraction increases with inequality. While when we further move to higher inequality where fewer farms enjoy the high price wedge, the negative effect of concave water response may take the dominance and total extraction falls below the one under medium inequality. In this case, the relationship between inequality and resource extraction is an inverted-U shape. However, if inside option is concave, or if the effect of the convex inside option is not big enough to offset the concave water response at any land level, resource extraction changes with inequality monotonically. In the end, this is an empirical question that we are going to examine in the next section of the paper.

2.2.3 Participation in cooperative regime

Since the purpose of this paper is to identify the factors that deter or foster cooperation, this section examines how land inequality affects farmers' willingness to participate in a voluntary cooperation regime in a theoretical framework. Although noncooperation is the Nash Equilibrium in unregulated situation, cooperation can benefit resource users as a whole by internalizing all the externalities that resource users impose on each other. From the social planner's point of view, cooperation is no doubt the first best if there is no other social cost such as monitoring cost to ensure the enforcement of cooperation. However, the benefit from cooperation is not distributed evenly across resource users and the objection from certain types of users may damage the cooperation. In this section we examine how inequality and heterogeneity affect the users' willingness to join in cooperation.

Under cooperation, farmers choose their extraction efforts $\{e_i\}$ to maximize their joint profits:

$$\max_{\{e_i\}\geq 0} \sum_{i=1}^{n} [\delta(l_i) f(l_i, be_i + cE) - e_i]$$

FOC for this optimization problem:

$$\delta(l_i) f_2(l_i, be_i^* + cE^*) = \frac{1}{b + nc} \tag{2.3}$$

With cooperation, farmers consider the social marginal product of their extraction effort $\frac{1}{b+nc}$, rather than the private marginal product $\frac{1}{b+c}$. As $c < 0$, the former is bigger than the latter. Define $w_i^* \equiv be_i^* + cE^* = (b+c)e_i^* + cE_{-i}^*$ and $\psi(l_i)$ as the response curve of water to land input under cooperation, we have

Lemma 3: Water input under cooperation is lower than the noncooperative equilibrium level for any farm with positive land area. The difference is bigger for larger land endowment:

a) $w_i^n > w_i^* > 0$, $e_i^n > e_i^* > 0$ for any i with $l_i > 0$;

b) $\frac{d(w_i^n - w_i^*)}{dl_i} > 0$ and $\frac{d(e_i^n - e_i^*)}{dl_i} > 0$ for any $l_i > 0$.

Proof: see Appendix 2.B.

When deciding whether to join the cooperation in water management, a farmer has to consider whether the net benefit from cooperation is positive:

$$\Delta\pi_i = \delta(l_i) \left[f(l_i, \psi(l_i)) - f(l_i, \phi(l_i)) \right] - e_i^* + e_i^n \tag{2.4}$$

and it varies across farms according to:

$$\begin{aligned} \frac{d\Delta\pi_i}{dl_i} &= \delta'(l_i) \left[f(l_i, \psi(l_i)) - f(l_i, \phi(l_i)) \right] + \delta(l_i) \left[f_1(l_i, \psi(l_i)) - f_1(l_i, \phi(l_i)) \right] \\ &+ \delta(l_i) \left[\psi'(l_i) f_2(l_i, \psi(l_i)) - \phi'(l_i) f_2(l_i, \phi(l_i)) \right] + \frac{de_i^n}{dl_i} - \frac{de_i^*}{dl_i} \end{aligned}$$

The first two terms are negative, while the third and fourth terms are positive[5]. Therefore, the sign of the derivative depends on the relative sizes of these two opposite terms.

More intuitively, we can decompose the relative benefit from cooperation into two countervailing effects: a private loss due to reduced production effort against a public gain from reduced externality. On one hand, all farms have to suffer a private loss since all farms use less water for production under cooperation, regardless of farm size. And by Lemma 3, the bigger the farm sizes, the bigger the cut in water input, and therefore the bigger private profit loss under cooperation. While on the other hand, all farmers share the same reduced externality (as externality enters production function as the total extraction efforts of all farms). Therefore, the net benefit from cooperation is bigger for small farmers, i.e., $\frac{d\Delta\pi}{dl_i} < 0$.

The effect of change in inequality on resource extraction can be written as:

[5]The third term is positive because $f_2^* - f_2^n = f_2^n \frac{(1-n)c}{b+nc} > 0$ increases with f_2^n which further increases with l_i (see the proof for Lemma 3 in Appendix 2.B).

$$\begin{aligned}\frac{d\triangle\pi_i}{d\sigma} &= \frac{d\triangle\pi_i}{dl_i} * \frac{dl_i}{d\sigma} + \sum_{j\neq i}\frac{d\triangle\pi_i}{dl_j} * \frac{dl_j}{d\sigma} \\ &= \frac{d\triangle\pi_i}{dl_i}\varepsilon_i + \sum_{j\neq i}\frac{d\triangle\pi_i}{dl_j}\varepsilon_j \end{aligned} \tag{2.5}$$

where,

$$\begin{aligned}\frac{d\Delta\pi_i}{dl_j} &= \delta(l_i)\left[\frac{d\psi(l_i)}{dl_j}f_2(l_i,\psi(l_i)) - \frac{d\phi(l_i)}{dl_j}f_2(l_i,\phi(l_i))\right] - \left(\frac{de_i^*}{dl_j} - \frac{de_i^n}{dl_j}\right) \\ &= \frac{de_i^n}{dl_j} - \frac{de_i^*}{dl_j} \\ &= -\frac{c}{b(b+cn)}\left[\phi'(l_j) - \psi'(l_j)\right] > 0 \end{aligned}$$

A mean-preserving spread of land distribution affects $i's$ net profit from cooperation through two channels: 1) through change of one's own land area ("decreasing returns to scale effect"); 2) through change of externality by the change of others' land area ("reduced negative externality effect"). An empirically interesting question that we are examining is: for a fixed land endowment l_i (for example, mean value of farm size), how does farmer's net profit from cooperation vary with inequality. In this case, inequality affects net profit only by changing the negative externality (i.e., the second term in Eq. (2.5)):

$$\frac{d\triangle\pi_i}{d\sigma}\mid_{l_i} = -\frac{c}{b(b+cn)}\sum_{j\neq i}\left[\phi'(l_j) - \psi'(l_j)\right]\varepsilon_j\mid_{l_i}$$

Therefore, the effect of inequality on one's net profit for a fixed farm size depends on the weighted sum of the change of response curves' slopes of all the other farms. As $c < 0$, $\phi'(l_i) > \psi'(l_i)$ for any $l_i > 0$, the sign of the weighted sum depends on the curvature of the response curve, i.e., $\kappa \equiv \phi''(l_i) - \psi''(l_i)$. This is similar to Proposition 1 and 2. If $\kappa < 0$, the weighted sum is negative for a fixed farm with mean land size, while it is more likely to be positive if $\kappa > 0$. Moreover, the sign of κ may vary with l_i since $\phi''(l_i)$ and $\psi''(l_i)$ have also been proved to be nonconstant by Lemma 2. As a result, the sign for the sum of the weighted slope difference is ambiguous, depending on the curvature of the difference of the two response curves.

Proposition 3: Given Assumption 1-5, *a) In a voting experiment for a collective action on water management, bigger farm holders are less likely to vote for the collective action as their net benefits from cooperation are smaller.*

b) The effect of land distribution inequality on the net benefit of cooperation varies among farmers. For a fixed farm size at mean value, the sign of the effect of land inequality depends on the curvature of the difference of two response curves between NE and cooperative equilibrium. Higher inequality leads to bigger net profit for the mean land *value if the difference of two response curves is a convex function of land size.*

So far, we have developed several theoretical predictions from the model that we can investigate in the next empirical part, which consists of two parts: First, we will examine the empirical relationship between inequality and groundwater stock change at village level; Second, we will conduct analysis on the data from choice experiment to elicit farmers' preferences for cooperation in water management and examine how inequality and heterogeneity influences farmers' preferences. Before the formal analysis, we first provide some background information about the survey area and describe the choice experiment that we have designed.

2.3 Empirical Analysis

Our main goal is to investigate empirically how inequality and heterogeneity affects the *outcome* of common property resource extraction and the possibility of collective action in resource management. For the first purpose, we collect the groundwater table data and land distribution data in Merguellil Valley of Tunisia over time periods. While for the second, we design a choice experiment to ask for farmers' preferences and their willingness to pay to shift to a cooperative outcome. In the following two sections, we will first make full use of village level data on inequality to investigate its effects on the fall in the water table. Second, we will exploit the information from the choice experiment to shed light on the farmers' preferences for policy change.

2.3.1 Survey area

Geographical condition

Situated in North Africa, Tunisia has a typical Mediterranean climate in the North and a Saharan climate in the South. Water availability varies widely across the country and over the seasons. Since the 1970s, successive Tunisian governments have engaged in large scale investment programmes to equip the country with an extensive water infrastructure with the aim of mitigating the effects of the vagaries of the weather. Thus, no less than 29 large dams, 200 tanks, and 766 lake reservoirs, more than 3000 boreholes and 151,000 wells have been built since the 1970s (Le Goulven et al. (2009)). Nearly 80% of the country's water is consumed by the agricultural sector, which is the largest water user and has contributed vastly to rural development.

Our study area, the Merguellil river basin, is located in the central area of Tunisia. Its population was 102,600 in 1994 population census and 85% residing in the *gouvernorat* of Kairouan. Approximately 85% of the total population live in the remote rural area but this proportion is decreasing steadily given the trend of rural-to-urban migration. Located in central Tunisia, this region has not been directly impacted by the growth of tourism but it has undergone changes through its relationship with the coastal areas: labour migration, water transfers and emergence of new markets for agricultural produce, especially water consuming products such as fresh fruits and vegetables.

The large El Haouareb dam divides the river basin into two parts: a hilly region upstream and the Kairouan plain downstream. The mean annual rainfall is approximately 300 mm in the plain and increases up to 510 mm in the upper part. Rainfall varies widely in time and space, and nearly 80% of annual rainfall is produced within a period of 12 days. This occasionally causes violent floods. The sporadic and unpredictably violent surface runoff led to the construction of the El Haouareb dam in 1989. However, the dam hardly serves the main function of storage because nearly two-thirds of the outflow of the El Haouareb reservoir infiltrates into the karst aquifer while another quarter disappears through evaporation (Le Goulven et al. (2009)). Therefore groundwater becomes the major water source in the Kairouan plain. Due to the limited recharge of water released from the dam, changes in the water table levels are largely driven by pumping for irrigation purpose. Economic development, intensification of agriculture combined with a population growth have led to excessive water withdrawals from aquifers. Furthermore, the export of water from the hinterland to the coastal cities for tourism purpose, has exacerbated the problem of over-exploitation of water resources. Like in many parts of the country, the subsidization of private wells has resulted in their dramatic increase from 100 in 1960s to about 5000 in 2008 (Le Goulven et al. (2009)). As a result, the water table level has been falling relentlessly over from -42 meters in 1986 to -52 meters in 2006. It is expected to reach nearly -60 meters in the next 10 years by 2015.

Institutional evolution

Collective management of irrigation water at the tribe level was common in the region during 18th and 19th century, and dates back from the 13th century in oases (Al Atiri (2006)). Water was considered as a right by farmers and was shared equitably between the irrigation perimeters according to rules enforced initially by communities and later on from the early 20th century, enforced more formally by associations of stakeholders.[6] However, changes in social structure together with technology change introduced by French colonization imposed pressure on resource use and weakened the traditional collective management system. After independence in 1956, the Tunisian government took over the management right from the tribes and implemented policies that encouraged rural development by centralizing water management. These include building large hydraulic infrastructure and transferring water spatially from the hinterland to coastal areas, subsidizing intensive irrigation technologies and setting up water management institution from top to down. These policies have played a very important role in economic growth in Tunisia, but meanwhile intensified the pressure on water demand. This has resulted in the fall of the groundwater table as well as other ecosystem degradation such as soil erosion have become major environmental problems in the region.

Since the 1970s, the development and management of public irrigation schemes was en-

[6]For instance, the *associations of oasis owners* created between 1912 and 1920, and the *associations of special interest in hydraulics* instituted in 1933 whose functions are similar to the modern Association of Collective Interest (AIC) and Group of Collective Interests (GIC) (Al Atiri (2006)).

sured by a centralized agency (*Office de Mise Valeur* or OMV) represented in each *gouvernorat.* In 1989, the OMVs were replaced by regional offices of the Department of Agriculture in charge of agricultural development in each (*Commissariats Régionaux de Développement Agricole,* CRDA). Towards the end of the 1980s, the willingness of the State to disengage from the management of the schemes was reaffirmed by the decentralization of the management of the irrigation schemes. Thus water users' associations—Association of Collective Interest (AIC) which were later in 1999 turned into Group of Collective Interests (GIC)—were created to be part of local collective management schemes. Their number increased rapidly from 100 AIC in 1987 to over 2700 GIC at the end of 2002. Among these 1100 were involved in the management of irrigation water. Thus, by late 2001 nearly 60% of irrigated public land was transferred from the CRDA to GICs (Albouchi (2006)). Over time the ambit of the GICs has extended from the maintenance and management of irrigation schemes to rural development. The evolution of these institutional arrangements reflects the state's commitment to decentralization and empowerment of water user associations. However, these associations do not seem to have the financial, technical and organizational capabilities to adequately fulfill their mission. Thus, farmers have little confidence in these institutions which are confronted with internal conflicts and tensions. Many farmers complain about the unreliable supply of the water in irrigation schemes under the management of GICs and resort to private wells whenever there is water shortage. The wells are deepened using a local manual technique (*forage à bras*) as the water table drops, without intervention of the CRDA water police because the authorties prefer to turn a blind eye to these practices and to encourage regional agricultural development. As Le Goulven et al. (2009) put it, "*The Merguellil basin provides an ideal case study to analyse the effect of the progressive establishment of water infrastructure, ..., [it] also provides the opportunity to examine the modes of governance, as well as the economic and regulatory tools which might assist in the control of access to water resources*".

2.3.2 Choice experiment: Design and Implementation

Design of the experiment

We design a choice experiment to elicit farmers' preferences for collective action towards achieving the stabilization of the water table level and management of the common resource in a sustainable manner. Our aim is to determine the farmers' willingness to pay to switch to a cooperative outcome that would upset the status quo. To do so, the choice experiment will focus on some of the main constraints faced by the farmers that explain their current non-cooperative behaviour. Relaxing those constraints may induce a shift in the farmers' behaviour. The extent to which current actions remain private information is clearly a major contributing factor to the current lack of coordination among farmers even within the GICs. For instance, the constant use of unlicensed wells and boreholes, and sabotage of the monitoring system through the destruction of meters are commonplace and prevent water user associations from functioning efficiently. Thus, transparency and information revelation regarding farmers' water use and defrauding behaviour, by reducing information imperfection, may be an effective pathway to foster cooperation. Measures to improve the transparency and enforcement of the system are therefore critical in any policy change. Finally, since water consumption is proportional to the total irrigated areas, imposing a constraint of irrigated lands might be useful in conserving water. After consulting Tunisian local researchers (Institut National Agronomique de Tunisie, INAT and Institut de recherche pour le développement, IRD) and local stakeholders (Ministry of the Agriculture, and the Regional Commission for Agricultural Development, CRDA of Kairouan), we selected policy attributes of interest to the farmers in Merguellil as shown in Table 2.1.

Table 2.1: Choice Experiment Attributes

Attributes	Description
Restriction on irrigated land area	Extent of land restriction in irrigation: 0%, 10%, 20%, 30%
Meter reading	Institution responsible for reading the meters: 1. Water management unit organized by Department of Agriculture 2. Local Authority
Transparency	Publicize water use, damage to meters: 1=Yes, 0=No
Installation fee	How much fee would you pay (in Tunisian Dinars per year): 0, 10, 20, 30

The first attribute pertains to the *restriction on irrigated land area*. It constitutes a straightforward and transparent method for reducing water usage. It has the advantage of being easily monitored by the neighboring farmers, and therefore a desirable attribute to control water extraction. In the empirical analysis, we will treat this variable as an ordinal categorical variable, with four dummies to denote each of the four levels: 0, 10, 20 or 30% land restriction (in real empirical framework, only three dummies will appear to achieve full-rank of variable matrix). The second attribute, *meter reading* indicates the institution the farmers would trust to be responsible for monitoring the meters and is a proxy variable for accountability. Because corruption may occur, it is important that the water users believe in the fairness of the monitoring system. This attribute is captured by a binary variable that denotes two different regimes: a new water management unit organized by department of Agriculture, and local authority. The third attribute relates to *transparency*. This attribute aims at making information regarding individual water use, fraud and sabotage public so that the system can be trusted and be less prone to free riding. It is captured by a simple binary variable, indicating whether water use information for every water user is published on a blackboard in the village every month. The fourth attribute included in the choice experiment, the *installation fee*, asks farmers how much they would be willing pay to install a water meter on the wells. This attribute allows us to estimate welfare changes in monetary term.

In combining the levels of the attributes into choice sets, orthogonality design has been used to avoid strict dominance of one alternative over the others. Careful arrangement ensures balanced distribution of attribute levels and balanced utility across alternatives. These combinations generate 64 possible choice sets. In this choice experiment, 16 out of the 64 possible choice sets were selected and separated into two groups with each consisting of eight choice sets. Table 2.2 shows the example of a choice set [7].

Implementation of the survey

A trial survey was carried out in a small sample of farmers in the Kairouan plain to assess the relevance of the questions and the reaction of the farmers. In May and June 2007, the actual survey of 250 farmers was conducted. The survey was carried out mainly in the downstream catchment where much of the over-exploitation of the groundwater takes place, with a few surveyed villages located upstream. Each farmer has to fill 8 choice sets. During the implementation of the survey, the enumerator carefully explained the policy attributes and how to make choices: this was done to avoid any misunderstanding given the low literacy levels among farmers.

In addition, the enumerators provided the respondents with information on the current state of the water table and its likely future negative evolution should the current rate of water extraction continue. The government's intentions were explained in the following paragraph:*'In order to stabilize the groundwater table at the current level, the government is designing a policy to encourage people to reduce water use. In order to do this, the government plans to charge groundwater use by metering. The Department of Agriculture will institute a water management unit throughout the Merguellil Valley. It will install water meters for all the wells in the the gouvernorat of Kairouan (Merguellil Valley) and will charge groundwater use based on the volume used. The volumetric price will be the same as in the public irrigation scheme.'* To prevent strategic voting, respondents are informed that "*the majority rule would be applied on the final voting outcome. i.e., if more than half of the people in the village vote for policy change, the new water management association will be formed and collective action will be taken.*"

In addition to the choice experiment, the survey also includes sections on 1) socio-economic and demographic characteristics; 2) cultivation and irrigation information; and 3) information about the farmers' attitudes towards the environment and the use of water in the region, to gain an understanding of how personal beliefs shape users' attitudes towards policy. The information collected in these sections is required to control for heterogeneity among farmers and investigate the effect of such heterogeneity on preferences.

A supplementary village survey was conducted in all the sample villages in December

[7]The full version of the questionnaires is attached in appendix 2.D.

Table 2.2: Choice Set Example

	Restriction on land area to be irrigated	Who reads the Meter	Transparency	Installation Fee (TD/year)	Tick the Policy you Prefer
Policy A	20% of land is not to be irrigated	Water Management Unit	Not Public	20	☐
Policy B	No restriction	Water Management Unit	Water use and damage of meter made public to all farmers every month	30	☐
Policy C	I would like to keep the status quo and don't vote for the new policy				☐

2010 and January 2011 in order to better capture the heterogeneous circumstances faced by farmers in the Merguellil. Village level data pertaining to the water table change since 1990 was collected. We also collected information on the distribution of farm land and the distribution of well depths for the year 2007. This information allows us to examine the effect of inequality within each village on the farmers' behaviour. A map of the sampled villages is attached in Figure 2.4 in appendix 2.A. The villages in the West and North West of El Haouareb Dam are located in the upstream part of the aquifer. These include villages in the town of Hafouz and some villages in the town of Chebika. The distance of each village to the dam is also collected.

