AN ASSESSMENT OF PENSIM2

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Abstract

The Department for Work and Pensions (DWP)'s Pensim2 model is a dynamic microsimulation model. The principal purpose of this model is to estimate the future distribution of pensioner incomes, thus enabling analysis of the distributional effects of proposed changes to pension policy. This paper presents the results of an assessment of Pensim2 by researchers at the IFS. We start by looking at the overall structure of the model, and how it compares with other dynamic policy analysis models across the world. We make recommendations at this stage as to how the overall modelling strategy could be improved. We then go on to analyse the characteristics of most of the individual modules which make up Pensim2, examining the data used and the regression and predictions used in each step. The results from this examination are used to formulate a set of short and medium-term recommendations for developing and improving the model. Finally, we look at what might become possible for the model over a much longer time frame – looking towards developing a 'Pensim3' model over the next decade or so.

Key Words Pensions; microsimulation; policy analysis

JEL classification H55

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Executive Summary

Introduction

In 2003 the Institute for Fiscal Studies (IFS) was commissioned to produce an audit of the Department for Work and Pensions (DWP)'s Pensim2 microsimulation model. Pensim2 is a dynamic microsimulation model which aims to estimate the future distribution of pensioner incomes, this enabling analysis of the distributional effects of proposed changes to pensions policy.

The main characteristics of Pensim2

Pensim2 is one of a number of dynamic microsimulation models in existence around the world. In general these models are used for modelling the relationship between economic variables like pensions, savings, labour market status, earnings and related parameters in a long-run scenario (over the course of several decades into the future). This is done by using large scale datasets containing representative samples of individuals and households (either from administrative or household survey data) and then 'growing' the sample through time by simulating the relevant life events for each individual and each family. Over time, complete synthetic life histories are built up for each individual, including data on mortality, labour market status and work history, retirement age, savings and pensions contributions, and so on. The model is divided into 'modules', each of which determines a number of economic outcomes. The full list of modules and the sequence of estimation are shown as an Appendix to this report.

Advantages of the Pensim2 approach

- Pensim2 uses micro-level data, which is an improvement on the previous generation of long-run models which relied on aggregate time series data. Micro data allows modelling of the distributional effects of policy. Panel data (where the same individual or household is followed over time) is also used in estimation, which helps with modelling transitions between, for example, different labour market states. Also new synthetic cohorts of people can be introduced into the model when simulating forward in time.

- Pensim2 models a very wide range of economic processes and emphasises the linkages between different economic outcomes.
- The model user is allowed to specify various parameters at run-time, which allows additional flexibility.

Criticisms of the Pensim2 approach

- Some economists argue that 'structural dynamic models', which attempt to estimate the underlying preferences of the individuals used in the model, are preferable to simulating forward in a 'mechanical' fashion based on the observed data. We compare the features of a typical dynamic structural model with the Pensim2 model in Section 4.1 and find that there are theoretical arguments both for and against the structural approach. At a practical level, however, it is important to realise that it is not possible to estimate a fully structural dynamic model of all the processes covered by Pensim2 using existing computer technology, as the model would be too slow. Hence Pensim2 may have to remain largely 'non-structural' for the foreseeable future even if a structural approach were thought to be unequivocally preferable to the existing modelling methodology.
- Pensim2 implicitly assumes that the relationships between different economic processes are 'structurally stable' over a 50-year time horizon. This means that, for example, the same processes that determine choice of pension provider today will continue to do so every year from now until 2050. Whilst it is not clear what alternative assumption would be preferable, it is important to recognise that the results from Pensim2 will be sensitive to the assumption of structurally stable processes.[1]
- It would be useful if a complete econometric description of the model – i.e. a clear description of all the regressions that are estimated in Pensim2 with the order in which they are estimated – could be published alongside the Pensim2 base documentation. This would enable users to see more easily what the links between the various modules are, as well as what economic variables are *exogenous* (i.e.

[1] When the model is calibrated, implicitly the relationships are being changed, although these still may not reflect the relationships that exist in the future. For those relationships where past data would suggest an obvious direction of change, it would be possible to incorporate these into projections of future relationships.

determined by factors outside the model itself), and *endogenous* (i.e. treated as variables which are determined at least partially *inside* the model).

- The scope and number of processes included in Pensim2 means that it is not just a pensions model, but could be used for many other policy analyses. For example, it seems well suited to modelling the long-run impacts of changes in personal tax and benefit policy on the public finances; tuition fees for higher education; and 'asset based welfare' policies such as the child trust fund. Indeed if the processes contained within the Pensim2 model are accurately modelled then it could be utilised to model the effect of policy reform on outcomes such as fertility and household composition. However, there are some areas of omission from the current scope of the model.[2] These include:
    - A health module. It would be useful to investigate the possibility of detailed modelling of health status using information from the *British Household Panel Survey* (or *English Longitudinal Study of Ageing* for those aged 50 and over once the data become available). This would improve mortality and disability modelling considerably.
    - Modelling the accumulation of housing wealth and the decision to move house seems important as it is one of the key forms of wealth holding in the UK. It is also possible that housing wealth will be used as a substitute for pension accumulation by some UK citizens in the future.
    - Incorporating intergenerational linkages into the model, particularly as regards modelling educational attainment.
- None of the Pensim2 modules currently contain variables to control for the business cycle (macroeconomic) effects in the regressions used in each module.