2.3.3 Choice experiment: Model specification

We specify three different choice models: multinomial logit, conditional logit and mixed logit. While multinomial logit model is a standard limited dependent variable model, conditional logit model is used to control for individual's fixed effects as each respondent completes 8 choice sets. However, both multinomial logit and conditional logit are subject to the assumption of independence from irrelevant alternatives (IIA) which may be violated either due to nested choices or unobserved variables. The IIA assumption postulates that the odds between two alternatives is independent of the change in an third alternative. Put differently, this assumption predicts "that a change in the attributes of one alternative changes the probabilities of the other alternatives proportionately" (Train (1998)). Moreover, it is reasonable to believe that different individuals may have different preferences on those attributes. Mixed logit is a highly flexible model that obviates these limitations of standard logit models by allowing for unrestricted substitution patterns, correlation in unobserved factors and random taste variation (Train (2003)). Instead of constant coefficients in utility function, it assumes coefficients vary randomly over individuals representing each individual's tastes.

$$U_{nj} = \alpha Z_n + \beta_n' X_{nj} + \epsilon_{nj} \tag{2.6}$$

where, Z_n are observed individual n's characteristics, X_{nj} are choice j's attributes, β_n is a vector of unobserved coefficients assumed to vary across individuals according to some distribution; ϵ_{nj} is an unobserved random term that is identically and independently distributed extreme value, independent of α, β, X, and Z.

In this model, the probability of individual n chooses choice j is:

$$P_{nj} = \int \left(\frac{e^{\beta_n' x_{nj}}}{\sum_k e^{\beta_n' x_{nk}}} \right) f(\beta) d\beta$$

In words, the mixed logit probability is a weighted average of the logit formula evaluated at different values of β, with the weights given by the density $f(\beta)$ (Train (2003)). We will estimate the mixed logit model assuming the variables coefficients have normal distribution.

We will first analyse how policy attributes alone affect farmers' choice. Then, we will control for farmers' individual characteristics, i.e. variables Z_n in equation (2.6). As the logit model identifies only through within-group (choice set) variation, it is necessary to interact Z_n with alternative specific constant (ASC) in the model to account for preference heterogeneity that can be explained by observed factors.

2.4 Empirical results

2.4.1 Data description and inequality measurement

Our final data consists of a sample of 246 households living in 28 villages in the Merguellil Valley. We focus mostly on farmers outside the public irrigation perimeters located in Chebika, Kairouan and El Batan since they rely almost exclusively on private wells as their source of water supply. The mean age of the farmers in our sample is 40 years. All respondents except one are men. Most respondents (nearly 75%) did not study beyond primary school.

Regarding farm characteristics, the average farmer cultivates seven hectares equipped with one private well or borehole. It is interesting to note that the average well is 45 meters deep (with a standard deviation of 9m) which is still below the authorized depth of wells.[8] If this figure is reliable then it may imply that the regulation limiting the depth of wells is too liberal and is not suitable to address the current over-exploitation even if it was enforced. The water table level decreased by 18m on average between 1990 and 2007. However, the fall in the water table between 2007 and 2011 is captured by a categorical variable. Indeed, although our question asked specifically the levels of the water in 2007 and the current level, the respondents' (here the village leaders) answers were very vague such that the fall in the water table appears in only three levels: 5m, 10m, 15m.[9] We therefore recode the continuous water table fall data into three categories and treat it as a three-level ordered categorical variable: 1 denotes *expected reasonable decrease in the water table* (5m); 2 denotes *fast decrease* in the water table (10m); and 3 represents *very fast decrease* in the water table (15m). Irrigation technologies are also fairly widely spread in the regions: for instance 75% of farmers use drip irrigation and 40% use sprinklers. The summary statistics of the survey data is listed in Table 2.6 in Appendix 2.A.

The information collected on land distribution within each village allows us to measure inequality within village. We also measure a similar inequality indicator based on well depth. As the data on land distribution are grouped observations[10], we measure land distribution inequality based on the method proposed by Kakwani and Podder (1976). In particular, we estimate parametrically the Lorenz curve using the grouped observations by assuming the

[8]Tunisian law regulates groundwater extraction by restricting the depth of private wells. Wells with less than 50 meters can be dug without authorization, while wells with depth beyond 50 meters require authorization from the Minister of Agriculture who sets a limit on the the depth and speed of the flow. Sometimes payment is required if the use of such well is not considered as being in the public interest.

[9]Note that the mean water table fall is 6.5m between 2007 and 2011.

[10]More specifically, the data show the number of farms in a village with farm land in each of following categories: 0-2 hectares; 2-4 hectares; 4-6 hectares; 6-10 hectares; 10-20 hectares; 20-50 hectares and over 50 hectares.

following specification $\eta = a\pi^{\alpha}(\sqrt{2}-\pi)^{\beta}$, and calculate the Gini concentration ratio as:

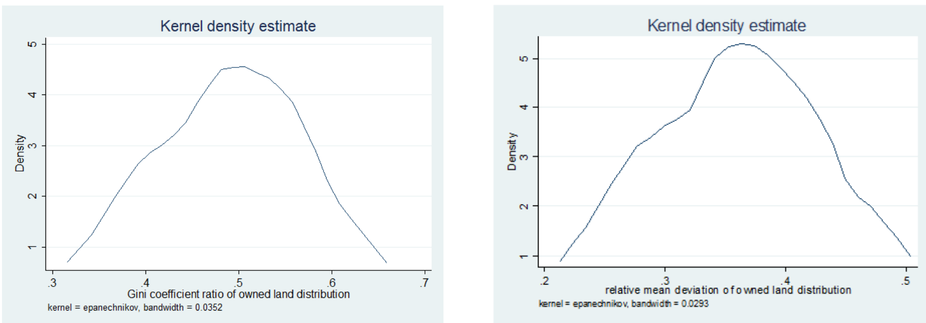
$$\begin{aligned} CR &= 2\int_0^{\sqrt{2}} f(\pi)d\pi \\ &= 2a(\sqrt{2})^{1+\alpha+\beta}B(1+\alpha,1+\beta) \end{aligned} \tag{2.7}$$

where, $B(1+\alpha, 1+\beta)$ is the Beta function. For the purpose of comparison, we also estimate the relative mean deviation which is defined as:

$$\begin{aligned} T &= \frac{1}{2\mu}\frac{1}{N}\sum_{i=1}^{N}|x_i-\mu| \\ &= (\sqrt{2})^{1+\alpha+\beta}\frac{a\alpha^{\alpha}\beta^{\beta}}{(\alpha+\beta)^{\alpha+\beta}} \end{aligned} \tag{2.8}$$

where, the second equation represents the empirical estimated Lorenz curve above[11].

The inequality measurements are shown in Figure 2.1. The left panel shows the distribution of the Gini concentration ratio while the right panel shows the distribution of the relative mean deviation. Both measurements show a large variation of land inequality level across villages.



(a) Gini coefficients

(b) Relative Mean Deviation

Figure 2.1: Inequality of Land Distribution Within Village

We also measure the inequality of well depths for each village based on individual well's depth (Figure 2.2). Except for an outlier, the distribution of relative mean deviation of well depths across villages is more homogenous than land distribution and is mostly centered around 0.1-0.2.

2.4.2 The effect of inequality in land distribution on water resource exploitation

As discussed earlier, there are disagreements in the theoretical literature regarding the effect of inequality on common property resource conservation. The paper does not attempt to settle the disagreement, but rather attempts to contribute to the discussion by providing an empirical analysis using evidence from Tunisia. We are interested in investigating the extent

[11] A brief introduction of this method is included in Appendix 2.C. Please refer to Kakwani and Podder (1976) for details of this method.

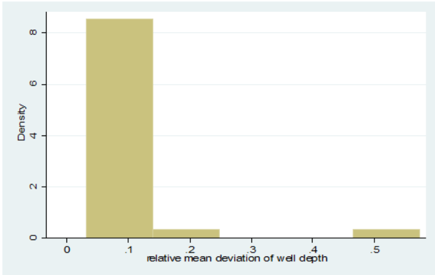
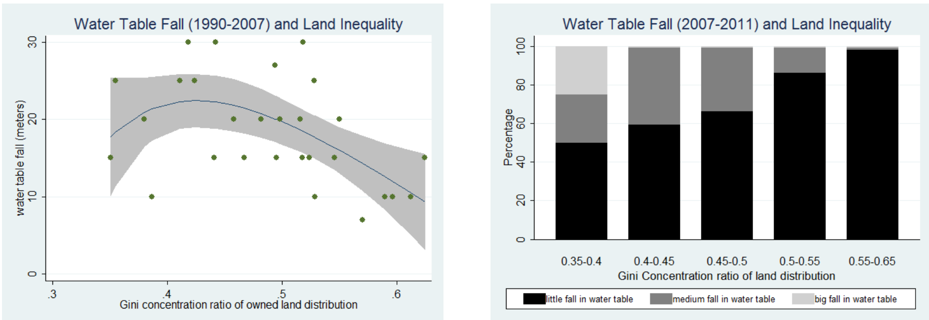


Figure 2.2: Inequality of Well Depths Distribution Within Village

to which inequality in land distribution and in well depth determines the variation in the water table across villages. Given a very small sample size for village level inequality data (28 villages), the empirical analysis in this section is more of the nature of a ”stylised fact” than an econometric analysis. For this purpose, we first show the graphical relationship between water table fall and land inequality in Figure 2.3.



(a) (b)

Figure 2.3: Water Table Fall and Land Inequality

Panel (a) depicts the scatterplot of water table fall during 1990-2007 against Gini coefficient of land inequality, and a fractional polynomial fitted curve, which shows water table fall during 1990-2007 has an inverted U-shaped relationship with Gini coefficient. This pattern echoes the theoretical inverted U-shaped relationship between resource exploitation and inequality (Dayton-Johnson and Bardhan (2002); Aggarwal and Narayan (2004)), i.e. extreme equality or extreme inequality is good for groundwater conservation, while median inequality accelerates groundwater extraction. Similarly, Panel (b) shows the stacked histogram of water table fall categories during 2007-2011 by Gini coefficient groups: as Gini coefficient increases, it's more likely that water table falls less. Different from (a), the relationship is monotonic rather than an inverted U-shape.

To complement with the nonparametric analysis, we also run a parametric regression of water use against land inequality according to the following specification:

$$\ln(\Delta WaterTable)_v = \beta_1 CR_v + \beta_2 CR_v^2 + \beta_3 T_v^{well} + \alpha X_v + \epsilon_v \tag{2.9}$$

where, the dependent variable measures the fall in the water table level (log) at village v. The right hand side variables include the inequality measurements of land (CR_v)and well depths (T_v^{well}), as well as other observable (X_v) and unobservable (ϵ_v) village characteristics.

The first seven columns in Table 2.3 show the OLS estimation of the effect of the determinants on the fall in water table levels from 1990 to 2007. The coefficient of Gini concentration ratio is consistently positive and statistically significant (at the 5% or 10% level depending on the specification) while its square term is negative and significant. The turning point of land inequality is around 0.44-0.47, just below the median point at 0.50. The result remains qualitatively identical when inequality is measured by relative mean deviation (column 2). Moreover, there is no evidence that inequality in well depths contributes to water table fall in a similar manner as land inequality (column 3 - 4) unless we control for inequality in land distribution as well (column 5-6). The effect is more significant especially after we remove the outlier in the distribution of relative mean deviation of well depths (column 6). However, as mean deviation of well depth is mostly distributed around 0.1-0.2, the turning point for the U-shape of well depth inequality (around 2.8) is too far on the right of the distribution to be plausible. Therefore we remove the quadratic term in regression and find land inequality remains significant inverted U-shape relationship with watertable fall from 1990 to 2007 (column 7). To our surprise, neither the number of farms nor the total area of farmland has effect on the fall of groundwater table, after controlling for the land inequality measures.

Notwithstanding these appealing results, the above regressions may suffer from *simultaneity* because our inequality measures (land and well depth) are based on 2007 data while the data on the change in the water table level pertains to the period 1990-2007. As documented early, local farmers usually respond to the fall in the water table by digging deeper wells. As a result, inequality in well depth may be affected by the fall in the water table. On the other hand, the critical situation of the water resources in general and the water table level in particular may also have impact upon the land inequality. For instance, although land is usually transferred through inheritance, there are also a number of cases where farms are sold to relatively wealthy outsiders (especially civil servants and executives) who are able and willing to invest in agriculture[12]. This recent dynamic is made more salient by the critical water situation. However, we can hardly find any instruments for the endogenous variables. To circumvent the endogeneity problem, we estimate equation (2.9) using the change in the water table level between 2007 and 2011 as the dependent variable. We estimate this model using an ordered logit model because the responses provided have only three levels which we recoded into a categorical variable. To avoid multicollinearity, we do not include the quadratic term of Gini coefficient. The results are shown in column (8)-(14). We find that higher inequality in land distribution is associated with a diminished decrease in the water table after attempting to circumvent endogeneity. These results again suggest that inequality seems to facilitate

[12]Personal correspondence with Tunisia environmental department officer.

Table 2.3: The Effect of Inequality on Groundwater Table Fall

	water table fall from 1990 to 2007 (log)							water table fall from 2007 to 2011						
	OLS							ordered logit						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Land Gini Concentration	29.783 **				25.400 *	17.151	24.648 *	-22.175 *	-22.246 **				-23.567 *	-22.57 *
ratio	(12.340)				(13.262)	(12.025)	(13.118)	(12.642)	(10.119)				(12.569)	(12.134)
Land Gini Concentration	-31.922 **				-27.825 **	-20.452	-27.084 **							
ratio (sq)	(12.312)				(13.130)	(11.827)	(12.988)							
Relative Mean Deviation		26.032 **								-24.914 **				
of land distribution		(11.733)								(11.454)				
Relative Mean Deviation		-38.487 **												
of land distribution (sq)		(15.811)												
Relative Mean Deviation			-5.119	14.037	-3.663	18.705 **	-3.545				31.316	63.389 *	21.919	59.696
of well dpeth distribution			(4.755)	(11.254)	(4.176)	(9.453)	(2.717)				(20.216)	(36.884)	(20.283)	(37.299)
Relative Mean Deviation			7.013	-83.776	4.262	-103.886 ***								
of well depth distribution (sq)			(8.683)	(49.592)	(7.583)	(42.680)								
downstream	-0.496	-0.438	-0.319	-0.427	-0.420	-0.405	-0.382							
	(0.322)	(0.316)	(0.350)	(0.335)	(0.348)	(0.304)	(0.343)							
downstream*distance	0.002	0.001	-0.002	-0.002	0.002	0.004	0.002	0.1229 *	0.101 *	0.0986 *	0.0706	0.0627	0.140 **	0.131 *
	(0.007)	(0.007)	(0.009)	(0.008)	(0.008)	(0.007)	(0.007)	(0.065)	(0.052)	(0.052)	(0.051)	(0.054)	(0.067)	(0.068)
number of farms in	-0.00040	-0.00040	-0.00008	-0.00020	-0.00037	-0.00066	-0.00028	0.00567			0.01203 **	0.00833	0.00544 *	0.00194
village	(0.00036)	(0.00036)	(0.00054)	(0.00051)	(0.00051)	(0.00046)	(0.00049)	(0.00443)			(0.00537)	(0.00582)	(0.003)	(0.003)
total farm land area	0.00002	0.00002	0.00002	0.00002	0.00002	0.00004	0.00002	-0.00042			-0.00094	-0.00071		
	(0.00004)	(0.00004)	(0.00005)	(0.00004)	(0.00004)	(0.00004)	(0.00004)	(0.00061)			(0.00057)	(0.00059)		
percent of farms within	0.728 *	0.654	0.792	1.776 *	1.052	2.265	0.996	2.720	2.558	2.674	-10.283	-9.220	-6.503	-3.003
public irrigation scheme	(0.402)	(0.393)	(0.923)	(1.020)	(0.806)	(0.848)	(0.755)	(2.227)	(2.160)	(2.148)	(9.223)	(10.603)	(9.268)	(10.919)
constant	-3.506	-1.001	3.376 ***	2.672 ***	-2.235	-0.941	-2.080							
	(2.928)	(2.019)	(0.328)	(0.489)	(3.220)	(2.859)	(3.183)							
N	28	28	28	27	28	27	27	28	28	28	28	27	28	27
Prob > F	0.044	0.052	0.408	0.209	0.088	0.017	0.067	-11.572	-13.278	-13.328	-11.462	-9.969	-10.950	-8.655
adjusted R-sq	0.477	0.293	0.022	0.130	0.266	0.441	0.288	0.015	0.014	0.014	0.014	0.015	0.009	0.005

Note: Sample size 27 denotes the sample from which the outlier in well depth inequality is excluded. Standard errors are in parentheses. ***,**,* denote significant level at 1%,5%,10% separately.

water conservation. More specifically, we calculate the odds-ratio using the coefficients in the table, and find that if a village's Gini concentration ratio of land distribution decreases by 0.01, the odds of a *fast decrease* in the water table versus an *expected reasonable decrease* is 1.25, holding everything constant. Likewise, the odds of a *very fast decrease* in the water table versus a *fast decrease* is 1.25, ceteris paribus. The coefficient of well depth remains insignificant in most specifications. As *downstream* is highly correlated with limited dependent variable, we remove it from the regressions. The *distance downstream* shows significantly positive impact on groundwater table fall, i.e., villages located further downstream experienced more serious fall in groundwater table, indicating the externality across villages.

The evidence in this section shows that village level inequality in land distribution has a positive effect on groundwater resource conservation in our sample villages, although we are not quite sure about the U-shaped relationship due to small sample size (hence poor inference). Inequality in well depth, however, may accelerate water extraction, probably due to fierce competition among water users. The particular geological condition in Merguellil plain facilitates this possibility. Villages further downstream from the dam also face higher water table fall, as the dam and upper stream users reduce the overflow of water from upstream.

2.4.3 Choice experiment: Estimation results

We have analyzed the effect of land inequality on common property resource conservation in previous section. While from a policy perspective, land redistribution is an unlikely policy tool for water conservation. Instead, to avoid the tragedy of the commons, the removal of hurdles that impede cooperation among water users appears to be a more practical and appealing alternative. For this purpose, we design a choice experiment to find out whether farmers have preferences for collective water conservation and if yes, what other institutional design has impeded them from engaging in collective action. This section shows the results of choice experiment.

Table 2.4 presents the results of the various choice models controlling only for the choice sets attributes: That is, we estimate the probability of choosing a particular management policy as a function of the attributes of the policy and the alternative specific constant (ASC) alone, ignoring the heterogeneity of respondents. The ASC takes value 1 for either of the policy options A and B, and equals 0 for the 'status quo' option. The first two columns are the results from multinomial logit and conditional logit regressions separately, while column (3)-(5) present the mixed logit results where some policy attributes coefficients are treated as random coefficients. Furthermore correlation between random coefficients are allowed in Column (6). We summarize the main results from Table 2.4 as follows: *(i)* The positive ASC coefficients in all columns indicate that on average farmers have positive willingness to pay for the watermeter, henceforth are willing to engage in collective action to achieve groundwater conservation. *(ii)* Farmers are indifferent to restrictions on irrigated land that do not exceed 10%. They are weakly against a 20% land restriction but strongly oppose restrictions of 30% and above. As a matter of fact, fallowing is a common practice in the Merguellil valley, and irrigated land restriction of less than 20% does not affect the agriculture production much. Beyond this level, however, such restriction becomes a binding constraint. Although, from the perspective of water management, land restriction is a straightforward policy instrument with low monitoring cost, it may face strong opposition from farmers. *(iii)* Throughout all specifications, farmers express a inclination for a transparent regime which makes private information on individual water use public to all users. As mentioned in the last section, "water stealing" by digging well deeper or damaging water meter is common under current water management scheme. Demand for information and transparency reveals that hidden action leads to exploitation competition among farmers and damages the potential of cooperative use of groundwater. *(iv)* Moreover, the positive and significant coefficient of the *meterreading* variable shows that farmers prefer the new arrangement to be monitored (reading water meter and collecting fees) by local government to the elected GIC leader. This result is consistent with the story that farmers mistrust the current existing structures of the GICs which are often seen as accomplices with some vested interests, by indulging themselves in private dealing with some farmers to the detriment of the general interests. Although during the survey we emphasized the fact that our experiment intends to design a a new regime organized by the central department of agriculture, the similarity of the denomination of institution used in the survey (Water user association and GIC) seem no different to farmers who draw inference from past experience. Thus, outsiders tend to be considered as more neutral and therefore preferred by many farmers[13].

Considering the possibility that different farmers may have different degree of preferences over transparency and accountability, we estimate the model in mixed logit specifications and results are presented in Column (3)-(6), where the coefficients for these two variables are assumed random and normally distributed. Farmers' preferences for land restriction are assumed to be homogeneous across farmers as fallowing is a common practice in the whole region. In other words land restriction is not characterized by random coefficients in our analysis. In Column (3) and (4), we allow only one random parameter for either *transparency* or *meterreading* separately in each specification. The average coefficient for each variable remains the same sign as in the multinomial or conditional logit model. In Column (3), the average coefficient for variable *transparency* is 0.307, slightly higher than the one if assumed constant. The standard deviation of this coefficient is statistically significant, implying a large variation of this coefficient across the population. By normal distribution, we can calculate that 56.3% of farmers have positive coefficients for this variable. That is to say, a weak majority of farmers prefer transparent management. Likewise, Column (4) presents result of mixed logit model assuming the coefficient for *meterreading* is a random parameter. The average coefficient of this variable becomes statistically insignificant when heterogeneity is allowed.

[13]This point is also confirmed by the Tunisian environment officials.

Table 2.4: Choice Experiment Results Without Individual Characteristics

	(1) multinomial logit	(2) conditional logit	(3) mixed logit	(4) mixed logit	(5) mixed logit	(6) mixed logit
ASC	-0.350 ***	1.207 ***	1.328 ***	1.330 ***	1.545 ***	1.620 ***
	(0.123)	(0.112)	(0.124)	(0.119)	(0.133)	(0.134)
irrigated land restriction 10%	0.032	-0.067	-0.002	-0.138	-0.071	-0.027
	(0.121)	(0.079)	(0.089)	(0.088)	(0.098)	(0.096)
Irrigated land restriction 20%	0.040	-0.063	-0.152	-0.113	-0.227 **	-0.225 **
	(0.135)	(0.094)	(0.106)	(0.098)	(0.110)	(0.110)
irrigated land restriction 30%	-0.422 ***	-0.396 ***	-0.704 ***	-0.465 ***	-0.812 ***	-0.837 ***
	(0.173)	(0.086)	(0.107)	(0.092)	(0.116)	(0.115)
meter reading by local authority	0.167 ***	0.149 **	0.265 ***	0.093	0.172	0.193 *
	(0.084)	(0.064)	(0.074)	(0.109)	(0.116)	(0.115)
transparency	0.298 ***	0.246 ***	0.307 **	0.305 ***	0.316 **	0.354 **
	(0.100)	(0.062)	(0.149)	(0.067)	(0.154)	(0.160)
fee	-0.005 **	-0.008 **	-0.006	-0.010 **	-0.009 *	-0.009 **
	(0.002)	(0.004)	(0.005)	(0.004)	(0.005)	(0.005)
Standard Deviation of Random Coefficient						
meter reading by local authority				1.275 ***	1.274 ***	1.287 ***
				(0.118)	(0.125)	(0.128)
transparency			1.930 ***		2.063 ***	1.486 ***
			(0.157)		(0.174)	(0.196)
Correlation between coefficients						
corr(meterreading,transparency)						1.464 ***
						(0.215)
N	5736	5736	5736	5736	5736	5736
Prob > LR χ^2	0.000	0.000	0.000	0.000	0.000	0.000
log likelihood	-3910.119	-1881.360	-1732.209	-1819.071	-1686.891	-1667.561

The standard deviation is large and significant indicating wide variation in water users' willingness to pay for this policy attribute. This result is preserved when both *meterreading* and *transparency* are treated as random but uncorrelated coefficients in Column (5). Nevertheless, if we allow both coefficients be correlated (Column (6)), the average coefficient on *meterreading* turns bigger and significant at 10%, with 56% of respondents indicating preference for local authority. Moreover, the positive correlation between two coefficients suggests that those who prefer transparency also prefer outsiders (in this case local authority instead of GIC leader) to monitor the new system. This result again reconciles our former discussion about the current GIC management.

Based on results in column (6) in Table 2.4, we can calculate farmers' willingness to pay for the new transparent although more restrictive system in terms of water consumption. On average, farmers are willing to pay 172 Tunisian Dinar (TD) to shift to the new regime, which aims to enforce cooperative use of water and stabilize groundwater table. They are also going to reduce their contribution by TD 89 if more than 30% of land is prohibited from irrigation relative to the non-restrictive scenario. Farmers are on average willing to pay additional TD 38 for a transparent regime, although there are about 40% of respondents who prefer not publishing water user's information and not knowing other users' use. Moreover, on average farmers are willing to pay TD 20.5 for local authority to take accountability, ceteris paribus.

So far we have known farmers' preferences for policy change. Nevertheless, the above discussion doesn't take account of the heterogeneity across villages and farmers. This concern takes us to Table 2.5, in which we include all the other observed and unobserved heterogeneity at village and individual level in the choice models. The specifications are similar to Table 2.4, including a multinomial logit model (Column (1)) and various mixed logit model specifications (Column (2)-(5)) . Column (2)-(4) have similar specifications except the variables that are assumed to have random coefficients. As both standard deviations and correlation between random coefficients are significant, we consider the specification presented in Column (4) as a better fit than the former two and henceforth only discuss its result here. Besides the finding that the policy attributes have qualitatively the same effects on farmers' choice as in Table 2.4, we also observe the following interesting results:

First, although the number of farms within village has little effect, land inequality does have impact on farmers' preferences. According to Proposition 3, we assume a nonlinear effect which also interacts with land value. We find farmers from villages with higher land inequality are more willing to engage in collective action and pay for a water conservation regime. According to the results in Column (4), the marginal effect of land Gini coefficient at mean (log) land value and mean Gini-coefficient on willingness to pay for the policy change is 4.61[14] , meaning as land Gini coefficient increases by 0.1 unit (mean preserving) from the

[14]The marginal effect in logit model is calculated as $f(\beta X)\beta = \frac{exp(\beta X)}{1+exp(\beta X)}\beta = \frac{exp((-156.894+2*122.444*0.4900227+4.114*10.18511)*0.4900227)}{1+exp((-156.894+2*122.444*0.4900227+4.114*10.18511)*0.4900227)} * (-156.894 + 2 * 122.444 * 0.4900227 + 4.114 * 10.18511) = 4.61.$

mean value, i.e., from 0.49 to 0.59, the probability of mean land value holder to opt for the new policy increases by 46.1%.

Second, rich farmers (with greater proportion of irrigated land and higher land value)[15] tend to be more reluctant to a policy change. This can be seen from the negative marginal coefficient on *log(landvalue)*, which is -0.628 at mean value of land Gini coefficient (since the marginal effect has the same sign as the marginal coefficient). In addition, the negative coefficient of the interaction term between *transparency* and *log(landvalue)* reveals that richer farmers dislike transparency, although on average farmers prefer transparency. This finding confirms the usual assumption that rich farmers are the beneficiaries of the current water management scheme.

Third, education has a positive effect on farmers' willingness to pay for water conservation action. Compared to the illiterate counterparts, farmers with primary school education qualification are more willing to vote for the policy change, although even higher education doesn't show higher effect. Interestingly, farmers' environmental awareness and concern show positive impact [16]. However, only the concern of water scarcity in the aquifer (indicated by Factor 1) is not enough for one to make change, but the awareness of externality makes difference. We find those who are more aware of the externality of own's action on other people are more likely to opt for the new policy which may improve water management.

Fourth, as expected, farmers living in villages downstream are more keen to stabilize groundwater table as they tend to be particularly harmed by the water use of farmers living upstream, although further downstream does not necessarily mean higher demand for a groundwater conservation policy[17].

Finally, we also find farmers who have experienced a greater fall in the water table fall since 1990 are more likely to vote for a cooperative management of the resource.

By now, we should point out that the specifications through Column (2)-(4) may suffer from endogeneity bias caused by the fact that water table fall from 1990-2007 is also an outcome variable that may be determined by unobserved village level characteristics. These village characteristics may for example reflect the coordination tradition in the village, or other social connection among villagers, which could also affect villagers' preferences for policy change. To account for these possible unobserved characteristics, we include two new

[15]Usually those growing olive trees and other water demanding crops such as water melon, tomatoes, etc.

[16]We asked ten questions in the farmer survey about their environmental concern. The questions start from general attitudes towards global water scarcity to more specific local scarcity and awareness of externality, in the form of score of importance. As most people don't have idea about the more general questions, we only ask the last five questions which focus on local region. The scores from these five questions are then integrated into two factors using factor analysis.Factor 1 shows one's awareness of water scarcity in the local aquifer, factor 2 indicates one's awareness of externality of self's water use on the others. Lower scores indicate a higher degree of environmental awareness.

[17]This result seems puzzling. While it may not be if we realize that the degree of land inequality is positively correlated with the distance to the dam downstream. In a regression of land inequality level (not included in the current paper) on binary variable *downstream* and interaction term $downstream * distancetothedam$, we find both coefficients are significantly positive. This fact may be resulted from the local landscape and its unique geological environment. As land inequality has positive effect on villagers' inclination to water conservation, downstream distance may work through the same mechanism. Here, we treat land inequality as an exogenous variable which is formed by geology and in history, we don't assume it be correlated with other unobservables which also affect people's inclination to collective action.

Table 2.5: Choice Experiment Results With Individual Characteristics

	(1) multinomial logit	(2) mixed logit	(3) mixed logit	(4) mixed logit	(5) mixed logit
Attributes and interactions					
ASC	1.547 ***	40.560 ***	48.366 ***	50.585 ***	11.441 **
	(0.279)	(10.708)	(11.553)	(11.815)	(9.490)
Irrigated land restriction 10%	-0.001	-0.069	-0.132	-0.096	-0.097
	(0.125)	(0.093)	(0.102)	(0.100)	(0.101)
Irrigated land restriction 20%	-0.036	-0.205 *	-0.267 **	-0.260 **	-0.260 **
	(0.140)	(0.110)	(0.115)	(0.114)	(0.115)
Irrigated land restriction 30%	-0.469 ***	-0.698 ***	-0.794 ***	-0.825 ***	-0.824 ***
	(0.181)	(0.112)	(0.121)	(0.121)	(0.121)
meter reading by local authority	0.193 **	0.240 ***	0.140	0.110	0.120
	(0.088)	(0.077)	(0.119)	(0.118)	(0.119)
transparency	0.308 ***	0.326 **	2.946 **	2.765 **	2.800 **
	(0.105)	(0.149)	(1.322)	(1.201)	(1.195)
transparency*log(landvalue)			-0.250 **	-0.241 **	-0.243 **
			(0.128)	(0.117)	(0.117)
fee	-0.003	-0.007	-0.009 *	-0.009 *	-0.008 *
	(0.002)	(0.005)	(0.005)	(0.005)	(0.005)
Inividual Characteristics					
Number of farms in the village	-3.86E-005	-0.001	-0.001	-0.001	-0.003 ***
	(0.00004)	(0.00039)	(0.00044)	(0.00046)	(0.00074)
Land Gini Concentration ratio	-4.776 ***	-123.158 ***	-151.030 ***	-156.894 ***	-35.590 **
	(1.565)	(37.266)	(40.358)	(41.268)	(17.625)
Land Gini Concentration ratio (sq)	1.729	96.164 ***	119.690 ***	122.444 ***	
	(2.634)	(36.507)	(39.391)	(40.306)	
Relative Mean Deviation of well depth dist'n	-0.157	-1.148	-1.547	-1.697	0.041
	(0.107)	(1.594)	(1.705)	(1.736)	(1.562)
% irrigated land	0.036	-0.754	-0.898 *	-0.910	-0.770
	(0.048)	(0.512)	(0.558)	(0.590)	(0.603)
land value (log)	-0.137 ***	-2.232 ***	-2.475 ***	-2.645 ***	-2.388 ***
	(0.044)	(0.729)	(0.774)	(0.798)	(0.790)
Land Gini concentration ratio.*(log)landvalue	0.283 ***	3.229 **	3.769 **	4.114 **	3.590 **
	(0.097)	(1.486)	(1.570)	(1.618)	(1.608)
factor 1 of environment concern score	-0.033	-0.147	-0.218	-0.248	-0.290 *
	(0.092)	(0.159)	(0.168)	(0.177)	(0.180)
factor 2 of environment concern score	-0.181 **	-0.477 **	-0.433 ***	-0.423 ***	-0.503 ***
	(0.078)	(0.116)	(0.123)	(0.131)	(0.134)
Education-primary school	-0.036	1.033 ***	1.161 ***	1.154 ***	1.144 ***
	(0.035)	(0.230)	(0.245)	(0.254)	(0.251)
Education-secondary school and above	-0.024	0.274	0.428	0.394	0.371
	(0.037)	(0.246)	(0.270)	(0.279)	(0.288)
downstream	0.030	2.612 ***	2.660 ***	2.732 ***	2.190 ***
	(0.053)	(0.493)	(0.534)	(0.547)	(0.544)
downstream*distance to the dam	0.001	-0.019 *	-0.014	-0.015	0.006
	(0.001)	(0.010)	(0.011)	(0.012)	(0.012)
(log) watertable fall 1990-2007 (m)	0.005	1.228 ***	1.262 ***	1.292 ***	2.475 ***
	(0.035)	(0.369)	(0.400)	(0.416)	(0.575)
coordination degree in village ceremony					3.078 ***
					(0.631)
coordination degree in mosque maintanance					0.095 **
					(0.352)
Standard Deviation of Random Coefficient					
meter reading by local authority			1.257 ***	1.233 ***	1.246 ***
			(0.139)	(0.135)	(0.136)
transparency		1.872 ***	1.967 ***	1.608 ***	1.601 ***
		(0.159)	(0.171)	(0.241)	(0.240)
Correlation between coefficients					
cov(meterreading-local,transparency)				1.185 ***	1.173 ***
				(0.252)	(0.260)
N	5,424	5,424	5,424	5,424	5,424
LR χ^2		247.54	315.33	342.9	343.28
Log likelihood (pseudo in mlogit)	-3143.814	-1520.28	-1485.33	-1471.54	-1454.92

Note: **Factor 1 and 2 of environmental concern scores** are constructed from factor analysis with the scores from last five questions in Environmental Concern in farmer's questionnaire. **Factor 1** shows one's awareness of water scarcity in the local aquifer, and **factor 2** indicates one's awareness of externality of self's water use on the others. Lower scores indicate a higher degree of environmental awareness.

variables "*villagers' coordination in village ceremony*" and "*villagers' coordination in maintenance of mosque*" in the last column. These two variables reflect the coordination degree in traditional or religious activities and are evaluated by the village leader. They are included as an effort to proxy for omitted variable in the previous regressions. The coefficients on both variables are surprisingly highly significant and positive, implying that these two variables have at least partly captured the omitted villages' fixed effect that have influenced villagers' policy preference. Under this new specification, the impact of land Gini coefficient turns less significant. To avoid multi-collinearity, we remove its quadratic term in the regression. As a result, the marginal effect of Gini coefficient on the probability of a farmer who has mean level of land value and is in a village with mean Gini coefficient to vote for policy change reduces to 0.60 [18], i.e. for 0.1 unit increase in land Gini coefficient from the mean value (0.49), the probability of voting for policy change for a farmer with mean land value increases by merely 6%. Moreover, the demand for transparency keeps consistently high. The average willingness to pay for a regime especially with transparency varies from TD -40 for the highest land value holder to TD 112.5 for the lowest land value holder, with the medium land value holder's willingness to pay at TD 33.6.

In summary, the result from choice experiment shows majority of farmers are willing to pay a significant amount of money for a transparent collective water management system with neutral agent accountable for the management. This result on the other hand reveals the main obstacles that impede the formation of cooperation under current institution are asymmetric information and lack of monitoring. Although such information problems arise from high transaction costs of collecting and conveying data regarding the status of the resource being exploited (Libecap (2008)), our experiment shows, on average farmers are willing to pay for the transaction cost in order to implement a cooperative water management regime. Moreover, installing water meter and a "name and shame" policy by publishing water use information once a month offers a practical policy alternative at a reasonable low cost.

2.5 Discussion and Conclusion

A major priority for Tunisian water managers in the Merguellil Valley is to find ways to stop the continuous decline of the water table. This issue is important because of the economic and environmental consequences of such decline. The main cause of this depletion of the groundwater, the over-exploitation of the aquifer due to the multiplication of unlicensed wells and boreholes, is well known. Despite the existence of a legislation regulating drilling of boreholes and wells, the authorities are reluctant to enforce the law for both economic and social reasons. Nonetheless, managing the groundwater has become imperative if irreversible damages are to be prevented. To provide a better understanding of the farmers' likely attitudes towards policy changes designed to stabilize the water table level, a policy choice experiment

[18] The marginal effect is calculated as: $f(\beta X)\beta = \frac{exp(\beta X)}{1+exp(\beta X)}\beta = \frac{exp((-35.590+3.590*10.18511)*.4900227)}{1+exp((-35.590+3.590*10.18511)*.4900227)} * (-35.590 + 3.590 * 10.18511) = .60145887$

has been used. The present experiment seeks to elicit farmers' willingness to pay to shift from the current status quo regime where the groundwater is being over-exploited to a regime that ensures a sustainable management of the groundwater.

Undoubtedly, this new regime will be costly to the farmers because that under the new policy 1) groundwater will be no longer free; 2) meters will be installed in each farm and institutions monitoring closely water use as well as potential defrauding behavior will be implemented; 3) restriction to irrigated areas might be imposed in cases of serious water scarcity. The main benefit to the farmers is that a stabilization of the water table, in addition to ensuring a good quality of water, guarantees the reliability of the water supply and a relatively low extraction cost.

Our analysis suggests that, assuming that the respondents are representative of the farming community of the Merguellil Valley, farmers seem ready for a policy change to manage the groundwater, even if this means they have to pay substantial short term costs (pricing of groundwater, metering and quantity restriction) to reap long term benefits. The condition for such acceptance however, is that farmers require transparency and independent monitoring. These requirements, they believe, should guarantee them equal and fair treatment. Heterogeneity among farmers is key in explaining the willingness to shift to an alternative regime or to remain with the status quo. As land distribution becomes more unequal, farmers seem to be more willing to engage in collective action to achieve a more sustainable management of the aquifer. On the other hand, we also find evidence to support that heterogeneity is good for local property resource preservation, in particular, greater land inequality also results in the milder fall of the water table. However this fact is not perceived by villagers, who usually have higher demand for equality in water use under more unequal land distribution. This seemingly contradictory finding reconciles the prediction by Baland and Platteau (1999) : In voluntary provision problems, inequality may contribute to the efficient outcome while "in regulated settings, inequality tends to reduce the acceptability of available regulatory schemes". Finally, the opposition of policy change may very likely come from wealthier farmers, as they are the beneficiaries from the current region and they may oppose to any new policy that could threaten their current position.

Our findings have very strong policy implications. As more government involvements try to be put in place to tackle the "common property tragedy", it is important to notice any intervention needs to remove the obstacles which impedes cooperation at local level in the first place, as it might be "partly determined by the same factors that make collective actions unsuccessful" (Bandiera et al. (2005)). Except changing wealth distribution, building a transparent system and make private information public among all users may be a more practical policy option.