Module-by-module analysis and recommendations

We make a number of recommendations regarding ways to improve individual modules in Pensim2. The short-run recommendations – which could be implemented immediately or in the near future – mainly concern minor amendments to specifications

[2] Presumably, the modular approach of Pensim2 should allow such modules to be added at a later date without significantly affecting the structure of the model.

of individual regressions used in the model. These are listed in Table 6.1 in the main report.

The medium-term recommendations would involve larger changes to the model. These are listed in Table 6.2 of the main report. The most important recommendations are:

- Take recent changes in the Income Support / Pension Credit system into account when modelling the future relationship between mortality and Income Support / Pension Credit eligibility. This will be particularly important for policy simulations.
- Allow assignment of educational characteristics to new cohorts of young people in the model to vary by the observable characteristics of their parents. In effect, this would introduce an element of intergenerational linkage into the model.
- Move towards joint modelling of couples' employment outcomes rather than having the female partner's labour market outcome being conditional on the male partner's.
- Try to incorporate income or substitution effects which might affect the level of private savings – in particular the impact of tax and benefit reforms which might affect support for pensioners or the expected returns to private saving.
- Exploit data from the newly released *English Longitudinal Study of Ageing* (ELSA) to improve modelling of pension scheme tenures (contingent on a reasonable time series of ELSA data becoming available).
- Use the *British Household Panel Survey* to model pension tenures for younger individuals not covered by ELSA.
- Allow feedbacks to pension scheme decisions from the tax/benefit system and the macroeconomy.

The future – towards "Pensim3"

As well as giving short-to-medium-term recommendations, we attempt to look beyond that horizon to ask what might be possible in the much longer term. There are two main areas in which major improvements should be possible:

(1) New data sources, particularly:

  - The *English Longitudinal Study of Ageing* (ELSA).
  - The DWP's proposed disability survey.

- Inland Revenue administrative data on tax credits and pension contributions.
- The proposed ONS asset and wealth survey.

(2) Technical improvements. According to Moore's Law (Moore, 1965), whereby computer transistor densities double every eighteen months, by 2014 the average desktop personal computer should be around 100 times more powerful than the average 2004 model. In particular, it may be possible to develop a dynamic structural model of the entire Pensim2 process, or at least some key aspects of it. It will also be much easier to estimate the current model or a moderately more complex version of it in a reasonable timeframe.

1. Introduction

In Autumn 2003 the Institute for Fiscal Studies (IFS) was commissioned to produce an audit of the Department for Work and Pensions (DWP)'s Pensim2 microsimulation model. As explained in DWP's summary description of the model (DWP 2001), Pensim2 is:

> *…a dynamic microsimulation model whose principal purpose is to estimate the future distribution of pensioner incomes. This will enable analysis of the distributional effects of proposed changes to pension policy.*

The structure of this audit report is as follows. In Sections 2 to 4, we are interested in tying down what the overall approach taken by DWP to long-run pensions modelling is, how it fits into a formal econometric framework, how it compares with other attempts to model pensions around the world and elsewhere in the economics literature, and what the overall implications of the model are. Section 2 presents a brief overview of the approach which Pensim2 takes in modelling pensions and other economic processes over a 50-year time horizon. Section 3 then describes some of the main advantages of this approach. Section 4 sets out a number of possible lines of criticism of Pensim2, and offers some possibilities for redesigning the model to address these criticisms.

Section 5 goes from the general to the specific with a detailed examination of Pensim2 on a module-by-module basis. For each of the modules we have looked at, we assess whether there are any improvements, additions, or robustness analyses that could be carried out either now or in the near future to improve the model's functionality. Based upon on our recommendations in Sections 4 and 5, Section 6 presents a set of 'action points'. These range from very minor to quite major suggestions for improvement, but should all be implementable in the near future, if funding permits.

Section 7 focuses on a much longer time horizon – what might a 'Pensim3' model look like in the year 2015 (say), assuming that computational power continues to progress at the current rate. A long-term view also allows us to make recommendations regarding factors that are fixed in the short run (such as the content of the data sets used, for instance; any changes made to data collection would take several years to feed through to practical uses in modelling).

The objectives of Pensim2 are extremely ambitious – amounting to nothing less than the simulation of the UK population and demographic changes, labour market, income distribution and government support for pensioners 50 years into the future. The ease of such a project is also hindered by limitations in the complexity of current economic models, the availability of data and the processing power of computers. It is inevitable in such a project that many aspects of the models have to be relatively simple. The objective of this report therefore is not to be over-critical, but instead to try to highlight where efforts to make the next improvements to the model should be focussed.