Chapter 2 Appendix

2.A Statistics and map of study area

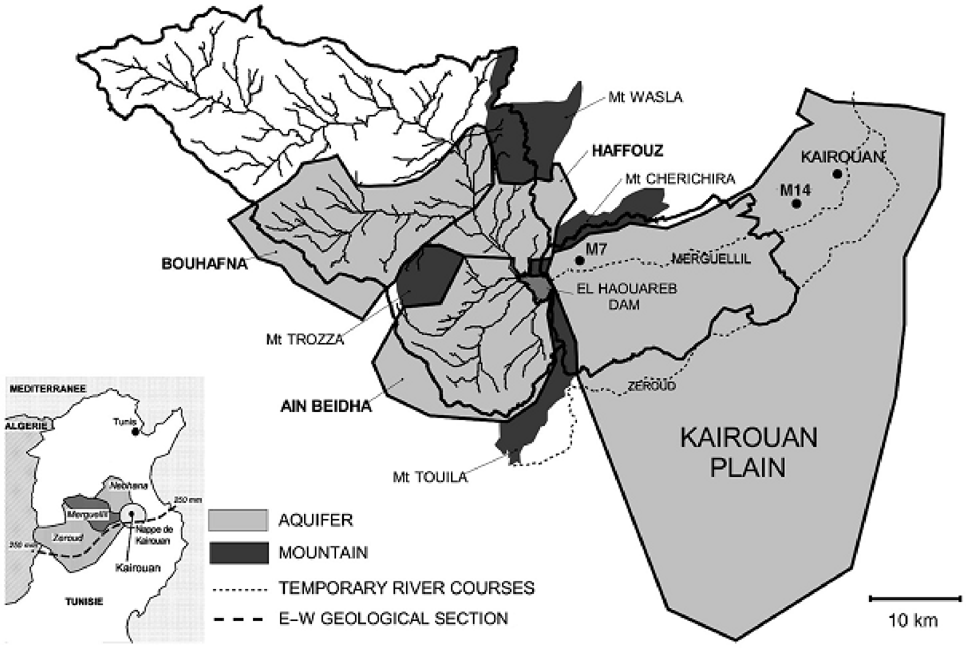


Figure 2.4: Location of Survey Area. Cited from Albouchi (2006)

Table 2.6: Tunisia Data: Summary Statistics

	mean	s.d.
Individual level (sample size=246)		
Gender (1=male)	1.004	
Age	40.615	14.77
Education		
Illiterate	0.18	0.39
Primary school	0.54	0.5
Secondary school	0.22	0.41
college	0.02	0.14
university	0.04	0.19
Cultivated land area(ha)	7.39	6.71
% of land irrigated	0.92	0.202
currently in GIC	0.03	
number of private wells	1.05	0.24
Use dripping technology	0.75	0.44
Use sprinkling technology	0.39	0.49
Village level (sample size=28)		
number of households	472.36	523.1
number of farms	355.75	319.76
0-2 ha	50.04	44.07
2-4 ha	64.36	52.92
4-6 ha	70.14	90.42
6-10 ha	84.5	88.99
10-20 ha	49.43	50.03
20-50 ha	29.36	39.69
50 ha and above	7.93	8.88
Downstream to the dam	0.86	0.36
Fall of watertable from 1990 to 2007(meter)	18.36	6.78
Mean of welldepth (meter)	45.55	9.36

2.B Proof of Lemma

Proof for Lemma 1.

The proof follows entirely from Bardhan et al. (2007). By the definition of $g(l_i)$, $f_2(l_i, g(l_i)) = h(l_i, g(l_i)) = \frac{1}{b+c}$. By the implicit functions theorem, we determine:

$$g'(l_i) = -\frac{h_1}{h_2} \tag{2.10}$$

It is obvious from Assumption 1 with $h_1 = f_{12} > 0$ (i.e. the two inputs are complementary) and $h_2 = f_{22} < 0$ that $g'(l_i) > 0$. It implies the response curve of collective input to the private input ($w_i = g(l_i)$) is upward sloping and always above zero for any positive private (land) input. This result is derived directly from the setting of constant marginal extraction cost which is the same for everyone and the assumption of complementarity relationship of both inputs.

By differentiating expression (2.10) with respect to land, we get:

$$g''(l_i) = -\frac{h_{11}h_2^2 - 2h_1h_2h_{12} + h_{22}h_1^2}{h_2^3} \tag{2.11}$$

The condition $g''(l_i) \leq 0$ is equivalent to the determinant $\begin{vmatrix} 0 & h_1 & h_2 \\ h_1 & h_{11} & h_{12} \\ h_2 & h_{12} & h_{22} \end{vmatrix}$ being ≤ 0 which in turn is equivalent to $h(l_i, w_i)$ being quasi-concave (Theorem 21.20 in Simon and Blume (1994)).

Proof for Lemma 2.

Under differentiated price, most farmers produce under an amplified marginal product of water and thus would extract more water than in the baseline model. In another word, $\phi(l_i) > g(l_i)$. This effect of product price on resource use is also discussed in the Clark model of fisheries under open access: resource users may accelerate their extraction in the presence of higher resource prices all things being equal (Clark (1973)). By the implicit functions theorem, we determine the slope of the response curve of water to land as

$$\phi'(l_i) = -\frac{h_1}{h_2} - \frac{h}{h_2}\frac{\delta_i'}{\delta_i} \tag{2.12}$$

where δ_i and δ_i' are abbreviations for $\delta(l_i)$ and $\delta'(l_i)$ separately. By Assumption 3-5 and Lemma 1, $\phi'(l_i) > g'(l_i) > 0$, i.e. the response curve of water under differentiated market is upward sloping and has a steeper slope, not only because water is complement to land, but also because the price wedge gives farmers the incentive to accelerate extraction. Same as in the baseline model, the effect of mean-preserving spread in land distribution depends on the curvature of the response curve, which is

$$\phi''(l_i) = g''(l_i) - \frac{h^2 h_{22}}{h_2^3}\left(\frac{\delta_i'}{\delta_i}\right)^2 + \frac{2h\,(h_2 h_{12} - h_1 h_{22})}{h_2^3}\frac{\delta_i'}{\delta_i} + \frac{h}{h_2}\frac{2\delta_i'^2 - \delta_i''\delta_i}{\delta_i^2}$$
$$= g''(l_i) - \frac{h^2 h_{22}}{h_2^3}\left(\frac{\delta_i'}{\delta_i}\right)^2 + \frac{2h}{h_2^2}\left(h_{12} + g'(l_i)h_{22}\right)\frac{\delta_i'}{\delta_i} + \frac{h}{h_2}\frac{2\delta_i'^2 - \delta_i''\delta_i}{\delta_i^2} \qquad (2.13)$$

However, the sign of expression (2.13) is ambiguous. We establish earlier that $g''(l_i) \leq 0$. By Assumption 3-4, we are certain that the second term is positive and the third term is negative if $0 \leq g'(l_i) \leq -\frac{h_{12}}{h_{22}}$ and positive if $g'(l_i) \geq -\frac{h_{12}}{h_{22}}$. Finally, the sign of the last term depends on the sign of $2\delta_i'^2 - \delta_i''\delta_i$.

As the function itself displays, the curvature of $\phi(l_i)$ depends on the shape of $\delta(l_i)$. We can demonstrate this with a simple exercise. Assume $\delta(l_i)$ is convex at lower part of the land distribution and concave at higher end. Define $\tilde{l}$ as the inflection point of the price function $\delta(.)$, i.e. the point at which the second derivative $\delta''(l_i)$ changes from being positive (for any $l_i < \tilde{l}$) to negative (for any $l_i > \tilde{l}$). For intermediate values of land endowment l_k, i.e. around the inflection point $\tilde{l}$, δ_k' is relatively larger than the slopes for small or large endowments. The sign of $2\delta_i'^2 - \delta_i''\delta_i$ in equation (2.13) is unambiguously positive for $l_i \to \tilde{l}^+$ since then $\delta_i'' < 0$, implying that the fourth term in Eq. (2.13) is negative together with the first and the third term. Then the sign of $\phi''(l_i)$ depends on the magnitude of the positive effect (second term) relative to the negative effects (the other three terms). For $l_i \to \tilde{l}^-$, the sign of $2\delta_i'^2 - \delta_i''\delta_i$ is ambiguous without further structure imposed on the shape of the price function $\delta(.)$. In any event, whatever its sign, the overall sign of $\phi''(l_i)$ remains undetermined.

As land endowment moves away from $\tilde{l}$, δ_i' decreases and becomes negligible when l_i is small enough or big enough. Neglecting all terms with δ_i' we then have $\phi''(l_i) \approx g''(l_i) - \frac{h}{h_2}\frac{\delta_i''}{\delta_i}$. For large land endowment where $\delta_i'' < 0$, we are certain that $\phi''(l_i) < 0$. While for small land endowment where $\delta_i'' > 0$, then $\phi''(l_i) \lesseqgtr 0$ again depending on the relative magnitude of the two terms. ■

Proof for Lemma 3.

By Eq. (2.2) and (2.3) we have: $f_2^* \cdot (b + nc) = f_2^n \cdot (b + c)$, so that $f_2^* > f_2^n$, where f_2^* and f_2^n represent marginal product of water input under cooperative and noncooperative equilibrium separately. Since f_2 is a decreasing function of water input w_i, we then easily get $w_i^n > w_i^* > 0$ for any i. And because $e_i = \frac{w_i - \frac{c}{b+cn}\sum_{j\neq i} w_j}{b}$, a fall in all w_i (and any other w_j) also leads to a fall in e_i, i.e., $e_i^n > e_i^* > 0$.

Moreover, $f_2^* - f_2^n = f_2^n \frac{(1-n)c}{b+nc} > 0$, that is $f_2^* - f_2^n$ increases with f_2^n, which by assumption further increases with land endowment, then the difference between marginal product of water under two optimum is bigger for larger land holder. Since marginal product of water decreases with water input, for a bigger rise in marginal product of water, larger farmer has to suffer a bigger cut in water input under cooperation. In other words, the difference $w_i^n - w_i^*$

becomes larger for big farmers, or equivalently $\phi'(l_i) > \psi'(l_i)$, i.e. water response curve to land has a bigger slope under the Nash Equilibrium. Given that both functions $\phi(l_i)$ and $\psi(l_i)$ are increasing and greater than 0 for $l_i > 0$, it has to be the case that farmers' water extraction is consistently lower should they agree to engage in cooperation: i.e. $\phi(l_i) > \psi(l_i)$ for any $l_i > 0$. The difference in water input is also reflected in difference in water extraction effort, and $\frac{d(e_i^n - e_i^*)}{dl_i} > 0$. In other words, bigger farmers have to bear more of the brunt of the conservation effort should they join cooperation.■

2.C Method to measure inequality from grouped observation

This appendix introduces briefly the method of using grouped observation to calculate inequality measurement first developed by Kakwani and Podder (1976).

Suppose a positive variable X of a family is a random variable with probability distribution function $F(x)$, and density function $g(x)$, and mean μ. The first moment distribution function of X is given by

$$F_1(x) = \frac{1}{\mu}\int_0^x Xg(X)dX$$

The Lorenz curve is the relationship between $F(x)$ and $F_1(x)$. The curve is shown in Figure 2.5. The equation of the line $F_1 = F$ is called egalitarian line.

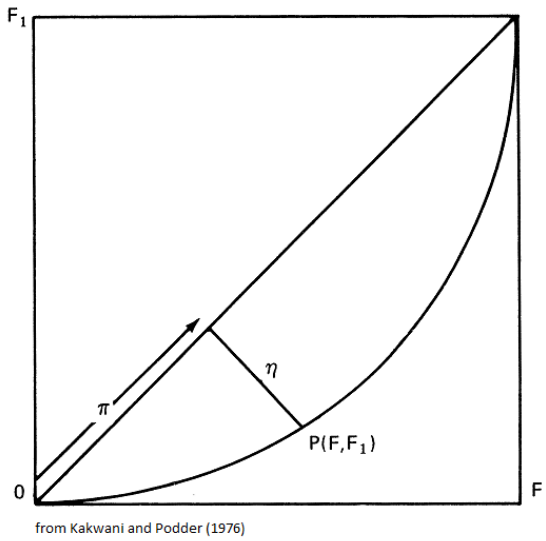


Figure 2.5: Lorenz Curve

Let P be any point on the curve with co-ordinates (F, F_1), and

$\pi = \frac{1}{\sqrt{2}}(F + F_1)$ and $\eta = \frac{1}{\sqrt{2}}(F - F_1)$;

then η will be the length of the ordinate from P on the egalitarian line and πwill be the distance of the ordinate from the origin along the egalitarian line. Since the Lorenz curves lie below the egalitarian line, $F_1 \leq F$ which implies $\eta \geq 0$. Further, if X is always positive, the above equation implies η to be less than or equal to π.

The equation of the Lorenz curve in terms of π and η can now be written as:

$$\eta = f(\pi)$$

where πvaries from zero to $\sqrt{2}$.

We can write the Lorenz curve functional form as:

$$\eta = a\pi^{\alpha}(\sqrt{2}-\pi)^{\beta}, \qquad a > 0, \alpha > 0, \beta > 0 \tag{2.14}$$

when $\alpha = \beta$ the Lorenz curve has a symmetric shape, with the value of η at $\pi$and $(\sqrt{2}-\pi)$ be equal for all values of π.

In the empirical application, we estimate F and F_1 using the grouped observations of land distribution, calculate $\hat{\pi}$and $\hat{\eta}$, and regress $log(\hat{\eta})$ on $log(\hat{\pi})$ and $log(\sqrt{2}-\hat{\pi})$ according to eq. (2.14) to obtain the estimates $\hat{a}$, $\hat{\alpha}$ and $\hat{\beta}$, which can be substituted into eq. (2.7) and (2.8) for Gini Concentration Ratio and Relative Mean Deviation of land distribution.

2.D Questionnaires

The data were collected from two separate surveys: the first survey was conducted in April 2007 with farmers' questionnaire; the second survey (follow-up) was conducted in Dec.20010-Jan.2011 with village level questionnaire in villages where the first survey was conducted.

Department of Economics
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2007 AquaStress Irrigation

Survey Questionnaire*

This survey is only used for the purpose of academic analysis.
Your information will be kept confidential.

Code: ________________________________

Street: ________________________________

Village: ________________________________

Town: ________________________________

Post code: ____________________________

Phone number: _________________________

Enumerator: ___________________________

Date: ____dd____/____mm____/_____yy____

* The questionnaire should be asked by the enumerator, rather than filled by the respondent. The enumerator should explain the attributes of the choice sets and how to make choices carefully to the respondent. All the questions, if not mentioned specifically, are referred to the facts based on the year of 2006.

Hello, my name is _____________ and I work for AquaStress project funded by the European Union. We are conducting a research on the usage of water for agricultural purposes in the Merguellil valley. We would appreciate it if you could respond to some questions that will help us ensure that any policy changes regarding agricultural water usage will address the actual needs of the farmers in the area. The process will not take more than 30 minutes.

First of all, we would like to ask you something about your farm, so that we can see if we have interviewed a broad range of farms. This information will remain strictly anonymous and confidential and will be used for statistical analysis only.

❖ **Part I: Background Information**

Q1 Your gender

☐1 Male ❑ ☐2 Female ❑

Q2 Your age _________

Q3 Your family size [Q3a]______ *(household size, include all the people who share the same budget)*

How many children at 16 or below [Q3b]____________

Q4 How many people work on your farm, including permanent and temporary workers? (both include family labor and hired labor)

Permanent [Q4a]_________ Temporary [Q4b]___________

Q5 Which of these educational levels have you completed?

☐1 Illiterate
☐2 Able to write and read, but no schooling before
☐3 Primary School
☐4 Secondary School
☐5 Upper Secondary School
☐6 Professional qualification
☐7 University degree

Q6 Please indicate which income (profit) group best approximates your farm income before tax.

- ☐1 0 - 1 999 TD
- ☐2 2 000 - 3 999 TD
- ☐3 4 000 - 5 999 TD
- ☐4 6 000 - 7 999 TD
- ☐5 8 000 - 9 999 TD
- ☐6 10 000 - 11 999 TD
- ☐7 12 000 - 14 999 TD
- ☐8 15 000 - 17 999 TD
- ☐9 18 000 - 19 999 TD
- ☐10 20 000 - 24 999 TD
- ☐11 25 000 - 29 999 TD
- ☐12 over 30 000 TD

Q7 How much land you own? [Q7a]________ (ha)

How did you get your land? [Q7b] ☐1 Inherited ☐2 Purchased

And how long you have owned the land? [Q7c]________ (years)

What is the present value of your land? [Q7d]________ (TD)

Q8 Have you rented land from someone else? [Q8a] ☐ Yes ❑ ☐ No ❑

(If YES, ask) How much land you have rented? [Q8b]________ (ha)

How long have you rented the land? [Q8c]________ (years)

How much do you pay for the rent each year? [Q8d] __________ (TD/ha)

Have you let out land to someone else? [Q8e] ☐ Yes ❑ ☐ No ❑

(If YES, ask) How much land you have let out? [Q8f] __________ (ha)

How much do you charge for the rent each year? [Q8g]_________ (TD/ha)

Q9 How many residential and non-residential buildings do you have?

[Residential][Q9a]__________ [Non-residential] [Q9b] ________

Present Value for each of them

[Q9c]________+[Q9d]__________+[Q9e]________+[Q9f]_______= TOTAL[Q9g]___________

Q10 How many livestock you have?

Sheep [Under 6 months] [Q10a]________ [Over 6 months][Q10b]_________

Goats [Under 6 months] [Q10c]________ [Over 6 months] [Q10d]__________

Cattle [Under 1 year] [Q10e]_________ [Over 1 year] [Q10f] ____________

Chicken [Under 3 months] [Q10g]________ [Over 3 months] [Q10h]__________

Q11 Number and value of other assets:

Tractors [number] [Q11a]__________ [value] [Q11b]__________

Greenhouse [number] [Q11c]__________ [value] [Q11d]__________

Seeding-machine [number] [Q11e]__________ [value] [Q11f]__________

Harvesting-machine [number] [Q11g]__________ [value] [Q11h]__________

Other 1 (specify) [Q11i]_______ [number] [Q11j]__________ [value] [Q11k]__________

Other 2 (specify)_[Q11l]______ [number] [Q11m]__________[value] [Q11n]__________

Q12 What are the main products of your farm? [Multiple choices are applicable.]

☐ 1 Cereals ❑ ☐ 2 Olive ❑ ☐ 3 Vegetables ❑ ☐4 Gardening❑ ☐ 5 Other Fruit trees ❑

☐ 6 Fodder (for sheep or goats or cow)❑

Q13 Other incomes (TD/year)

Number of people in the household doing off-farm work [Q13a]_______

Annual off-farm income for each member

[Q13b]_______ + [Q13c]_______ + [Q13d]_________ + [Q13e]_________

Annual remittances from the emigrants from the outside family members [Q13f]____________

❖ **Part II: Irrigation Information**

Q14 What is the main irrigation technology you use?

☐₁ Flooding ❑ ☐ ₂ Furrowing ❑ ☐ ₃ Sprinkling ❑ ☐ ₄ Drip ❑

☐ ₅ Others_________________ ❑

Q15 What is the source of water you use for irrigation? (If multiple choices, please specify the percentage of water from each selected source)

☐ ₁ Water from the public irrigation scheme ❑ [**Q151**a] ____________%

☐ ₂ Surface water from the artificial lakes ❑ [**Q152**a] ____________%

☐ ₃ Ground water from the well of your own farm ❑ [**Q153**a]____________%

☐ ₄ Ground water from the well of the other villagers ❑ [**Q154**a] ____________%

☐ ₅ Ground water from the collective well ❑ [**Q155**a]____________%

☐ ₆ Others (please specify) _____________________ ❑ [**Q156**a]____________%

Q16 [Ask if the farm uses groundwater] How many wells do you have on your farm? When were they constructed? What was the installation cost for each? What is the depth, capacity and pump rate for each?

Infrastructure	**No.**	**Date (mm/yy)**	**Investment cost (TD)**	**Depth (m)**	**Capacity (m^3)**	**Head requirement (m)**	**Pump Rate (l/hr)**	**Energy? (Diesel / Electricity)**
Private well	A1							
	A2							
Collective well	C1							
	C2							

Q17 What is the area of the land you cultivated ? ______________ (ha)

Q18 What is the area of the irrigated land? __________________(ha)

How is the land allocated across different crops?

Crop name						
Cultivated area (ha)						
Irrigated area (ha)						
Source of water*						
How many days each week?						
How many months?						
How many hours per irrigation (day)?						
Number of hours did you irrigate last year in total? (<u>hrs/day</u> * <u>days/week</u> * <u>4.5 weeks/month</u> * <u>months</u>)						
Harvested Product						
Sold quantity						
Sale price						

❖ **Part III: Water Management**

Q21 Are you provided with water by a GIC? □1 Yes □2 No (If yes, finish Q22-Q24)

Q22 How and how much do you pay for the water provided by the GIC?

□1 By volume [Q22a]__________TD/m^3

□2 By acreage and crop type [Q22b]

[crop 1: [Q22b1]_____] [Q22b1']______TD/ha [crop 2: [Q22b2]______] [Q22b2']_____TD/ha

[crop 3: [Q22b3]_____] [Q22b3'] _____TD/ha [crop 4: [Q22b4] _____] [Q22b4']_____TD/ha

□3 By acreage [Q22c]__________ TD/ha

□4 Other (please specify) [Q22d]______________

Apart from water cost, do you pay additional fees to the GIC, for example, administration cost?

[Q22e]□1 Yes ___________ TD □2 No

Q23 How was the leader of the GIC elected?

□1 Voted for by villagers □2 Selected by the government □3 Other (Please specify) _______

Q24 Do you participate in the management of water resource in the village?