2. The main characteristics of Pensim2 and other dynamic policy analysis models

The Department for Work and Pensions describes Pensim2 as a dynamic microsimulation model. Whilst studying the literature to learn more about the methods which economists use for modelling pensions, savings, labour market status, earnings and other related economic phenomena in the long run, we have found that Pensim2 is an example of one of a range of models around the world which have similarities in their construction and in the purposes they are used for. Some recent examples of this type of model for other countries are:

- Polisim (USA) (MacKay, 2003)
- DYNACAN (Canada) (Morrison, 2003)
- SESIM (Sweden) (Swedish Ministry of Finance, 2004)
- Destinie (France) (Dueé and Rebillard, 2004)
- A model of the Chinese social insurance system (Xiong et al, 2003)

Models of this type share some important characteristics. These are as follows:

- The models start off, as far as is possible, with 'large data files that are representative cross-sections of their national populations' (Caldwell and Morrison, 1998). This is to ensure that the aggregate totals and distributions of model outcomes such as for pensions expenditure, tax payments, and the underlying distribution of earnings, match the equivalent overall statistics for the country which the data are taken from. Sometimes more than one 'large scale' source of data is used for different parts of the model analysis. Common sources of 'large scale' data are administrative sources

– for example, tax receipts, benefit agency records, or census information. In some cases, the large-scale data files are lacking in the full set of information necessary to estimate the model effectively, and the data have to be supplemented with smaller scale datasets with a wider range of covariates, which are then matched or 'fused' with the larger data in some way.

- The models are 'grown' through time by simulating the relevant life events for each individual and each family. This can be done year-on-year for the (starting) year t, t+1, t+2, in discrete time, or by starting at t, and predicting a life event at (t+n), where n is positive and possibly non-integer (continuous time). The predictions of life events at time t+1 are based on observed characteristics in period t but with a stochastic component added in, making them Markov processes. The stochastic component is added in to preserve unobserved heterogeneity in the future simulated data, giving a realistic distribution of the economic dependent variables.
- Over time, complete synthetic life histories are built up for each individual. These will typically include the following 'life events' and economic information:
    - Earnings
    - Tax contributions and benefit receipt
    - Mortality
    - Partnership/separation
    - Fertility
    - Education
    - Disability/ ill health
    - Employment / self employment
    - Job/work characteristics
    - Retirement
- A typical model is divided into 'modules', where each module deals with the calculation of outcomes for one of the areas shown above, possibly taking the outcome of other modules as inputs. The processes that govern events in each of these modules are first estimated using a variety of data sources, and then using the estimated parameters to generate predicted values, the life events of individuals are

simulated in sequence (the simulation sequence for Pensim2 is shown in the Appendix by way of example).

- The order of simulation is important insofar as it determines what current information is available as an input for modules 'further down the line' (it therefore imposes exclusion restrictions). In such a modular approach, it is certainly not obvious which order the outcomes should be simulated in, and as such it is possible that conclusions could be sensitive to these. In practice, we would expect most of the outcomes to be jointly determined (for example, the decision to have children, and the labour market status of an individual) rather than the sequential nature of Pensim2.

3. Advantages of the Pensim2 approach

In this section we highlight some of the relative advantages of the current Pensim2 approach.

a) using micro-level data

The approach taken by Pensim2, and other models like it across the world, represents a positive development in long-run policy analysis compared with what was done in previous decades. Before the development of long-run microsimulation models, policymakers tended to rely on time-series based studies using aggregate variables. Pensim2 represents an improvement on aggregate modelling because:

(i) it allows modelling of the distributional effects of policy. Studies based on aggregate data are unable to model the position of individuals in the distributions of earnings, income and so on at any particular point in time.

(ii) Pensim2 uses panel data which provides information about individual dynamics. For example, how much do individuals and families move up and down the relevant income distribution from year to year? Aggregate measures of income over time give us no information on this.

(iii) Ageing the population forward in time allows the introduction of new, synthetic cohorts into the model, as specified by the fertility module. These new cohorts can then enter the labour market at ages estimated using the

education and labour market modules. This is a significant advance over macro-based models which can only extrapolate general trends forward in time.

b) modelling a range of processes

The range of processes covered by Pensim2 is extensive (as shown in the Appendix). Whilst arguably still further processes would need to be included for a 'complete' model of individuals' and households' economic choices and circumstances over the lifecycle, it seems fair to say that Pensim2 captures most, and perhaps all, of the processes necessary to simulate the pensions system over the next 50 years.

c) allowing user interactions

Pensim2 has the useful feature of allowing the user to specify certain parameters at run-time (for example the rate of return to the stock market which is an important component in the savings and pensions models). This makes it easy for the model to produce analyses of what will happen to pensions spending and other economic variables under different assumptions about how the economy will behave over future decades (for example, assuming a given average rate of return on stock market investments, or a given proportion of individuals graduating from higher education). Of course care should be taken when setting these parameters – and in particular attention should be paid to whether they are likely to be affected by the processes contained within Pensim2 itself – for example the proportion of individuals graduating from higher education might be affected by labour market returns.

4 Criticisms of Pensim2's overall approach

In this section we focus on some general criticisms of the current Pensim2 approach which might help inform future developments.

4.1 Criticism from proponents of structural dynamic models

Whilst the approach taken to modelling pensions in Pensim2 is very common in the recent literature, there also exists a class of models, which we shall call 'structural

dynamic' models[3], which analyse similar processes using a different approach. Recent papers in this vein include:

- French, 2000
- Rust and Phelan, 1997
- Van der Klaauw and Wolpin, 2002
- Blau and Gilleskie, 2000 and 2001.

We will use the van der Klaauw and Wolpin paper as an example of this type of model in our discussion below. Van der Klauuw and Wolpin (hereafter abbreviated to VW) model the relationship between labour supply decisions, state and private pension accumulation, health status and health insurance, and retirement decisions in the United States. The general idea of this model, and others in a similar vein, is as follows:

- Rather than using a 'mechanical' simulation based on feedback from regression parameters at *t-1* (and stochastic perturbations) in the models for formation of each process at time *t* and then iterating forwards, these models attempt to recover the underlying structural parameters of the economic agents involved. This involves modelling individuals as 'rational agents' optimising a utility function which is forward looking. So for example, in the VW paper, utility is a function of the discounted present value of consumption and leisure in each future time period. Individuals make choices at time *t* based on the information available to them about what this will mean for their well-being going forward into the future, rather than simply maximising a utility function based on a single period (as happens in many empirical labour supply models, for example). As VW themselves put it:

> *'Unlike earlier static lifetime models… dynamic models account better for the sequential nature of the retirement process in which individuals adjust their behaviour as events unfold. Structural estimation of the fundamental parameters of preferences and constraints as opposed to reduced form analyses permits the simulation of policy experiments that act directly on constraints and which may be outside of current or prior policy regimes'. (van der Klaauw and Wolpin, 2003)*

[3] It is important to stress here that our use of the term 'structural' here does not mean that we think Pensim2 has no structural features. For example, many of the modules have explicit or implicit exclusion restrictions in terms of the set of variables which are used as regressors in each module, so the Pensim2 model is not a pure 'reduced form' approach .

- This focus on discounted lifetime utility vastly increases the computational complexity of the model. The model needs to be solved by backwards induction (numerical integration by drawing from a distribution of shocks in A, the terminal period: then A-1, the 'terminal minus one' period, and so on.) Optimal work and consumption has to be calculated at all possible values of the 'state variables' (work, assets, etc) and so in practice a large number of points is calculated and then polynomial interpolations are used to calculate the spaces between these points.
- The complexity of these models means that they can cover only a limited subset of the processes covered by large-scale models like Pensim2. For example, the VW paper covers pensions accumulation, labour supply and retirement decisions and consumption/savings choices but does not include any treatment of disability, education or housing.
- Models like VW are usually estimated on much smaller data sets than the large scale models like Pensim2 (although the former are usually restricted to subgroups of the population where larger samples may be available). In particular Pensim2 utilises the LLMDB which contains a sample of 400,000 across all age groups.
- By way of illustration, Table 4.1 shows how many features of the economy are captured by the van der Klaauw and Wolpin model compared with Pensim2 (of course, the two models may treat different processes very differently).

Table 4.1 Comparison of the characteristics modelled in Pensim2 and the VM model.

Module	**Pensim2**	**VW**
Mortality	Yes	Yes
Institutional care	Yes	No
Migration	Yes	No
Education	Yes	No
Health/disability	No	Yes
Partnership	Yes	Yes
Fertility	Yes	Yes
Labour market status	Yes (sequential)	Yes (joint)
Job characteristics	Yes	No

Earnings	Yes	Yes
NI contributions	Yes	Yes
Housing	Yes	No
Savings	Yes	Yes
Pensions	Yes	Yes
Taxes and benefits	Yes	Yes
Expectations data	No	Yes

Obviously, as this is a simple comparison of a particular model from the two model types we have identified, there may be features of both models which are atypical of the 'genre' from which they arise. For example, VW's use of subjective expectations data is atypical of economic models in general, even in dynamic contexts. Nonetheless it is a useful illustration of the relative strengths and weaknesses of the two types of models.

Clearly, Pensim2 covers a wider range of processes than VW. The latter does not consider institutional care, migration, education (it is assumed fixed, as only men and women from age 40 and over are included), fertility, job characteristics (apart from whether a pension is offered), or housing. On the other hand, Pensim2 does not model labour supply jointly, relying instead on a model where the male partner's labour supply is estimated first, with the female partner following.

Comparing the dynamic structural approach with Pensim2

It is instructive to consider the differences between Pensim2 and 'structural' models like that set out in the van der Klaauw and Wlopin paper considered above. Estimation of Pensim2 relies on deterministic links between different processes (with stochastic components added in), with as many processes modelled as possible, and the sample aged year-by-year to build up a long-run simulation of the paths of economic variables. The dynamic structural approach, by contrast, models economic variables as the outcome of individually and family-specified utility maximisation subject to constraints given by policy (and sometimes externally imposed to guarantee realistic results). In this type of model, a value function (e.g. discounted present value of lifetime utility) is maximised subject to uncertainty and stochastic shocks, with the solution derived by backwards recursion under dynamic programming. Pensim2 sits firmly in the first camp of models in its current incarnation.