□1 Yes □2 No

[If yes, please explain how] ________________________________

Q25 Are you satisfied with the management by GIC?

□1 Yes □2 No □3 Can't tell.

Q26 Which factor do you think the management of GIC should improve? (Please rank the first three important factors using 1, 2, 3, with '1' for the most important.)

□1 Irrigation efficiency Rank _______[Q26a]

□2 Equality (For example, equal policy for different sizes of farms; Or same price for all the farmers) Rank _______[Q26b]

□3 Transparency (For example, how often the farmers should meet together with the committee of the GIC; or the water use information should be made public to all the farmers) Rank _______[Q26c]

□4 Price level Rank _______[Q26d]

❖ **Part IV: Credit constraints**

Q25 Have you ever received any subsidy for use of some irrigation technology? ☐ Yes ☐ No

[If yes, answer the following question] **What** and **how much** is this subsidy? **How** did you use this subsidy, for example use on digging wells or improve irrigation technology?

Nº	**Subsidy name**	**How much?**	**How did you use this subsidy?**
1	[S1a]	[S1b]	[S1c]
2	[S2a]	[S2b]	[S2c]
3	[S3a]	[S3b]	[S3c]

Q26 In the past 5 years, on average how much could you borrow from the bank for agriculture production each year? [Q26a]___________

How much can you borrow from friends or relatives each time? [Q26b]_______________

Are these enough? [Q26c]________

How much do you want to borrow for your production each year if possible? [Q26d]__________

How are you going to use this money? [Q26e]

☐1 Investment in irrigation infrastructure ☐2 Investment in machinery

☐3 Planting more cash crops ☐4 Others [Please specify] ________________

❖ **Part V: Environmental concerns**

Q27 Please indicate your strength or agreement or disagreement for each of the following statements from 1-5, where 1 means ***strongly agree*** and 5 means ***strongly disagree***. If you don't know (or can't tell, please leave it blank.)

The Earth has very limited resources for human beings.

Strongly agree ***Strongly disagree***

1 2 3 4 5

The balance of nature is very delicate and easily upset.

1 2 3 4 5

Water is as important for nature as for humans.

1 2 3 4 5

There will be serious water scarcity in the future if current water usage doesn't change.

1 2 3 4 5

Groundwater and surface water are connected.

1 2 3 4 5

The water resource in the Merguellil valley has been very scarce.

1 2 3 4 5

I should be concerned how my water usage affects the availability of water for others.

1 2 3 4 5

I should pay for water by the exact amount I have used.

1 2 3 4 5

I will reduce using water if other people in my village do the same.

1 2 3 4 5

I will reduce using water if other people in the whole Merguellil valley do the same.

1 2 3 4 5

❖ **Part VI: Choice Experiment**

Thank you for your patience to reply to all of these questions. We would like to ask you about your opinion on the water policy design. As you may know, the Merguellil valley is facing a more and more serious water scarcity problem. The groundwater table has decreased from 42 meters below ground in 1986 to 52 meters below ground in 2006. If the water table keeps decreasing at this speed, the water table will be nearly 60 meters in 20 years. In order to stabilize the groundwater table at the current level, the government is designing a policy to encourage people to reduce water use. In order to do this, the government plans to charge groundwater use by metering.

The Department of Agriculture will institute a water management unit throughout the Merguiellil valley. It will install water meters for all the wells in the gouvernorat of Kairaouan (Merguellil valley) and will charge groundwater use based on the volume used. The volumetric price will be the same as in the public irrigation scheme.

In order to improve water management efficiency and equality, the farmers' opinion on meter reading and information release will be taken into account when designing the policy. The installation fee has to be required from the farmers. You have the right to choose which level of installation fee you are willing to pay in terms of the corresponding policy design (for example, which restriction will be imposed.). And you have the right to opt out this policy and keep your current situation, with water table deteriorating at the current pace.

No matter which policy you choose, majority rules will be applied on the final voting outcome, i.e., if more than half of the people in the village vote for policy change, the new water management association will be formed and collective action will be taken.

The proposed policy will be changed in the following way:

1. **Restriction on irrigation area**: This indicator restricts the percentage of the farm area that are not allowed to be irrigated. There are four levels of this indicator: No restriction, 10% of land are not allowed, 20% of land are not allowed, 30% of land are not allowed.
2. **Meter reading:** It refers to who is responsible for reading water meters that you would like to choose. There are two alternatives: local government authority, or newly formed water management unit.
3. **Transparency:** This indicator refers whether the waer use quantity and the deliberate damage of water meter will be made public to all the farmers in the village. If yes, you can observe how much water used by other farmers in your village, and whose water meter has been broken deliberately.

4. **Installation fee:** It refers to how much each year you are willing to pay for meter installation on your farm corresponding to each different possible policy. The meter generally cost 30 TD. But you can choose to pay less in some policies, and the difference will be covered by the government. There are four possible levels for you too choose: Free (0 TD), 10 TD, 20 TD, 30 TD.

In order to design policy which is best for the farmers, we need your help to make sure the plan suits the needs of the farming population and for this reason we ask for your opinion on a number of different scenarios that can be applied.

In the following cards we present a number of different scenarios that can emerge from the application of this plan. In each card there are 3 scenarios. Among those 3 scenarios we ask you to choose the one you prefer most. The third scenario in each card corresponds to the case that you choose to keep your current situation, with the groundwater table level decreasing at the current speed. There is no right or wrong answer and whatever you say will be treated as strictly confidential.

Note: The 16 choice sets are divided into 2 groups (Choice Set 1-8 and Choice Set 9-16). Each respondent anwers only 1 group of choice sets.

Choice Set 1

	Restriction on land area to be irrigated	**Who reads water meter**	**Transparency**	**Installation fee (TD/year)**	**Tick the policy you prefer**
Policy A	20% of land is not allowed to be irrigated	Water Management Unit	Not public	20	☐
Policy B	No restriction	Water Management Unit	Water use and damage of meter public to all the farmers	30	☐
Policy C	I would like to keep the current status quo and don't vote for the pricing policy.				☐

Choice Set 2

	Restriction on land area to be irrigated	**Who reads water meter**	**Transparency**	**Installation fee (TD/year)**	**Tick the policy you prefer**
Policy A	30% of land is not allowed to be irrigated	Local Government	Not public	0	☐
Policy B	No restriction	Local Government	Water use and damage of meter public to all the farmers	0	☐
Policy C	I would like to keep the current status quo and don't vote for the pricing policy.				☐

Choice Set 3

	Restriction on land area to be irrigated	Who reads water meter	Transparency	Installation fee (TD/year)	Tick the policy you prefer
Policy A	10% of land is not allowed to be irrigated	Local Government	Water use and damage of meter public to all the farmers	20	☐
Policy B	No restriction	Water Management Unit	Not public	10	☐
Policy C	I would like to keep the current status quo and don't vote for the pricing policy.				☐

Choice Set 4

	Restriction on land area to be irrigated	Who reads water meter	Transparency	Installation fee (TD/year)	Tick the policy you prefer
Policy A	No restriction	Local Government	Water use and damage of meter public to all the farmers	30	☐
Policy B	10% of land is not allowed to be irrigated	Water Management Unit	Water use and damage of meter public to all the farmers	20	☐
Policy C	I would like to keep the current status quo and don't vote for the pricing policy.				☐

Choice Set 5

	Restriction on land area to be irrigated	Who reads water meter	Transparency	Installation fee (TD/year)	Tick the policy you prefer
Policy A	10% of land is not allowed to be irrigated	Water Management Unit	Water use and damage of meter public to all the farmers	10	☐
Policy B	30% of land is not allowed to be irrigated	Water Management Unit	Not public	0	☐
Policy C	I would like to keep the current status quo and don't vote for the pricing policy.				☐

Choice Set 6

	Restriction on land area to be irrigated	Who reads water meter	Transparency	Installation fee (TD/year)	Tick the policy you prefer
Policy A	30% of land is not allowed to be irrigated	Water Management Unit	Not public	30	☐
Policy B	20% of land is not allowed to be irrigated	Water Management Unit	Water use and damage of meter public to all the farmers	30	☐
Policy C	I would like to keep the current status quo and don't vote for the pricing policy.				☐

Choice Set 7

	Restriction on land area to be irrigated	Who reads water meter	Transparency	Installation fee (TD/year)	Tick the policy you prefer
Policy A	No restriction	Local government	Not public	10	☐
Policy B	10% of land is not allowed to be irrigated	Water Management Unit	Not public	0	☐
Policy C	I would like to keep the current status quo and don't vote for the pricing policy.				☐

Choice Set 8

	Restriction on land area to be irrigated	Who reads water meter	Transparency	Installation fee (TD/year)	Tick the policy you prefer
Policy A	20% of land is not allowed to be irrigated	Local government	Water use and damage of meter public to all the farmers	30	☐
Policy B	20% of land is not allowed to be irrigated	Water Management Unit	Not public	10	☐
Policy C	I would like to keep the current status quo and don't vote for the pricing policy.				☐

Choice Set 9

	Restriction on land area to be irrigated	Who reads water meter	Transparency	Installation fee (TD/year)	Tick the policy you prefer
Policy A	20% of land is not allowed to be irrigated	Local government	Not public	10	☐
Policy B	No restriction	Local government	Not public	20	☐
Policy C	I would like to keep the current status quo and don't vote for the pricing policy.				☐

Choice Set 10

	Restriction on land area to be irrigated	Who reads water meter	Transparency	Installation fee (TD/year)	Tick the policy you prefer
Policy A	10% of land is not allowed to be irrigated	Water Management Unit	Not public	30	☐
Policy B	30% of land is not allowed to be irrigated	Local government	Not public	30	☐
Policy C	I would like to keep the current status quo and don't vote for the pricing policy.				☐

Choice Set 11

	Restriction on land area to be irrigated	Who reads water meter	Transparency	Installation fee (TD/year)	Tick the policy you prefer
Policy A	30% of land is not allowed to be irrigated	Water Management Unit	Water use and damage of meter public to all the farmers	10	☐
Policy B	10% of land is not allowed to be irrigated	Local government	Not public	30	☐
Policy C	I would like to keep the current status quo and don't vote for the pricing policy.				☐

Choice Set 12

	Restriction on land area to be irrigated	Who reads water meter	Transparency	Installation fee (TD/year)	Tick the policy you prefer
Policy A	No restriction	Local Government	Water use and damage of meter public to all the farmers	30	☐
Policy B	10% of land is not allowed to be irrigated	Water Management Unit	Water use and damage of meter public to all the farmers	20	☐
Policy C	I would like to keep the current status quo and don't vote for the pricing policy.				☐

Choice Set 13

	Restriction on land area to be irrigated	Who reads water meter	Transparency	Installation fee (TD/year)	Tick the policy you prefer
Policy A	No restriction	Water Management Unit	Not public	20	☐
Policy B	20% of land is not allowed to be irrigated	Local Government	Water use and damage of meter public to all the farmers	0	☐
Policy C	I would like to keep the current status quo and don't vote for the pricing policy.				☐

Choice Set 14

	Restriction on land area to be irrigated	Who reads water meter	Transparency	Installation fee (TD/year)	Tick the policy you prefer
Policy A	30% of land is not allowed to be irrigated	Local Government	Water use and damage of meter public to all the farmers	20	☐
Policy B	20% of land is not allowed to be irrigated	Local Government	Not public	20	☐
Policy C	I would like to keep the current status quo and don't vote for the pricing policy.				☐

Choice Set 15

	Restriction on land area to be irrigated	Who reads water meter	Transparency	Installation fee (TD/year)	Tick the policy you prefer
Policy A	10% of land is not allowed to be irrigated	Local Government	Not public	0	☐
Policy B	30% of land is not allowed to be irrigated	Water Management Unit	Water use and damage of meter public to all the farmers	20	☐
Policy C	I would like to keep the current status quo and don't vote for the pricing policy.				☐

Choice Set 16

	Restriction on land area to be irrigated	Who reads water meter	Transparency	Installation fee (TD/year)	Tick the policy you prefer
Policy A	No restriction	Water Management Unit	Water use and damage of meter public to all the farmers	0	☐
Policy B	30% of land is not allowed to be irrigated	Local Government	Water use and damage of meter public to all the farmers	10	☐
Policy C	I would like to keep the current status quo and don't vote for the pricing policy.				☐

AquaStress Irrigation

Survey Questionnaire

<u>For Village Leader ONLY</u>

(follow-up survey)

Village: ________________________________

Town: _________________________________

Oct-30- 2010

Hello, my name is _____________ and I work for AquaStress project funded by the European Union. This is a complementary survey to a survey we conducted in 2007 in Merguellil valley, on the usage of water for agricultural purposes in your village. For research purpose, we need some additional information about your village. We would appreciate it if you could respond to some questions about your village. The process will not take more than 30 minutes.

This information should all be pertained to the level in year 2007. If you can't remember exactly about that year, you should give us the information in the time period which is close to 2007.

1. How many households ____________ and farms _____________were there in your village in 2007?

Among them, how many __________ farms were operated by individuals / companies from outside of the village (including companies from cities)?

2. How many religion / clan groups in your village? ___________

What's the percentage of population for each group ?

Group name (or code)	% of population of the whole village
1	
2	
3	
4	
5	
6	
7	

Note: If there are more than one type of classification, please use the one mainly used (or recognized). Please add more rows if necessary at the back of questionnaire.

3. What is the total area of farm land in your village ? _____________

How are the farm lands distributed1?

Area of each farm (in hectare)	Number of farms in this category
0-2	
2-4	
4-6	
6-10	
10-20	
20-50	
>50	

1 The original questionnaire asks the respondent to list the farm land area for each farm in the village. But in the real survey, only the distribution of the farm land area is obtained.

4. What's the soil quality of land in your village, compared to other villages in Merguellil valley? Please circle the one level within the following scale: ____________________

a. Very good *b. Good* *c. Average* *d. Bad* *e. Very bad*

5. How much does the farm land worth in your village? (in other words, if some farmer wants to sell his land, what price can he possibly get for each **acre** of the land?) You can give a range if different land value differently. And please give the value in terms of 2007 year level.

__________________________________ dinar/acre

6. How many boreholes were there in your village in year 2007? Could you please give a list of the depth of all the wells in your village at that time? 2

Category	Well depth	Number of wells in this category
1		
2		
3		
4		
5		
6		

Note: add more rows if necessary.

7. Could you please tell me how much has water table level in your village changed during the last 20 years?

What's the level in 1990 ________________ meter under ground
and what's the level in 2007, _____________ meter under ground
and what's the current level? ______________ meter under ground

8. How many people in your village were working outside as migrants in 2007? If not available, please give the number in the year which is closest to 2007. ___________________________

9. Could you please recall the prices of the following items in 2007?

item	unit	price
diesel	dinar/litre	
electricity	dinar/kwh	
sheep (under 6 months)	dinar/each	
sheep (over 6 months)	dinar/each	
goats (under 6 months)	dinar/each	
goats (under 6 months)	dinar/each	
cattle (under 6 months)	dinar/each	
cattle (over 6 months)	dinar/each	
chicken (little)	dinar/each	
chicken (adult)	dinar/each	

2 The original questionnaire asks the respondent to list the well depth for each well/borehole in the village. But in the real survey, only the distribution of the depths is obtained.

10. What score (1-5, from lowest to highest) would you put for the coordination level in the following village level activities:

1) Construction and maintainance of village road

1 2 3 4 5

2) Village ceremony

1 2 3 4 5

3) Maintanance of village mosque

1 2 3 4 5

4) Maintainance of irrigation ditch and other irrigation facilities

1 2 3 4 5

11. How is village leader selected in your village?

1) Voted by villagers
2) Appointed by local government
3) Appointed by Akhond
4) Appointed by the local elders

Chapter 3

The effect of migration on children's education attainment in rural China

3.1 Introduction

This chapter is concerned with the education of children in rural China, and how it has been affected by the overwhelming trend of internal labour migration within the country. It contributes to the existing economic and socio-economic research on the impact of migration by examining the causal effect of parental migration on the educational attainment of children in rural China. In particular, we compare long-run education outcomes of children whose parents engaged in long-distance migration work during their children's schooling period, to the outcome of those whose parents didn't migrate during their schooling age. In order to do this, we employ two different empirical strategies that we detail below.

The importance of education in contemporary China has long been recognized. Since the decentralization policy in education was initiated following the Chinese economic reforms of the 1980s, education inequality has continued to increase due to the unbalanced market economic development across regions (Postiglione (2006)). This situation is compounded by the fact that an increasingly larger population of working age adults are participating in inter-provincial migration activities, which in turn are affecting more and more school-aged children. Since the late 1990s, there have been around 100 million people on the move each year. For the main part, temporary labour migrants relocate from inner rural areas to east coast cities, which has often been attributed as an important factor in explaining the recent economic growth in China. The most significant expansion took place during 1990s, when cross-county temporary migration flows nearly quadrupled from slightly over 20 million in 1990 to 78 million in 2000, according to the 1990 and 2000 census. Given the huge scale, the impact of this migration trend on society is far-reaching and multifold. While it is only one of many outcomes of interest, a quantitative assessment of the relationship between parental migration and child schooling outcomes remains of key policy interest.

The impact of temporary migration on child outcomes has been the focus of sociological research (e.g. Biao (2007); Zhou et al. (2005); Gao et al. (2010)). As Gao et al. (2010) note, "parental migration is a risk factor for unhealthy behaviours amongst adolescent school children in rural China". Amongst their sample of school children with parents away from home, they document a positive association in the incidence of smoking, watching more television, and even contemplation of suicide. de Brauw and Mu (2011) examine how parents' migration affect children's health and nutritional development in rural China using another data set and find that children (aged 7–12) who are left behind are more likely to be underweight and take up more household chores. However, there have been few studies which have examined the effects of migration on education outcomes. For the main part, this literature focuses on descriptive comparisons of schooling performance in a relatively short time span (e.g. Liang and Chen (2007); Chen et al. (2009)), and does not claim to identify causal relationships.

This chapter attempts to fill this gap in the literature by looking at the impact of parental migration on children's lifetime education attainment in rural China. The sociological literature discusses three main mechanisms through which migrants will affect child education attainment: first, remittances sent back by migrants may ease credit constraints and lead to a higher schooling enrollment rate (Glewwe and Jacoby (2004)), and reduce their need to rely on paid or unpaid child labour; second, the migration of the primary wage earners (especially parents) may place greater demands on children to assist in supporting the household through both paid and unpaid labour, especially when migrants fail to remit sufficient earnings; third, the disruption of family life and the loss of parental attention and discipline may hinder the performance of children in school and may impose a large psychological cost on them (Lu and Trieman (2007)). Since these mechanisms often work in competing directions, the combined effect of these channels is ambiguous and may vary across different child age groups[1].

This paper will not attempt to separate the various mechanisms. Rather, it has the more limited objective of identifying the aggregate causal effect of migration on migrants' children's education during 1990s and 2000s in rural China. In order to quantitatively evaluate the impact, we employ two different empirical methodologies. The first approach uses a fixed effect instrumental variable approach to examine the effect of the incidence of father migration on the odds of children exiting school. The second strategy we use treats children's education and parents' migration as two correlated duration processes using the framework developed by Abbring and van den Berg (2003). By applying both strategies to the same China Health and Nutrition Survey data, we find that on aggregate father's migration doesn't improve nor hinder the lifetime education attainment of the left-behind children in the long run. Of course, this result does not preclude the existence of considerable heterogeneity in responses.

The paper proceeds as follows. In the next section, we provide background information on education policy and development constraints in China. In Section 3.3 we introduce a

[1] Another potentially important mechanism which has received considerably little attention in the literature (exceptions include Antman (2007)) is the fact that migrant parents often bring back information about work opportunities in the cities. The information may change their valuation of education (or local education) relative to other non-migrant parents. This value may be formed based on their working experience in the cities.

simple theoretical model which describes how rural families make child education investment decisions, and how migration can affect left-behind children's education attainment. Section 3.4 describes the data and Section 3.5 introduces empirical strategies that we use for our analysis, discusses the relative advantages and disadvantages of the alternative approaches, and presents our main results. Finally, Section 3.6 concludes.