Arguments for a structural approach

Drawing on a critique by Goldberger (1989), and just for the purposes of this section, we shall characterise models of the first type (like Pensim2) as 'mechanical' and of the second type as 'structural'.[4] The major pioneer of the 'structural' approach to modelling various economic processes involving small combinations of agents – intra-household and family processes in particular – has been Gary Becker.[5] Becker (1981) criticises 'mechanical' models on the grounds that they are not rooted in the following assumptions, which he sees as crucial:

(i) utility-maximising behaviour

(ii) stable and well-defined preferences over outcomes

(iii) equilibrium in markets (explicit or implicit)

The key point which Becker makes is that models in which a utility function is specified and estimated can lead to predicted relationships between parameters which are completely different from those which arise from simply regressing key economic variables on explanatory factors. For example, Becker's model of intergenerational income transmission (Becker and Tomes, 1986) suggests that if you raise a parent's income, you will *lower* their grandchild's income. This is contrary to what would be predicted from a regression coefficient on grandparent's income in a 'mechanical' model of grandchildren's outcomes, from the data which Becker uses. As Becker sees it, then, mechanical models can generate conclusions that are simply wrong.

Possible problems with structural models

Becker's evangelising of the economic approach to modelling human behaviour has been highly influential on the evolution of the economics profession over the past 25 years, to the extent that some empirical economists now regard a utility-maximising framework as a precondition of examining any particular problem or issue. However there are some important caveats and counter-arguments to the view that 'economic models are best'. In particular:

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[4] Goldberger was referring specifically to models of intergenerational transmission of income and wealth, but the distinction can be applied equally well to the wider-ranging models under discussion here.

[5] Becker refers to the structural class of models as 'economic' but this seems a rather skewed use of language to us as the mechanical models that Goldberger looks at, and that we look at, could hardly be described as 'non-economic'. Hence

- The components of utility, and the functional form used in the utility function, tend to make a big difference to the predictions of economic models (Goldberger, 1989). Without further assumptions, standard microeconomic theory tells us *nothing* about what should be in the utility function, as any observed behaviour can be interpreted as optimal under some utility function. This is a well-known issue in economic methodology (see for example, Boland, 1981, and Caldwell, 1983). In practice, individuals are often treated as (discounted) income or wealth maximisers, which is contentious – clearly it is not hard to imagine that non-pecuniary aspects of life might make a difference to one's welfare. In a family setting, the additional issue arises of how income is shared within the household, and whose utility is being maximised (Browning et al, 1994).

- Likewise, stable preferences is an identifying assumption without much justification in the theory itself – there seems no *a priori* reason why preferences should be stable over time (although this might in fact be the case empirically).

- The market structure under which the economic interactions take place in dynamic economic models is often quite simple, to facilitate estimation of key parameters. For example, a wage determination model might be a simple human capital model operating in a perfectly competitive environment where each individual of a given skill level is paid the same wage (following e.g. Roy, 1951). Whilst this may be a reasonable approximation in certain labour markets it seems to ignore a huge quantity of theoretical and empirical research on the determinants of wages which stresses other mechanisms which affect wages when the market diverges from the perfectly competitive paradigm. The simplicity of the market environment postulated in these types of models makes estimation feasible, but at the same time may call in question the applicability of the results to the real world. Likewise, if markets are in a state of disequilibrium rather than equilibrium, the simple assumptions about the market environment may not hold. (Of course, these criticisms are also true of the Pensim2 approach).

- As pointed out above, the complexity necessary to even approximate the choice process to a reasonable degree means that these models are limited to handling a

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we have decided to use 'structural' in this section. This should not imply however that we think that Pensim2 has no structural features. We have more to say in this issue in Section 4.3, on endogeneity.

small subset of economic phenomena at one time rather than an across-the-board 'general equilibrium' analysis. Also for the time being it has only been feasible to implement them on relatively small datasets (survey data rather than administrative data, for example). These restrictions will be reduced as the computational power of each new generation of computers increases. However, survey data also tends to be preferred over administrative data for the estimation of these models because the estimation of sensible utility functions usually requires the presence of variables in the dataset which are not always collected in administrative data (for example: educational attainment. In some cases family status and demographic variables are also absent from administrative data.)

This suggests that 'mechanical' models of pension accumulation and related features of the economy do have practical advantages over dynamic structural models, even if they may be methodologically inferior in some ways:

- They are estimateable on very large datasets and can cover a wide range of processes.
- They do not rely on assumptions of individual rationality or market structure which may be unrealistic. (But conversely, the parameter estimates from mechanical models will not have the clear interpretation in terms of individual behaviour that structural models do).