3.2 Policy Background

China Education System and separate job markets

China implements a popular public school system. Thanks to the nine-year-compulsory schooling policy, the basic education enrollment and attainment in China is kept at a steady high level, both in rural and urban areas, which is a feature that is not very common in other developing countries. Generally, the Chinese education system include 6 years primary school (5 years are applied in some area), 3 years secondary school, 3 years high school or 3 years vocational training school, and 2-4 years of college or university. Figure 3.1 plots the officially recorded school enrollment rates at different educational levels in China since 1978. We can see that the enrollment rate for primary schooling is nearly 100% and the one for secondary school are increasing fast since 1990 till it reaches a very high level after 2000. While high school and college/university enrollment rates are much lower, they have been increasing steadily during the last two decades. In particular, the university enrollment rate increased by nearly two folds due to the enrollment expansion policy implemented since 1999, which simultaneously encourages university to expand enrollment and changes from previous heavy subsidization system to market based fees pricing policy.

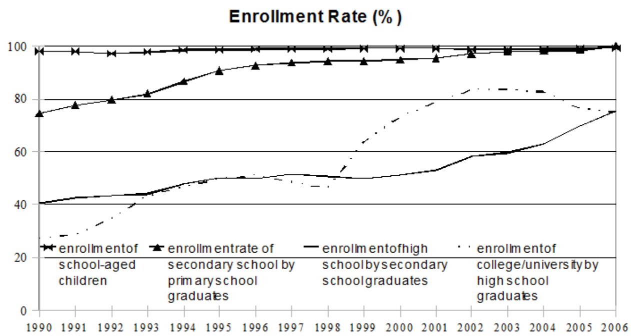


Figure 3.1: Enrollment Rate of Schools by Different Groups. Data source: National Bureau of Statistics of China (1991-2007).

Due to the limited supply of higher education opportunities, China has a system of educational rationing based on a meritocratic criteria, especially for levels beyond compulsory schooling. For rural people, education has more values than merely to improve one's ability. This is because of the separate job markets policy that traditionally implemented in China. The strict *hukou* registration system distinguishes rural residents from urban ones and discriminates the rural people from working in the cities and constrains population migration to a large extent. This is especially true during the pre-reform period, when going to university was once the only way for the rural people to get a job in cities, apart from joining the army.[2] However, in recent decades, along with the huge flow of labour migration from countryside to cities, the barrier between city and countryside has become less strict and rural people can easily get a job in city without any university degree, even though most jobs are limited to less well remunerated occupations, such as manufacturing and construction work or low skilled service sector work. Since the education requirement is usually low for these types of work, many high school aged children in fact gave up the chance for education and join in this big migration flow. This trend is also reflected in our sample. As we can see from Figure 3.2, the median age of migrants is decreasing over time, partly driven by the large majority of teenage young adults.

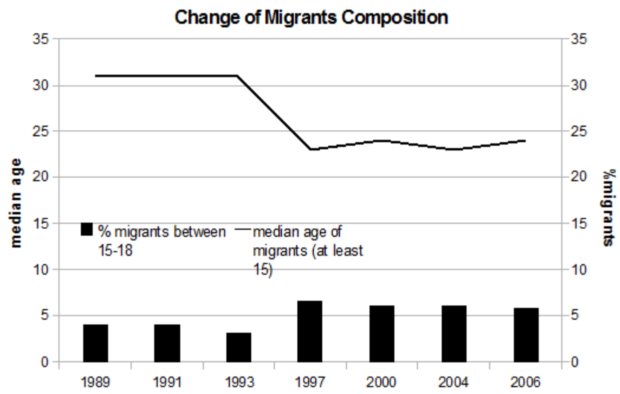


Figure 3.2: The Change of Migrants Composition in Age. Data source: constructed from CHNS data set by the author.

Education fiscal policy and regional inequality in education

Since the promulgation of education law in 1986, the Chinese education fiscal policy has switched from centralization during the pre-reform period to decentralization. This shift allows the local governments to make their own education plan according to local demand and leads to an easing of pressure on the central government over the responsibility to ensure access and equity. Local governments, especially for the small town and rural area, have to rely on local taxes to fund schools. However, due to the unbalanced development of the Chinese economy, educational inequalities continue to widen, not only between inner west and east coast areas, but also between rural and urban. Fees on books and other teaching materials such as chalk and paper had to be collected from households who sent their children to school. Many villages went into debt when they tried to universalize nine years of compulsory education. As a result, free compulsory education became unaffordable to many households, and high dropout rate is common in rural area, especially for girls (Postiglione (2006)). This discrepancy is even worsened by the new decentralization reform of the fis-

[2]Refer to Zhao (1997) for a general review of *hukou* system and its effect on migration and education.

cal policy implemented in 1994, since when the central government receives a much bigger share of the tax revenue than the local government, who is however responsible for financing compulsory education[3]. A recent paper by Yi et al. (2012) confirms this concern. Using a survey data specifically targeted at secondary school students from two provinces in North and Northwest China, Yi et al. (2012) find among the total number of students attending secondary school during the first month of the first term of grade 7, 14.2% had left school by the first month of grade 9. They argue poverty, poor academic performance and outside job opportunities are three main contributing factors.

The inequality situation meets a new challenge when 100 million people try to move from countryside to the cities, most of whom are young adults with children. Nearly 20 million children go to the cities with their parents (group of LanZhou University (2007)), while many others have to be left behind with grandparents. The *hukou* system, however, has prevented the young rural migrants from sharing this educational experience with their age cohort in the city. According to the 1986 Education Law, local governments are held responsible only for the education of children with local residential registration, irrespective of the large population movement since 1990. Consequently, no rural migrant child is automatically entitled to public education and their enrollment rate is only at 90.7% [4], much lower than 99.5% in the corresponding counterpart in sixteen provinces in eastern China (National Bureau of Statistics of China (2002)). All these restrictions explain why most migrants choose to leave their children at hometown, either by themselves, or under supervision of the children's grandparents.

3.3 Theoretical model

The conceptual framework we adopt here adapts the "fairly general human capital investment model" as presented in Glewwe and Jacoby (2004), but arguments it by explicitly modeling the choice of performing migration work. The probability of migration will depend upon the non-farm labour market and the reservation wage. The purpose of this model is to demonstrate different mechanisms that parent's migration may affect the child's education.

We assume each household has only one single child and one parent who makes decisions about how many years of education should be invested. In the rural family's context, household adult allocates time among three activities: child's supervision (L_t^{a1}), agricultural production (L_t^{a2}), and off-farm work (L_t^{a3}); while child allocates time between study (L_t^{c1}) and agricultural production (L_t^{c2}). Each has time endowment 1. The household makes decisions

[3]This effect of the fiscal decentralization on education lasts until the promulgation of the new education law in 2006 which guarantees the enforcement of compulsory education in poor area (especially the rural area and the underdeveloped western China) by providing subsidies from the central government. Since our data covers the time period from 1989 to 2006, we are not able to study the effect of this policy change in 2006 on the enforcement level of compulsory schooling.

[4]Some other data may be even less optimistic. In 2001, the China News Agency reported that only 12.5% of migrant children in Beijing were in school, and only 60% of the migrant children were receiving some form of education according to a survey carried out by Shanghai Academy of Social Sciences (The Integration of Migrant Children in Beijing Schools, in Postiglione (2006)). Nevertheless, most migrant children are enrolled in the informal "Min gong" schools (i.e.,migrant children school), which is set up in the city by migrants themselves, and often faces the risk of shut down due to the poor conditions and dangerous infrastructure.

on investing in human capital (H_t), and physical capital (K_t), for agriculture production in each time period. Human capital is accumulated by making investment in child's education level (e_t) and time inputs from parents' supervision ($L_t^{a_1}$) and child's study ($L_t^{c_1}$), at a price (p_t) for the education cost, such as tuition and book fees. The human capital transition equation is as follows:

$$H_{t+1} = H_t + \psi(X_t)G(e_t, L_t^{a_1}, L_t^{c_1}), \tag{3.1}$$

where $G(\cdot)$ is the human capital production function, and $\psi(\cdot)$ is the productivity parameter reflecting the school quality, child ability and motivation, which are all included in variable set X_t.

The household also makes decisions on investment in physical capital, which is an input for agricultural production, in addition to labour (both child and adult). The agricultural production function can be described as a standard production function: $y_t^a = \theta_t F(K_t, L_t^{a_2}, L_t^{c_2})$, where θ_t is the agriculture productivity parameter at time t, and K_t is the physical capital stock accumulated at time t, $L_t^{i_2}$ is i's labour input in agriculture production, with $i = a, c$ for adult and child respectively. Households earn income from agriculture production and migration wage revenue, which is simply $y_t^m = wL_t^{a_3}$, with wage depending on the human capital of the parent (H_t^a). The adult chooses to migrate if and only if $w \geq w_r$, that is, when the expected wage from migration is high enough to compensate for the reservation wage(w_r), with the latter being determined by the state variables such as household characteristics and transportation cost of migration. Therefore, a household accumulates physical capital according to

$$K_{t+1} = K_t + \theta_t F(K_t, L_t^{a_2}, L_t^{c_2}) + w(H_t^a)L_t^{a_3} * M_t - c_t - p_t e_t, \tag{3.2}$$

i.e., the change in physical capital comes from the agricultural income and migration income, after subtracting current consumption (c_t) and education costs ($p_t e_t$). In Eq. (3.2), $M_t = I(w \geq w_r)$, where $I(\cdot)$ is the indicator function. Credit constraint can be imposed by the requirement that $K_{t+1} \geq 0$, that is, the household is constrained by borrowing ability in current consumption and education investment. As equation (3.2) shows, migration can relax the budget constraint for households on education investment. In this sense, the child from the migrant family should have higher education attainment conditional on all the other factors.

Assume that the child is eligible for education up to period $T - 1$. The family starts to receive income from the child from period T onwards, when child works exclusively. During $0 \leq t < T$, the child may only help in agriculture production and so the household faces the choice of consumption, labour supply and investment in education. We assume current utility is an additively separable concave function of consumption (c_t), and education investment (e_t) since education is partly treated as a consumption good. At period T, the parent retires and then receives a return on their investment through a transfer from the child, who finishes education and enters the labour market. The continuation value may then be written as $r\Phi(K_T, H_T)$, where Φ is the utility enjoyed by the child with inherited physical capital (K_T) and accumulated human capital (H_T), with $r \in [0, 1]$ being the fraction transferred to the parents. In this paper, we assume r is exogenous. The household has no other endowment except time. Therefore, the household's objective function is to maximize

$$E_0 \left[\sum_{t=0}^{T-1} \delta^t U(c_t, e_t) + r\Phi(K_T, H_T) \right], \tag{3.3}$$

subject to time constraints:

$$1 = L_t^{a_1} + L_t^{a_2} + L_t^{a_3} \tag{3.4}$$

$$1 = L_t^{c_1} + L_t^{c_2}, \tag{3.5}$$

as well as equation (3.1) and (3.2) and the credit constraint. The maximand is the expected discounted utility flow valuated at the initial time period.

The first order conditions for an interior solution are:

$$U'(c_t) = \lambda_t \tag{3.6}$$

$$\mu_t \psi G'(L_t^{a_1}) = \lambda_t \theta_t F'(L_t^{a_2}) \tag{3.7}$$

$$\mu_t \psi G'(L_t^{c_1}) = \lambda_t \theta_t F'(L_t^{c_2}) \tag{3.8}$$

$$\mu_t \psi G'(L_t^{a_1}) = \lambda_t w * M_t \tag{3.9}$$

$$U'(e_t) + \mu_t \psi G'(e_t) = \lambda_t p_t, \tag{3.10}$$

where μ_t and λ_t are time-varying shadow values of human and physical capital that will be scaled by the discount factor δ^t. The system of equations can be solved to yield the education demand function:

$$e_t^* = e^* \left(\lambda_t, \mu_t, \psi(X_t), G'(e_t), G'(L_t^{a_1}), G'(L_t^{c_1}), \theta_t F'(L_t^{a_2}), \theta_t F'(L_t^{c_2}), w_t * M_t, p_t \right). \tag{3.11}$$

From first order conditions (3.6)–(3.10), we can see clearly that parent has to face the trade-off between the short-term benefit and the long-term return benefit. On the one hand, the higher income from parent's migration relaxes budget constraint, which is equivalent to the lower shadow value of physical capital λ_t. Therefore it may facilitate high education investment as seen directly from equation (3.10). On the other hand, the parent has to face the limited time constraint on child's development if he does labour migration work, which may require him working far away from home so that little time is left for supervising child's education and may forgo the long-term benefit from returns to human capital accumulation. Moreover, the parent's migration decision may also induce other family members to work more and have cross-effect on child's labour, which further decreases the child's time devoted to education (Eq.3.8). As a result, the net effect of parent's migration on child's education attainment is a combination of all these effects and the sign of the net effect is ambiguous.

If we write the determinants of education decision into deep parameters and shadow prices, we can find that child's education is a function of household endowments, agriculture productivity, other household characteristics, macro economic conditions, tuition fee and other cost on schooling, conditional on migration decision (further determined by household's characteristics and migration cost). Based on these, we can write down the reduced form for empirical models as follows:

$$e_{it}^{*} = e^{*}(\lambda_{it}, \mu_{it}, \theta_{t}, r, X_{it}, p_{t}, w_{t} \mid M_{it}) \tag{3.12}$$

And in the next section we are going to test how these variables affect children's education attainment, especially how fathers' migration has an impact.

3.4 Data

Data are drawn from the longitudinal China Health and Nutrition Survey (CHNS) data, which includes about 4,400 households with a total of 19,000 individuals in nine provinces that vary substantially in geography, economic development and public resources. Households were first surveyed in 1989, with follow-up surveys in 1991, 1993, 1997, 2000, 2004, and 2006. The timing of the survey is well-suited for the study of migration, as the 1990s experienced the most rapid growth in intra-national labour migration in China. Since follow-ups are only possible if the household didn't move out of the village, households that permanently moved to cities wouldn't be followed.[5] The attrition rate of the whole survey is 5%. Detailed demographic, economic, time use, labor force participation, asset ownership, and expenditure data were obtained, as well as health and nutrition status of children and elders. Local social and economic information at community/village level is also included.

Children's school enrollment is asked in each wave, together with total years of schooling, and what level of education has been obtained. As migration activity is not asked specifically in the survey till the wave 1997, we can't identify migrants straightforwardly in data before 1997. Therefore, we define migrants as individuals living away from home for at least six full months in the past year. The sample of interest in this paper consists of 2,554 rural children born after 1978, with both parents currently in the same household and with information on household assets, and village facilities. These children were born after cultural revolution and their education will have been affected by the promulgation of education law of 1986. As

[5]Given the strict implementation of *Hukou* registration system, the attrition due to selection is not a serious matter in this paper.

female's participation in migration labour market was low until the recent years[6], we don't include the children whose mothers did migration work during their schooling years in our subsample. Descriptive statistics of the subsample are presented in Table 3.1. The subsample is slightly overrepresented by boys, with the average number of years of schooling at 9 years, i.e., finishing schooling after graduating from secondary school. The difference between 5-year and 6-year primary school plans across regions is taken care of by adjusting all primary school graduates to finishing 6 years of schooling, no matter what plan of primary school is performed in that region[7]. The average household size is 4.69 people, and the average number of children within a family is a little over 2[8]. There is a big variation in the assets value and cultivated land area, with mean at 5630.56 (yuan) and 6.41 (mu) separately. Over half of the villages in the sample have a local public primary school, while high schools (and other higher levels) have to be reached in the nearest town. Electricity is available in most villages during our sample period while train stations are only rare. The information on the distance to the nearest train station is not available to many villages and therefore is not controlled in our empirical analysis. The sample distribution across provinces is not absolutely even, with the sample size reflecting the population weight in each province.

3.5 Empirical Strategies

This section describes the empirical strategies for estimating the causal effect of father's migration on children's education attainment. Two different empirical strategies are employed: i) fixed effect IV methodology (FE-IV), and ii) multivariate mixed proportional hazard model (MMPH). We discuss the relative advantages and disadvantages of each method in what follows.

The objective of the empirical analysis is to identify the causal relationship of parents' migration on children's education attainment. Given the panel data structure of child's enrollment history, a natural empirical approach is to examine how the change in incidence of parents' migration has impact on the odds of dropout of child. The first empirical approach we adopt is to exploit the panel data structure by removing the unobserved fixed effect of a child which may also affect his/her education attainment (such as ability). However, this approach treats school enrollment and migration only as two binary incidence choice variables, ignoring the natural process of schooling and migration which have their own dynamic durations and whose effects may persist over time. Due to these considerations, we adopt a second empirical approach that treats education and migration as bivariate duration processes during which one variable may have impact on the other. Both approaches will be presented

[6] In our sample, by our definition of migration, there are 19 out of 2840 rural children whose mother is the only parent who ever did migration work during their schooling time, compared to 241 children with only fathers once did migration work. Moreover, there are 42 children who have both parents once did migration work.

[7] As introduced in Section 3.2, although most regions implement 6-year primary schooling policy, some regions have only 5-year primary schools. The difference is due to discretion of each region according to their fiscal conditions.

[8] Although the one-child policy has been implemented since 1978, the enforcement was not very strict until the early 1980s and the restriction could be waived if the first child of the family is a girl for rural residents.

Table 3.1: CHNS Data: Summary Statistics

variable	min	max	mean	s.d.
a. Individual level				
birthyear	1978	2000	1984.59	4.74
gender	0	1	0.47	0.5
number of years of schooling when dropout	1	17	9.02	2.1
father's education	0	5	1.8	0.88
mother's education	0	5	1.28	0.98
father's first observed migration wave	1989	2006	1997.91	6.77
household size	3	11	4.69	1.28
number of children	1	6	2.04	0.89
value of assets(yuan)	18	506900	5630.56	16648.82
cultivated land(mu)	0	359	6.41	10.88
b. Community level				
public primary school in village	0	1	0.66	0.47
public secondary school in village	0	1	0.21	0.41
public high school in village	0	1	0.07	0.25
vocational school in village	0	1	0.04	0.2
electricity in village	0	1	0.97	0.17
train station in village	0	1	0.14	0.35
number of clinics in village	0	7	0.22	0.62
minority village	0	1	0.03	0.16
c. Province				
Liaoning		219		
Heilongjiang		215		
Jiangsu		218		
Shandong		215		
Henan		368		
Hubei		352		
Hunan		224		
Guangxi		383		
Guizhou		350		
N		2554		

Note: **gender**=0 for boy,=1 for girl. Parents' education levels have 5 categories: illiterate (0), primary school graduates(1),secondary school graduates(2),high school graduates(3),vocational school graduates(4),collage and above(5). **minority village**=1 for village mainly consisting of minority ethics people,=0 otherwise.

in this section separately and will be compared and contrasted.

3.5.1 Fixed effect IV approach

Empirical model

From the education (enrollment) demand function in equation (3.11), a reduced form model of the discrete decision of household h in village j to enroll child i in school at time t can be written as:

$$E_{iht} = \beta_0 + \beta_1 DadM_{iht} + \beta_2 W_{iht} + \beta_X X_{it} + \beta_Z Z_{ht} + \beta_V V_{jt} + P_i * T_t + u_i + \epsilon_{ijt} \tag{3.13}$$

where E_{iht} is a binary variable with 1 indicating that child i in household h is enrolled in school in year t. $DadM_{iht}$ is also a binary variable indicating whether child i's father is currently participating in labour migration at time t. W_{iht} is the household wealth at year t, so that β_2 captures the wealth effect of education. X_{it} includes individual level covariates which may affect child's enrollment decision, including age, gender, and dummies for how many years of schooling have been finished, in order to account for the effect of natural process of schooling. Household characteristics Z_{ht}, are introduced in the models to control for family preferences for education, factors affecting lifetime household wealth, and the likelihood that the household faces credit constraints, such as parents' education level, number of children. Village characteristics, V_{jt}, are also included to control for the education facility in the village. For example, whether there is a primary school or middle school in the village, as well as the distance to the closest corresponding school. Macroeconomic shocks and trends, education resources and policies may also affect child's education attainment, cost of education, and the demand for migrant labor, and we control for these effects using province-wave dummy variables, $P_i * T_t$. Moreover, shadow prices of physical capitals and return to education are also assumed constant within region at certain period and can be captured by $P_i * T_t$. Apart from all these, there are still some individual fixed effects (u_i) which we generally can't observe, such as innate ability, but can affect education attainment through education productivity parameter ψ_t. Idiosyncratic shocks are included in the error term ϵ_{ijt}.