4.2 Forward prediction in Pensim2

Pensim2 uses current data to estimate a number of processes within the different modules. These estimated relationships are then used in each discrete time period taking us to the year 2050 to simulate the various life events. It is therefore implicitly assumed that these relationships are stable over the time frame considered, so that, for example, the same processes that determine the allocation of housing tenure type at age 60 today continues to do so every year from now until 2050.

Assuming that the processes are structurally stable over a fifty-year time horizon is clearly a very strong assumption. Clearly, this is not a problem that may be easily overcome given the obvious lack of future data. However, at the very least, in order to minimize the possible errors in the predictions, there must be evidence in favour of the stability of the model during the sample period, and also of the accuracy of the estimated coefficients. If the model does not exhibit stability over the sample period, then it is unlikely to be appropriate in out-of-sample predictions.

The assumption of structural stability is perhaps less arbitrary than incorporating some speculative decision about how these processes may change in the future. So while it is acknowledged that this is not a problem that can practically be addressed, it does remain important to recognise that the results from Pensim2 will be sensitive to the implicit assumption of structurally stable processes. We will therefore comment on the modules where we believe that this may be a particular problem, and given the linkages, how this may impact upon further modules.

4.3 Endogenous processes and exclusion restrictions

The current literature for Pensim2 describes each module separately, and there is a flowchart (reproduced here in the Appendix) which shows the sequence in which modules are estimated to take the model forward year-on-year. In many cases, the output from one module is used as the input into another. For example, predictions from the labour market module (who is in work and who is inactive) feed into the module for pensions accumulation. It would be very useful if the DWP published a specification summary of the Pensim2 model, including a clear description of all the regressions that are estimated for a one-year run, with the order in which they are estimated. It would be useful to present the complete econometric specification in this way for several reasons:

- It would enable those outside of the DWP to compare the exclusion restrictions in the various modules. Many of the modules exclude certain sets of regressors from the equations specified, either for reasons derived from economic theory or because the regressors proved statistically insignificant in specification searches. It would be useful to have a clearer overall picture of what the exclusion restrictions look like.

- It would enable a clear identification of what variables are exogenous to all modules, and which are treated as exogenous in some, but not in others. For example, labour market status is treated as an exogenous input into the pensions module, but is an endogenous variable in the earnings module (hence the need for a selection correction in the latter case). A taxonomy of this kind would also enable potential identification problems (for example, uninstrumented endogenous variables) to be identified far more easily.

- It would facilitate the discovery of groups of modules which could be estimated jointly to improve model efficiency. With infinite computing power, it would in theory be possible to estimate the entire Pensim2 model jointly via maximum

likelihood. Of course due to the high number of equations and the huge datasets involved this will probably remain a fantasy in our lifetimes. But there may be subsets of modules which can be jointly estimated without an unacceptably large increase in estimation time.

4.4 Model scope and uses

In its current incarnation, the Pensim2 model encompasses labour market status and earnings for working age and pension age people; tax and benefit modelling for people of pension age; savings; migration; partnership and fertility; and the educational attainment of children who are 'born into' the sample as time moves forward. The naïve question to ask at this point would be: 'why not just model pensions?' The answer would be: 'because to model pensions properly, we have to model all these other processes too'. We certainly agree that all the processes modelled are important. However, in many ways the inclusion of all the extra processes means that Pensim2 is not just a pensions model, but could be used for many other policy analyses, even limiting the set of modules to those which are included at the moment. For example, it seems well suited to modelling the long-run impacts of changes in personal tax and benefit policy on the public finances. Some of the long-run impact of any current tax change will manifest itself through changes in pension accumulation, but there will also be other factors at work (for example changes in labour supply for working age people) which will affect the public finances well before individuals reach pension age. Further examples of processes which Pensim2 could easily be adapted to analyse include tuition fees, and 'asset-based-welfare' policies such as the child trust fund.

The ability of Pensim2 to provide insight into different policy issues will inevitably depend upon the appropriateness of the assumptions made to arrive at any prediction. So while Pensim2 could potentially be informative about, say, the number of pensioners who will be eligible for the Pension Credit, this number is likely to be quite sensitive to the various assumptions made throughout the modelling process. Furthermore, even if all the assumptions made are 'correct', there are many questions that are simply beyond the scope of Pensim2. These include (though are not limited to), the extent to which any increase in state pension provision will crowd out private savings, and the impact of pensioners downsizing their properties (see the following housing wealth subsection).

With the addition of some further modules, it would be possible to do even more. We feel that even though the scope of the model is wide as it stands, there are some important omissions at present. These are as follows:

Health module

Pensim2 does not feature a health module at the moment, although mortality is modelled, as is incapacity (in the labour market module) and receipt of 'extra cost' disability benefits (Disability Living Allowance and Attendance Allowance) for pensioners. We discuss possibilities for the introduction of a health module in the mortality and disability module subsections in Section 5.