Identification

As discussed in the model, the explanatory variable migration $DadM_{iht}$ is itself a binary choice variable which depends on whether the potential migration wage is bigger than the reservation wage plus migration fixed cost, which further depends on individuals' observed characteristics, such as education, age, household demographics, fixed cost involved with migration, and unobservables such as motivation, ability (as shown in Section 3.3). It is very likely that the unobservables that affect adult parents' migration decision may be correlated with the one that affects children's education attainment. For example, father's genetic ability is an important unobservable which may affect the probability of his migration. And there is enough evidence to believe that father's genetic ability is correlated with child's learning ability, which further affects child's education attainment. Migration is therefore likely an endogenous covariate in child's education equation. Ignoring this endogeneity may generate spurious effect from parent's migration to child's school performance. In order to identify the causal effect of dad's migration on child's education attainment, we need to remove the fixed effect in child enrollment equation that is correlated with $DadM_{it}$ by making use of panel data structure. However, this is not enough to deal with endogeneity of migration variable. Another source of endogeneity may come from the fact that dad migration and child's education are simultaneously determined. Some parents leave home to do the labour migration work mainly to collect enough money for funding children's further education, if they predict it is very likely according to child's current schooling performance. If this is the case, removing fixed effect will not be enough to solve the endogeneity problem. To account for this, an IV approach needs to be implemented.

Therefore a fixed effect IV approach is applied when estimating equation (3.13). The causal inference is achieved by instrumenting variation of father's migration with the exogenous variation in rainfall shocks during the previous growing season to identify the *local average treatment effect* (LATE) of father's migration behavior on child's current school enrollment decision. Instrument variables we use are the cubic multinomial combinations of deviation of rainfall from multi-year average in the growing season of last year and the area of cultivated land for the household. Rainfall data has been used widely as an instrument or proxy for rural household income in developing countries where income relies heavily on agriculture. The justification comes from the fact that agriculture productivity depends heavily on weather, especially in developing countries where the irrigation infrastructure is under developed. For example, Bjorkman (2006) uses the transitory rainfall variable, i.e., the difference between actual rainfall at time $t - 1$ and historical rainfall in that district, to proxy for household income in Uganda. It is also true that nonfarm job taking usually takes place if farmers can not get enough income from agriculture production due to the undesirable weather. Based on this fact, Giles and Yoo (2007) use rainfall shocks from the distant past during the growing season for typical Chinese agriculture production (July–November[9]) as instruments for the share of village laborers working in migrant destinations. This paper adopts the same strategy and use the rainfall shock during the last growing season as an instrument for father's migration probability in this year[10]. The area of land for cultivation is also used to instrument father's migration decision, and it has a wide variation across regions.

Although both outcome variable and endogenous independent variable are binary, An-

[9]See Giles and Yoo (2007) for detailed discussion about how to choose the most relevant seasons for rainfall information based on crop cycle knowledge in China. Although the sample area covered in their paper is much smaller than the one in our study, there exists a large overlapping and the July-November season is still applicable.

[10]Ideally, we should use rainfall shock for each county in order to get enough variations. Regrettably, we couldn't get county-specific weather data. We constructed average rainfall shock at province level instead, based on multi-year monthly rainfall records from several international-standard weather observation sites within provinces. As a result, we have 7 rainfall shock data (one for each wave) for each of 9 provinces.

grist (2001) proposes a simple two-stage least square estimation that is sufficient to infer causal effect of treatment. However, we emphasize that this approach is not the main and final approach in this paper. As we will discuss later, this fixed effects IV approach suffers a number of drawbacks which are inherent in the data structure and is therefore limited in providing definitive conclusions. Nevertheless, we still present its estimation results here for further discussion and comparison.

Results

The results are shown in the second and third column in Table 3.2. For comparison, we show the coefficients from a random effect probit model estimation in the first column. From the first result, we find most variables show reasonable signs on children's dropout. For example, girls and children from poorer families are generally more likely to drop out from school; and parents' education, especially mothers' education are important indicators of children's education (i.e., children with higher educated mothers generally stay in school for longer); the presence of primary schools in the village can increase local children's enrollment. This effect may reflect the better education quality or lower transportation cost for the students. Nevertheless, father's migration doesn't have significant effect on child's school enrollment.

The fixed effect IV approach, on the other hand, by addressing the endogeneity of independent variable, may produce consistent estimates. However, probably due to the limited variation of the rainfall shock across regions [11], the first stage regression (column 2) shows rainfall shocks are not effective instruments, nor the cultivated land area, except the availability of electricity and existence of high school may reduce father's migration probability. The probability of joint significance of these instruments is too low to validate excluded restriction for the IV approach. While the second stage regression gives a negative effect of migration on child's dropout, i.e., if a father is currently doing migration work, his child is 45.5% more likely to be enrolled in school compared to a counterpart whose father is not migrating. However, the effect is not significant from zero.

Advantages and disadvantages

Theoretically, the fixed effect IV estimation procedure should remove the fixed effects in the child enrollment choice equation, and at the same time solve the simultaneity problem between the outcome variable and the endogenous variable. However, the application of this approach in our study suffers from two practical drawbacks. First is the problem of weak instruments as we discuss earlier. Second, this approach cannot capture the natural dynamic process of schooling and migration. And more importantly, the nonconsecutive time series of this survey doesn't allow us to tell the exact time when the child dropped out[12], therefore, it's possible that father's migration took place after the child dropped out. For example, if a child was enrolled in school in 1993, but recorded as dropout at the wave of 1997, and as such it is

[11] Rainfall information is only available at province average level.
[12] Variable **dropout** is defined if a child didn't enroll in school this year and "the years of schooling finished" didn't change in the later years.

Table 3.2: Panel Data Regressions

Outcome: dropout	random effects	Fixed effects IV	
	probit model	1^st stage IV	2^nd stage
father is doing migration work	0.026 (0.132)		-0.455 (1.156)
rain fall shock		-0.082 (0.520)	
rain fall shock (square term)		-0.009 (0.038)	
rain fall shock (cubic term)		0.014 (0.092)	
father's age		0.575 (0.550)	
father's age (square term)		0.000 (0.000)	
child's gender	0.136 (0.053) ***		
chid's age	0.735 (0.079) ***	-0.566 (0.549)	-0.078 (0.006) ***
child's age (square term)	-0.012 (0.002) ***	0.000 (0.000)	0.006 (0.000) ***
father's education			
primary school	-0.083 (0.100)		
secondary school	-0.100 (0.100)		
high school	-0.189 (0.112) *		
technical school	-0.410 (0.354)		
college and above	0.062 (0.484)		
mother's education			
primary school	0.011 (0.071)		
secondary school	-0.175 (0.076) **		
high school	-0.313 (0.108) ***		
vocational school	-0.155 (0.402)		
child's finished education			
primary school	-0.343 (0.122) ***	-0.009 (0.007)	-0.100 (0.016) ***
secondary school	-0.321 (0.136) **	-0.017 (0.010)	-0.102 (0.026) ***
high school	-1.362 (0.173) ***	-0.020 (0.019)	-0.433 (0.041) ***
vocational school	-1.127 (0.186) ***	-0.049 (0.023) **	-0.413 (0.070) ***
college/university	-1.641 (0.276) ***	-0.031 (0.063)	-0.779 (0.118) ***
household size	0.002 (0.030)	0.004 (0.004) *	0.012 (0.009)
number of children in the household	-0.036 (0.042)	0.007 (0.010)	-0.019 (0.020)
value of assets (log)	-0.038 (0.021) *	-0.001 (0.003)	-0.006 (0.005)
area of cultivated land (log)		-0.002 (0.005)	
village facilities			
primary school in village	-0.126 (0.073) *	-0.003 (0.008)	-0.027 (0.014)
secondary school in village	-0.104 (0.072)	-0.012 (0.008)	-0.002 (0.020)
high school in village	0.035 (0.113)	-0.031 (0.013) **	0.014 (0.044)
vocational school in village	-0.187 (0.129)	0.024 (0.016)	-0.025 (0.040)
electricity available	0.136 (0.209)	-0.039 (0.018) **	0.026 (0.055)
constant term	-8.370 (0.688) ***	-16.004 (15.381)	0.263 (0.103) ***
province specific time trend	√	√	√
F test (1-probability of joint significance of rainfall shocks from zero)			0.913
F test (1- probability of joint significance of all instruments)			0.8832
Number of observations			6444
Number of groups			2354

Note: The baseline for parents' education is illiteracy. Standard errors are reported in parentheses. *,**,*** denote significance level at 10%,5%,1% separately.

likely that he dropped out during 1994-1997, but not clear about which exact year. If it was before 1997, when the dad was recorded as migrating, the coefficient we get from above practice doesn't identify the "causal effect" of migration on dropout. In this case, the timing effect should be explicitly modeled. This consideration leads us to pursue an alternative empirical strategy, that we present in the next section.

3.5.2 Bivariate Hazard duration model

Empirical model and selectivity

There is a large literature that treats schooling as a duration process, among which proportional hazard (PH thereafter) model is the most widely applied for modeling school attainment levels (Brown and Park (2002), Edwards and Ureta (2003), Glewwe and Jacoby (2004)). As recognized in Edwards and Ureta (2003), there are several advantages of PH model which makes it an attractive statistical framework: first, instead of being treated as a discrete choice in the static fixed effect model, the natural schooling process is properly covered by dynamic duration process; second, the PH model has an obvious advantage that it exploits all the available information in observations that are right censored, that is, observations for children who are still enrolled at the time of last survey (around 64% of sample cases). Third, another desirable feature of the proportional hazard model is that it readily yields an estimate of the underlying baseline hazard function, enabling us to identify the grade levels where dropout rates are concentrated, net of the effect of measured determinants of school completion.

Since Lancaster (1992) introduced heterogeneity into duration analysis, the mixed proportional hazard model has widely been used in economics, especially in the context of job search models (Abbring et al. (2005), Hujer et al. (2004)). In this model, the distribution of duration (T) may vary across individuals. Moreover, it assumes that all individual variation in the hazard function can be characterized by a finite-dimensional vector of observed explanatory variables $\mathbf{X}_i$ and unobserved heterogeneity term v_i, which can be interpreted as a function of unobserved explanatory variables. $\mathbf{X}_i$ can be time-invariant or time-variant. While the interpretation is most straightforward when $\mathbf{X}_i$ is time-invariant, in practice, many explanatory variables are often time-varying, and the hazard function is more likely affected by the current value of the explanatory variable (instead of, e.g. its value at the beginning of the spell). Van den Berg (2001) notes that the values of the time-varying explanatory variables at t may in some sense be endogenous because the subject under study may have inside information at t on the future realization of the random variable T, and this information may affect the values of his observed explanatory variables at t and his hazard rate at t. It may be erroneously concluded that the observed explanatory variables have a causal effect on the duration.

As emphasized in Abbring and van den Berg (2003), the empirical analysis of the treatment effect is hampered by selection problem: individuals who obtain a treatment may have systematically different outcomes than those who do not. If we apply this idea to our migration context, we find that child with dad doing migration work may have systematically different education attainment than those whose dad hasn't migrated. To be more specific, the children with dad migrating would have got less schooling even if their dads didn't migrate, if we found a positive effect of migration on the hazard of dropping out. This spurious dependence from related unobserved determinants makes the estimate of the effect of the previous duration biased.

To deal with these potential endogeneity issues in duration model, multivariate mixed proportional hazard (MMPH) model provides a useful framework by assuming that the durations of the time-varying explanatory variable, and the dependent variable, are all outcomes of stochastic processes. The values of the explanatory variables at t are influenced only by events that have occurred up to time t, and these events are observable. The information on the values at time t does not help in predicting a transition at t. Therefore, one may condition on the moment of treatment and compare what happens before and after this moment. In our context, the moment of treatment is defined as the first time since year 1985 when the father is observed to do migration work. The year 1985 is the year when individual identity card was issued, the use of which makes traveling much easier and reduces the fixed cost for migrants to some extent[13]. Although we may expect some regional variation in terms of the issuing time of ID cards, this information is absent from our data set and therefore the uniform starting point is applied in our analysis. The basic idea of defining migration as a duration process is as follows: since doing migration work away from home is a big decision to make, the ones who make the first moves usually face a large uncertainties and fixed cost such as searching and traveling cost. Therefore the duration time from year 1985 to the first time of migration may reflect households' demand and individual ability as well as migration cost. The unobserved heterogeneity of fathers (V_m) is assumed to be correlated with that affecting child's education duration (V_d). To proceed, we assume that, conditional on the multiplicative heterogeneity V, the realization of t_m (first migration) affects the shape of the hazard of t_d (dropout) from t_m onwards, in a deterministic way. It implies that the causal effect is captured by the effect of t_m on $\theta_d(t \mid t_m, V)$ for $t > t_m$. Note that it is ruled out that t_m affects $\theta_d(t \mid t_m, V)$ on $t \in [0, t_m]$. That is, it excludes anticipation effects.

Since these two durations are parallel, the model specification reads:

$$\theta_m(t_m \mid x_m, v_m) = \psi_m(t_m) \cdot \theta_{01}(x_m) \cdot V_m \tag{3.14}$$

$$\theta_d(t_d \mid t_m, x_d, v_d) = \psi_d(t_d) \cdot \theta_{02}(x_d) \cdot e^{\delta I(t_m < t_d)} \cdot V_d, \tag{3.15}$$

where subscripts m and d denote dad's migration and child's dropout separately, and $I(.)$ is the indicator function, which is 1 if father migrates before child drops out from school or always stays in school during our sample period (i.e., right censored education duration). Therefore, $\exp(\delta)$ identifies the treatment effect, i.e., the causal effect of dad's first migration

[13]A letter of introduction would be necessary for traveling before the ID card was issued.

on child's schooling if dad migrates before child drops out of school. As discussed above, V_m and V_d are potentially correlated.

The density distribution of t can be directly inferred from the hazard density:

$$\begin{aligned} f_m(t_m \mid x_m, v_m) &= \theta_m(t_m \mid x_m, v_m) S_m(t_m \mid x_m, v_m) \\ &= \theta_m(t_m \mid x_m, v_m) \exp\left[-\int_0^{t_m} \theta_m(s \mid x_m, v_m) ds\right] \\ f_d(t_d \mid t_m, x_d, v_d) &= \theta_d(t_d \mid t_m, x_d, v_d) S_d(t_d \mid t_m, x_d, v_d) \\ &= \theta_d(t_d \mid t_m, x_d, v_d) \exp\left[-\int_0^{t_d} \theta_d(s \mid t_m, x_d, v_d) ds\right] \end{aligned}$$

Since some children (fathers) are never observed to leave school (do migration work) during our sample period, right censoring of the durations is common. We define the censoring indicators κ_m and κ_d, with $\kappa_m = 1$ (respectively$\kappa_d = 1$) if t_m(respectively t_d) is right censored, in which case the hazard density is just the same as the cumulative probability of survival till the last observation. The individual likelihood contributions are given by:

$$l_m(t_m \mid x_m, v_m) = f_m(t \mid x_m, v_m)^{1-\kappa_m} \left\{\exp\left[-\int_0^{t_m} \theta_m(s \mid x_m, v_m) ds\right]\right\}^{\kappa_m} \tag{3.16}$$

$$l_d(t_d \mid t_m, x_d, v_d) = f_d(t \mid t_m, x_m, v_m)^{1-\kappa_d} \left\{\exp\left[-\int_0^{t_d} \theta_d(s \mid t_m, x_d, v_d) ds\right]\right\}^{\kappa_d} \tag{3.17}$$

Maximum likelihood function needs to integrate out the unobserved heterogeneity and obtain the joint probability given observed characteristics.

$$l_{m,d}(t_m, t_d, X) = \int_m \int_d l_m(t_m \mid x_m, v_m) l_d(t_d \mid t_m, x_d, v_d) dG(v_m, v_d) \tag{3.18}$$

To proceed, further assumptions about joint distribution of v_m and v_d are required. However, as Heckman and Singer (1984) note, the estimates obtained from duration models is very sensitive to the assumptions of the distribution of unobservables. Non-parametric procedures is therefore undertaken for estimation of the above empirical model. We assume $G(v_m, v_d)$ has two points of support for each argument v_m and v_d with the associated probabilities $\pi_1 = P(v_{m_1}, v_{d_1}), \pi_2 = P(v_{m_1}, v_{d_2}), \pi_3 = P(v_{m_2}, v_{d_1}), \pi_4 = P(v_{m_2}, v_{d_2})$. And the integrated hazard function in (3.16) and (3.17) are estimated as the sum of piecewise constants. The individual likelihood contribution can then be written as

$$
\begin{aligned}
l_{m,d}(t_m, t_d, X) = \; & \pi_1 \cdot l_d(t_d \mid t_m, x_d, v_{d_1}) \cdot l_m(t_m \mid x_m, v_{m_1}) \\
& + \pi_2 \cdot l_d(t_d \mid t_m, x_d, v_{d_2}) \cdot l_m(t_m \mid x_m, v_{m_1}) \\
& + \pi_3 \cdot l_d(t_d \mid t_m, x_d, v_{d_1}) \cdot l_m(t_m \mid x_m, v_{m_2}) \\
& + \pi_4 \cdot l_d(t_d \mid t_m, x_d, v_{d_2}) \cdot l_m(t_m \mid x_m, v_{m_2})
\end{aligned} \tag{3.19}
$$

Estimation is accomplished with maximum likelihood, where the probabilities of the mixing distribution are specified as logistic probabilities:

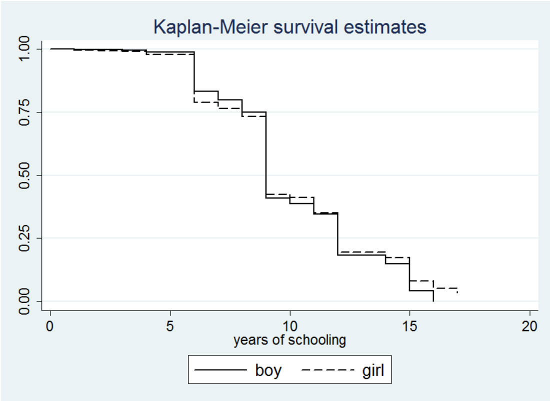
$$
\begin{aligned}
\pi_1 &= \frac{1}{1 + \exp(q_1) + \exp(q_2) + \exp(q_3)}, \\
\pi_2 &= \frac{\exp(q_1)}{1 + \exp(q_1) + \exp(q_2) + \exp(q_3)}, \\
\pi_3 &= \frac{\exp(q_2)}{1 + \exp(q_1) + \exp(q_2) + \exp(q_3)}, \\
\pi_4 &= \frac{\exp(q_3)}{1 + \exp(q_1) + \exp(q_2) + \exp(q_3)},
\end{aligned}
$$

where q_1,q_2,q_3 are parameters to be estimated.

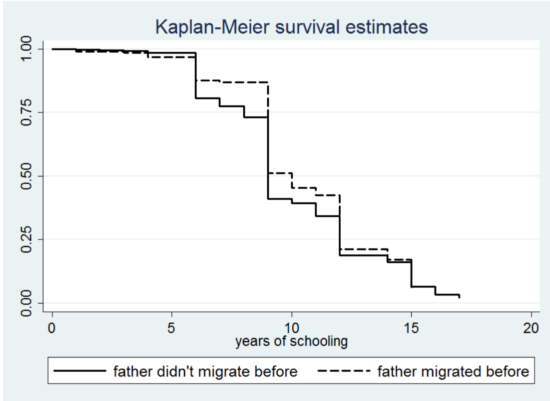
Estimation and Results

Before we present full estimation results, in Figure 3.3 we present descriptive evidence in the form of non-parametric Kaplan-Meier survival curves of schooling for school-aged children in our sample, grouped by gender, or father's migration history, or both. The big drops of survival step function in the schooling cut-off points[14] reflect the natural schooling process. Moreover, the difference between boys and girls are trivial in our sample, with girls generally face slightly higher hazard of dropout before finishing 9-years compulsory schools, but may obtain more education than boys once surviving the high school. The difference between children with different fathers' migration history is however more significant. Those whose fathers have ever done migration work stay at school longer in general than the others, as the former's survival curve weakly dominates the latter's in graph 3.3b, especially during secondary school (6-9 years of schooling) and high school (9-12 years of schooling) period. The third graph describes the gender difference of the effect of father's migration history on children's education attainment. Fathers' migration increase survival rate of schooling for both boys and girls by a significant margin, especially for girls during secondary school. This difference to some extent reflects the gender preference of households' education investment in rural China. The boys have the much higher priority than girls in the allocation of limited household resources. But with the extra income from fathers' migration, girls may be able to obtain more resource and education.

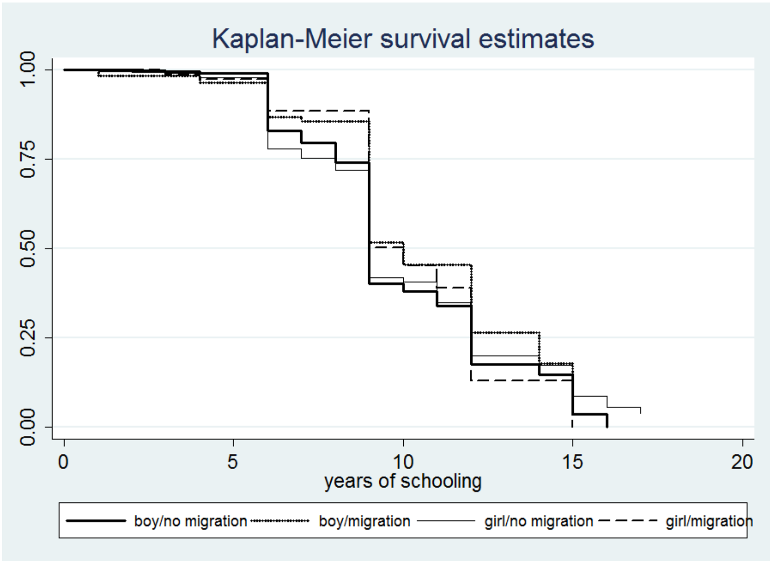
[14] These points are at 6^{th} year for primary school, 9^{th} year for secondary school, and 12^{th} year for high school.



(a) by gender



(b) by migration



(c) by gender and migration

Figure 3.3: Kaplan-Meier Survival Curves of Schooling for Rural Children

The estimation results of duration models are shown in Table 3.3 and 3.4 . Table 3.3 shows the results from single variable duration model of child's schooling (equation (3.15)), treating father's migration as a time varying exogenous variable. Different strata (where strata is defined so that all the observations in the same strata have the same baseline hazards) is used and the fit is in general improved if more detailed strata is defined, as shown in the change in likelihood values. As we can see, if we don't take account of the endogeneity of father's migration decision, the hazard ratios of child's schooling with fathers' migration are always below 1, indicating the history of father's migration lowers the child's hazard rate of dropout, no matter how strata are defined. However, all the coefficients are not significant from 1 at the probability of 10% level. Similar as in fixed effects estimation, parents' education levels determine child's schooling process to a great extent, i.e., children with higher educated parents usually have lower hazards of dropping out. The difference between girls and boys is not significant here. The more children at home, the more likely for a child to stop education early. However, school aged children from larger family (after controlling for the number of non-adults) stay longer in schools, possibly due to the insurance rule provided by the big families. Access to electricity is an important indicator of regional economic development, and found to improve children's enrollment by 30% on average. If we don't control for cohort, we can also see that younger cohorts in general get more education than the older ones, as in column (1). Again, the village-specific school availabilities, especially secondary school in village can also improve children's education attainment by a significant amount, as shown in column (1).

MMPH model is estimated with the joint distribution of heterogeneity by 4 points of support nonparametrically. Although we suspect selection may take a role, another advantage of this method in application is that no exclusion restriction is necessary, i.e., we don't need to model father's migration with instruments that are exclusive to schooling duration process[15]. The baseline hazard for each duration is estimated as a piecewise constant step function. For the duration of schooling, we break the natural schooling process into 7 groups: 0-5th, 5-6th, 7-8th, 9th, 10-11th, 12th, 12thabove, where each group s has its specific baseline hazard $\psi_d^s(t_d)$[16]. We make this distinction to accommodate the natural schooling process, in which survival in different school types has its own time course, especially for the final year at each level. Similarly, the baseline hazard for the natural duration of migration is also broken down into 6 piecewise constants, with the cut-off points same as the observational waves in the panel data, i.e., 1989, 1991, 1993, 1997, 2000, 2006[17]. By estimating these piecewise constant hazards nonparametrically, we are able to model the time trend of the macro economic development in China and the accompanied labour migration, and therefore separate the effect of macro time trend from individual variates.

Table 3.4 shows the estimation results of the bivariate duration model setting the treatment effect constant, i.e., the treatment effect is assumed to be constant throughout the whole treatment period. Column (1) shows the results from the same sample as we used in single duration model, while the second column uses a smaller sample in which all the fathers appeared in the survey since 1989. The coefficients under each column shows the estimated coefficient for each covariate, while the hazard ratios are the exponent of the coefficients, and are compared against 1. Similar to the earlier results, the average treatment effect δ in this model is very close to zero, indicating that on average father's migration doesn't improve a child's lifetime education attainment. The duration estimation of child schooling shows the similar results as in Table 3.3. On the other hand, the duration estimation of father's first migration shows younger and more educated father (especially college graduates) is more likely to migrate earlier, while family demands (e.g. the needs to look after young children)

[15]Nevertheless, in empirical analysis we still include rainfall variations as independent variables that are exclusive to child's schooling duration in migration function.

[16]The first baseline hazard is normalized to 1 to avoid multicollinearity in estimation.

[17]We assume the baseline hazard is the same between sectors from 2000 to 2004 and from 2004 to 2006, to avoid small sector sizes and inefficient inference. Similarly, the first baseline hazard is normalized to be 1.

Table 3.3: Single Duration Regressions

	Haz. Ratio			
	(1) no stratification	(2) stratified by (birthyear)	(3) stratified by (birthyear, province)	(4) stratified by (birthyr, region)
dad has ever done migration work before child's dropout	0.920 (0.115)	0.914 (0.115)	0.887 (0.122)	0.863 (0.121)
gender (1=girl)	0.909 (0.061)	0.902 (0.061) *	0.945 (0.069)	0.998 (0.075)
birthyear (mean removed)	0.945 (0.011) ***			0.946 (0.011) ***
household size	0.943 (0.042)	0.938 (0.043)	0.937 (0.045)	0.922 (0.045) *
children	1.163 (0.065) ***	1.170 (0.067) ***	1.166 (0.072) ***	1.130 (0.072) *
household assets value (log)	0.964 (0.025)	0.962 (0.026)	0.959 (0.028)	0.982 (0.030)
father's education				
primary school	0.757 (0.093) **	0.758 (0.094) **	0.764 (0.103) **	0.780 (0.108) *
secondary school	0.715 (0.088) ***	0.709 (0.088) ***	0.693 (0.093) ***	0.689 (0.095) ***
high school	0.609 (0.086) ***	0.598 (0.086) ***	0.579 (0.089) ***	0.571 (0.090) ***
technical school	0.439 (0.228) *	0.415 (0.219) *	0.300 (0.170) **	0.382 (0.222) *
College and above	0.938 (0.577)	1.078 (0.666)	1.349 (0.873)	1.520 (1.107)
mother's education				
primary school	0.948 (0.084)	0.958 (0.085)	0.941 (0.090)	0.928 (0.093)
secondary school	0.790 (0.078) **	0.790 (0.079) ***	0.790 (0.084) ***	0.768 (0.084) ***
high school	0.573 (0.083) ***	0.565 (0.084) ***	0.581 (0.091) ***	0.598 (0.096) ***
technical school or above	0.291 (0.212) *	0.311 (0.228) *	0.247 (0.191) *	0.264 (0.211) *
village facilities				
primary school in village	0.897 (0.084)	0.903 (0.087)	0.883 (0.094)	0.935 (0.104)
secondary school in village	0.873 (0.071) *	0.883 (0.073) *	0.900 (0.081)	0.893 (0.085)
high school in village	0.854 (0.115)	0.852 (0.116)	0.839 (0.127)	0.842 (0.134)
vocational school in village	1.081 (0.172)	1.096 (0.177)	1.157 (0.204)	1.144 (0.207)
electricity in village	0.739 (0.144) *	0.770 (0.153)	0.709 (0.152) *	0.711 (0.158) *
province dummy				
Heilongjiang	0.944 (0.174)	0.944 (0.177)		
Jiangsu	0.705 (0.124) **	0.698 (0.124) **		
Shandong	0.843 (0.137)	0.842 (0.138)		
Henan	0.985 (0.149)	0.975 (0.149)		
Hubei	0.893 (0.135)	0.905 (0.138)		
Hunan	0.838 (0.132)	0.814 (0.130)		
Guangxi	1.019 (0.154)	1.002 (0.153)		
Guizhou	0.877 (0.140)	0.881 (0.142)		
No. of subjects	2544			
No. of failures	935			
Number of observations	13019			
Log likelihood	-6192.110	-4047.441	-2158.912	-1876.287

Note: Strata is defined by category variables and sample within the same category having the same baseline hazard. The baseline for parents' education dummies are illiterate. The baseline for province dummies is *Liaoning*. The numbers in parentheses are standard errors. ***,**,* show the statistic significance at 1%, 5%, and 10% level separately.

may also keep the male adult staying at home. The limited cultivated land area, big variation of rainfall in previous year and the lack to electricity also pushes farmers to seek more off-farm job opportunities and income outside the village. This result is different from FEIV regressions, where instruments are too weak to have impact on migration probability. The difference may reflect the fact that migrants' first migration is driven by the low agricultural production from last year. While once they are out for the first time, they can build up contacts and gain more experience which make future migration much easier. Although being close to train station may reduce the transportation costs for migrating, it may also provide more local off-farm job opportunities so that farmers do not need to migrate. The piecewise constant baseline hazards show the general pattern of natural schooling process, with higher dropout rate at higher levels, and especially higher dropout rate at the last year of secondary school (λ_4) and high school (λ_6). The baseline hazards for father's migration also show the general macro economic trend, i.e., in general there is an increasing migration population over years, especially since mid 1990s. The efforts to search for heterogeneity however have been proved to be fruitless. The estimation with heterogeneity always goes to the mass point with probability nearly one, while others with probability nearly zero. The results shown here are from the estimation by imposing probability equal to 1 for one mass point. This implies that there is no selection in this context, i.e., for the fathers who are more likely to take migration jobs away from home, the children do not necessarily perform better in schools systematically. The reasons could be multifold. One possible reason is that migration selection does not (or at least not mainly) depend on individual ability, but rather, on networks and information (Zhao (2003)), which is however not available in this data set .

Considering that the data has an unbalanced panel structure, and some households are not surveyed in the first wave 1989, we can't observe whether the school-aged children's fathers went to do migration work in 1989 for those who entered the data in later waves. Any kind of assumption may bias the estimates. For this reason, we estimate the model using a smaller subsample which only consists of 2076 households that are first observed in 1989. The results are shown in Column 2 in 3.4. The results are generally similar to the first Column, and we again find the average treatment effect is nearly zero.

Although on average father's migration has negligible impact on child's lifetime education attainment, it is possible that the treatment effect differs across different schooling periods. For example, the treatment effect may focus on secondary school and high school participation, as depicted in Figure 3.3, in which the survival curve of the treated children dominates the one of the nontreated children during secondary and high school period. Based on this observation, we distinguish the treatment effect on compulsory schooling from the one beyond compulsory schooling. The results of the period specific treatment coefficients are shown in Table 3.5.

The results show the treatment effect coefficients vary a little across different school-

Table 3.4: Multivariate Duration Model(constant treatment effect)

	(1)		(2)	
Variables	coefficient	hazard ratio	coefficient	hazard ratio
δ	**-0.036 (0.174)**	**0.96**	**-0.036 (0.181)**	**0.96**
duration of child's schooling				
gender	-0.119 (0.080)	0.89	-0.076 (0.086)	0.93
birthyear	-0.075 (0.014) ***	0.93	-0.085 (0.015) ***	0.92
number of children in household	0.234 (0.064) ***	1.26	0.218 (0.067) ***	1.24
household size	-0.266 (0.049) ***	0.77	-0.178 (0.052) ***	0.84
household assets value (log)	-0.126 (0.028) ***	0.88	-0.063 (0.031) **	0.94
father's education				
primary school	-0.500 (0.133) ***	0.61	-0.441 (0.154) ***	0.64
secondary school	-0.582 (0.136) ***	0.56	-0.550 (0.156) ***	0.58
high school	-0.687 (0.158) ***	0.5	-0.647 (0.174) ***	0.52
vocational school	-1.529 (0.630) **	0.22	-1.527 (0.557) ***	0.22
college or university	-0.332 (0.880)	0.72	-0.233 (2.806)	0.79
mother's education				
primary school	-0.141 (0.106)	0.87	-0.129 (0.120)	0.88
secondary school	-0.290 (0.114) **	0.75	-0.224 (0.130) *	0.8
high school	-0.595 (0.165) ***	0.55	-0.501 (0.183) ***	0.61
vocational school	-1.655 (0.846) **	0.19	-0.809 (1.444)	0.45
village facilities				
primary school	-0.025 (0.105)	0.98	0.061 (0.126)	1.06
secondary school	-0.227 (0.098) **	0.8	-0.144 (0.106)	0.87
high school	-0.100 (0.173)	0.9	-0.186 (0.187)	0.83
vocational school	-0.022 (0.203)	0.98	-0.104 (0.207)	0.9
electricity	-0.966 (0.161) ***	0.38	-0.840 (0.187) ***	0.43
number of clinics	-0.044 (0.045)	0.96	0.003 (0.050)	1
province dummies	$\surd$		$\surd$	
baseline hazard				
$\lambda 2$ (4^{th}-6^{th} school year)	1.413 (0.222) ***	4.11	1.690 (0.234) ***	5.42
$\lambda 3$ (6^{th}-8^{th} school year)	1.460 (0.190) ***	4.31	1.561 (0.200) ***	4.76
$\lambda 4$ (8^{th}-9^{th} school year)	3.906 (0.177) ***	49.7	3.977 (0.186) ***	53.33
$\lambda 5$ (9^{th}-11^{th} school year)	2.735 (0.215) ***	15.42	2.817 (0.227) ***	16.73
$\lambda 6$ (11^{th}-12^{th} school year)	4.022 (0.220) ***	55.78	4.095 (0.235) ***	60.06
$\lambda 7$ (12^{th} and above)	4.039 (0.340) ***	56.76	4.033 (0.355) ***	56.42

Table 3.4: Multivariate Duration Model(constant treatment effect, continued)

	(1)		(2)	
Variables	coefficient	hazard ratio	coefficient	hazard ratio
duration of father's migration				
father's birthyear	0.036 (0.013) ***	1.04	0.032 (0.014) **	1.03
number of elderly (over 70) in household	-0.329 (0.302)	0.72	-0.289 (0.325)	0.75
number of children(6-16) in household	-0.103 (0.094)	0.9	-0.153 (0.105)	0.86
number of babies(0-6) in household	-0.218 (0.108) **	0.8	-0.289 (0.129) **	0.75
area of farm land (log)	-0.374 (0.083) ***	0.69	-0.364 (0.096) ***	0.69
father's education				
primary school	0.289 (0.329)	1.34	0.275 (0.335)	1.32
secondary school	0.221 (0.321)	1.25	0.107 (0.333)	1.11
high school	0.258 (0.346)	1.29	0.237 (0.366)	1.27
vocational school	0.111 (0.798)	1.12	0.106 (0.843)	1.11
college or university	2.511 (0.564) ***	12.32	1.654 (1.713)	5.23
rainfall shock in previous year	-0.152 (0.131)	0.86	-0.187 (0.151)	0.83
rainfall shock (square) in previous year	-0.162 (0.054) ***	0.85	-0.236 (0.069) ***	0.79
rainfall shock (triple) in previous year	-0.027 (0.027)	0.97	-0.036 (0.030)	0.96
village facilities				
primary school	-0.262 (0.222)	0.77	-0.344 (0.235)	0.71
seconary school	-0.115 (0.248)	0.89	-0.022 (0.277)	0.98
high school	-0.238 (0.371)	0.79	-0.129 (0.422)	0.88
vocational school	0.468 (0.444)		0.351 (0.475)	
electricity	-0.807 (0.328) **	0.45	-0.872 (0.347) **	0.42
train station in village	-0.618 (0.294) **	0.54	-0.628 (0.334) *	0.53
Close to a big river	-0.031 (0.221)	0.97	-0.068 (0.245)	0.93
number of clinics	0.023 (0.240)	1.02	0.057 (0.243)	1.06
minority	0.276 (0.414)	1.32	0.530 (0.402)	1.7
province dummies	√		√	
baseline hazard				
$\mu2$ (1989-1991)	0.345 (0.253)	1.41	0.241 (0.285)	1.27
$\mu3$ (1991-1993)	0.545 (0.246) **	1.72	0.609 (0.263) **	1.84
$\mu4$ (1993-1997)	-1.444 (0.445) ***	0.24	-1.395 (0.493) ***	0.25
$\mu5$ (1997-2000)	-0.852 (0.335) **	0.43	-0.777 (0.388) **	0.46
$\mu6$ (2000-2006)	-0.959 (0.360) ***	0.38	-1.169 (0.444) ***	0.31
unobserved heterogeneity				
v_d	-1.727 (0.232) ***	0.18	-3.091 (0.234) ***	0.05
v_t	-4.737 (0.709) ***	0.01	-3.573 (0.649) ***	0.03
likelihood function value	4955.593		4200.868	
number of observations	2546		2076	

Note: The duration of schooling is defined as the maximum years of schooling observed in the data; the duration of migration is defined as the time span between year 1985 and father's first observed migration. The baseline dummy for father's education is illiterate level. The numbers in parentheses are standard errors. ***,**,* show the statistic significance at 1%, 5%, and 10% level separately.

Table 3.5: Multivariate Duration Model (period specific treatment effects)

Treatment effects	(1) all sample	(2) subsample with observations in 1989
δ(compulsory school)	-0.116 (0.195)	-0.103 (0.206)
δ(beyond compulsory school)	0.246 (0.312)	0.189 (0.317)

Note: The numbers in parentheses are standard errors for the estimates.

ing periods. The point estimation shows fathers' migration increases children's attendance in compulsory school by around 11%, while decreases high school attendance by over 20%. However, none of these effects are significantly different from zero. This result reaffirms the insignificant constant treatment coefficient, that we can't find father's migration has significant effect on children's lifetime education attainment.

3.6 Conclusions and discussions

This paper studies the causal effect of intensive labour migration in rural China on child's education attainment through father's migration during the last one and a half decade. By making use of the panel data of school-aged children and their parents' migration labour market participation, two empirical approaches are attempted. Fixed effect IV method (FEIV), by removing the unobserved fixed effects of a child, and instrumenting the fathers' migration decision by rain fall shocks, is able to capture the effect of incidence of father's migration on the incidence of a child dropping out from school. However, due to the nonconsecutive panel data structure, this approach suffers from many drawbacks. Instead, a duration model, particularly the multivariate mixed proportional hazard duration model (MMPH), is estimated to identify the impact of father's migration history on a child's education attainment, while taking account of the natural dynamic process of schooling. Our estimation results show, even though there is a considerable worry about the negative impact of parents' absence due to long-distance labour migration on child's human capital development, we find father's migration has no significant effect on children's lifetime education attainment.

This result seems contradictory to other studies which focus on the negative psychological and behaviour outcomes of the migrants' children who are left behind. One explanation could be that the positive effect of father's remittances offsets the negative effect of father's being absent from home. However, since the information on remittance is not specifically asked in this survey, it is not very feasible to test this argument with this data set. Another reason could be that due to the limited number of cases, we exclude children whose mothers have ever been away from home doing migration work during children's schooling age. Considering mothers' critical role in children's development, especially in daily life care, not being able to study the impact of mother's migration constitutes the main limitation of this paper. Recent survey shows that females' participation in migration labour market is as competitive as the males' in scale. The effect of mother's migration on child's education becomes a even more prominent issue to examine. This no doubt is a topic that we should study in the future research.

The main contribution of this paper is that this is the first paper which applies multivariate hazard duration model on migration and education problem. The choice of this model has strong applicability in studying education problem in China, as the two main publicly accessible household panel data set from China are both collected from nonconsecutive waves. One of the data set is CHNS that is used in this paper, while the other one "The Gansu Survey of Children and Families" which focuses on rural children's welfare outcomes, including education, health and psycho-social development, is also collected from nonconsecutive waves: 2000, 2004, 2007 and 2009. As the timing of individual choice is not clear in nonconsecutive longitudinal data, estimating the effect of the incidence of one event on the incidence of another event by panel data models may very likely capture the spurious effect due purely to the timing. In this sense, duration model is superior to the fixed effects model.

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