Housing wealth

Whilst housing is modelled in Pensim2 for the purposes of calculating housing benefit for renters on low incomes, there is no treatment of the accumulation of housing wealth. Strong growth in the housing market (such as has been seen in the past few years) increases the wealth of owner occupiers.[6] By the time that parents are at or nearing retirement, their children may have left home in many cases, which may make a smaller house size more optimal for them. Also, retired people may be more flexible in their choice of location because there is no longer the requirement to live in an area where travel to work is feasible. These factors can create an incentive to 'trade down' to a smaller house, or to move region to an area where house prices are lower, to release wealth during retirement. If housing wealth is used to some extent as a substitute for wealth accumulation through pensions or saving, it would seem important to have some consideration of this in the Pensim2 model. Perhaps information from the *British Household Panel Survey* (BHPS) could be used in conjunction with house price data from government, building society or estate agent surveys.

Intergenerational linkages

At present, Pensim2 does not contain intergenerational linkages; that is, characteristics of parents do not help determine the characteristics of any children that are born in the model. Furthermore, there the model does not accommodate bequests (intergenerational

[6] Owner occupation is modelled using a sequential two stage estimation process: in the first stage it is predicted whether individuals are renting or not, and conditional upon not renting, a second relationship is estimated, which is used to predict whether they own outright, or are paying a mortgage.

transfer of resources). The model builders recognise that this is a limitation of the current model and it is our understanding that they intend to introduce such intergenerational linkages into future revisions, for example through the education module. One problem with introducing intergenerational linkages is that the data requirements for modelling intergenerational transmission of factors are quite stringent. Ideally we would wish to observe parents and children at a similar point in the life cycle (to ensure comparability between the two sets of observations), and over several years (to smooth out transitory shocks and focus on 'permanent' status). This is particularly important for variables which are time-varying through a person's working life (for example, earnings, occupation, and health). It is easiest to model intergenerational linkages between variables which change little over the (working age) life cycle (for example, educational attainment).[7] For a convincing model of intergenerational linkages, ideally we require either panel data with a very long time series element, or cohort study data following a cohort of individuals from birth through to adulthood and onwards. With regards to the former, the BHPS is still not really long enough (at 12 waves) to be of much use, except as regards modelling intergenerational links between parents' and children's educational attainment. As regards the latter, the cohort study data in the UK comprise the 1946 cohort study, the 1958 National Child Development Survey, the 1970 British Cohort Study and the 2000 Millennium Cohort Study. This provides a reasonable range of cohorts and could in principle be used to model transmission of earnings potential, occupation etc. between parents and children even *conditional on educational status* (thus getting at some of the factors determining earnings which are unobservable in cross-sectional data). However, the absence of a cohort from the 1980s or 1990s means that for individuals entering the labour market at the present time, it is impossible to model the intergenerational linkages with any certainty – which is a real shame. So it may well be that intergenerational modelling in future versions of Pensim2 is limited to education, at least until the millennium cohort are substantially older.

[7] However, if current trends continue we are likely to see more 'lifelong learning' and hence more attainment of educational qualifications for adults already in the labour market. This could mean that in the future, it becomes less and less appropriate to model education as a time-invariant characteristic.

4.5 Business cycle effects

None of the Pensim2 modules currently contains variables to control for business cycle (macro) effects in the regressions used in each module (for example, GDP growth, the unemployment rate, and so on).

For modules that are being estimated using panel data sets over a long period, which covers several business cycles, this should not matter too much, as we can expect that the results from the estimation will separate the underlying trends in economic variables from the short-run effects of the business cycle. This should be the case for modules estimated using the Lifetime Labour Market Data Base, for example. But for modules estimated using the British Household Panel Survey, which is only 12 waves long at the time of writing, it is less clear that the estimation procedure will separate underlying trends from cyclical effects. It might be useful if the parts of Pensim2 that are estimated using BHPS (for example the earnings module) could be re-estimated including one or more variables designed to capture business cycle effects, to see how much difference this makes. Obviously it is hard to forecast cyclical peaks and troughs going forward in time, so for the forward simulations of each module, it would probably be easiest to 'switch off' business cycle deviations. (This is most easily done by defining the business cycle variable to have mean zero over the sample period used for the original estimation – for example, a deviation from trend GDP growth).

While an earlier version of the Pensim2 did experiment with the inclusion of such cyclical effects, the Pensim2 development team considered this to be too complex to justify the implementation. It is unclear to what extent the inclusion of these effects affected the estimated relationships, and ultimately, the predictions of Pensim2.

4.6 Model-wide econometric issues

Nested Logit estimation

The nested logit models have been estimated sequentially. In the context of the housing module, for example, this involves first determining whether an individual is renting or not, and then conditional upon not renting, the second step determines whether individuals either own their housing outright, or are paying off a mortgage. While such a two-step procedure (estimating each of the relationships in sequence) does provide consistent parameter estimates for a correctly specified model, it is not as efficient as

simultaneous maximisation of the log-likelihood function (estimating both relationships together). There are two further problems that Train (2003) asserts argue against its use. Firstly, the standard errors from the second step are biased downwards (see Amemiya, 1978). This can therefore give the impression of greater precision than there truly is. Secondly, common parameters (which may be implied by the underlying structural model) are not constrained to be the same.

Of course, the main advantage of using sequential estimation is that it is much less computationally demanding. Whether simultaneous estimation is considered a feasible alternative or not will therefore depend upon the sample size and the complexity of the model.

We deal with other econometric issues in the next section, as they tend to relate to individual modules rather than occurring in several different places across the model.

5. Module-by-module analysis

In this section of the report we discuss issues relating to each module. The analysis here will draw on the points made in Sections 2 to 4, and will inform our suggested short-run changes and long-run changes in Sections 6 and 7. Certain modules are not featured as they were outside our main area of expertise – primarily the migration and institutional care modules. Additionally, we don't have a specific section on modelling taxes and benefits using the DWP's static microsimulation model PSM (Policy Simulation Model), although we do point out where the assumptions made in PSM or any other modelling strategy will be important.[8]

5.1 Mortality

During the consultation period, Pensim2 modelled mortality separately for men and women, and separately for those of working age, those of pension age up to age 80, and those aged over 80. An individual's probability of survival is modelled as a function of their age, region, receipt of disability benefit and measures of their individual economic well-being. The administrational data used for this analysis is very strong in terms of these characteristics, but does have some drawbacks. Data is taken from GAD, the LLMDB and the Retirement Pension administrative records.

[8] PSM was primarily used for determining incomes for those of pension age.

There are two main weaknesses to the current approach used for modelling mortality, both of which are a direct result of the limitations of the data used in the analysis: First an individuals mortality is modelled as a function of measures of individual level income rather than using either a family or household based composite. Second currently Pensim2 does not model health and therefore an individual's health is not included as a determinant of their probability of survival. Research using the *British Retirement Survey* (BRS) has shown that current family wealth is a significant determinant of subsequent mortality (and morbidity) and that this is still true once current health is controlled for (Attanasio and Emmerson, 2003). Omitting current health from this model is likely to lead to bias in the estimated coefficients.

In the medium term the modelling of mortality could be improved by incorporating a model of health (which would also be of use in the modelling of disability benefit receipt and labour market status). For the working age population health could be modelled using information from the *British Household Panel Survey* (BHPS). This data contains both subjective questions about general health and work-related health, and also a number of additional questions about specific health problems that are potentially more objective. (For further details of modelling health with the BHPS see Disney, Emmerson and Wakefield, 2003). As the BHPS sample size grows over time it may also be possible to use this dataset in the modelling of mortality. In part this will depend on the extent to which death is observed in the BHPS as distinct from attrition for other reasons. The modelling of both mortality and morbidity for those aged 50 and over could be conducted using the *English Longitudinal Study of Ageing*. This survey contains detailed information on health and measures of economic well-being, and has sufficiently large sample sizes so that over time a reasonable number of deaths will be observed. One potential problem that could arise with using any household based survey to model mortality (as opposed to administrational data) is that attrition from the survey could in fact represent unobserved death. The analysis of mortality using the BRS cited above explicitly incorporates a model of attrition from the survey that is not due to death.

In the short-term, given the data constraints, there is little room for further improvement in the modelling of mortality. For those of working and those of pension age but not over 80 it might be worth considering allowing the impact of standardised or relative income on mortality to vary by age. (Although for those above state pension age but not

over 80 this is in part included through the interaction of age and eligibility for income support).

As previously discussed, the current mortality module estimated separate models for those below the state pension age, those above the state pension age up to (and including) age 80 and those aged over 80, with separate models estimated for men and women. Given that the state pension age for women is set to gradually increase from age 60 to age 65 between 2002 and 2010. A better split is to model individuals aged under 65, those aged 65 to 80 and those aged 80 and over regardless of the state pension age. This change has since been implemented. However, considerations should be made to the fact that as the percentage of pensioners eligible for income support changes over time this might be expected to change the relationship between being eligible for income support and an individual's subsequent survival probability. At the very least it would seem sensible to consider individuals being eligible for income support if they are eligible for the Pension Credit Guarantee rather than the relatively more generous Pension Credit Savings Credit. Even in this scenario reforms that substantially increase or reduce the percentage of pensioners who would be eligible for income support in the future may lead to inaccurate modelling of their probability of survival. For example while being on sufficiently low income to be eligible for income support might be associated with a higher probability of death this would not necessarily imply that an increase in the generosity of income support which increased the number of eligible pensioners would increase their likelihood of dying.

5.2 Education

The education module is perhaps one of the simplest modules in Pensim2. In this module the level of education attainment is randomly assigned to all individuals at age 16 from which the age leaving education is calculated. As acknowledged in the Pensim2 documentation, in the present form the module is quite simplistic. It would be better to allow the assignment of educational characteristics to vary by observables as discussed in the final section of the respective Pensim2 series paper, rather then by random assignment.

In any case, the educational projections that the data is calibrated to are policy invariant. For example, if there is further expansion in higher education then we would ideally like the projections to reflect this. It is our understanding that such factors will be able to be

set as a user parameter in the final version of Pensim2 model and the ability to do this is welcomed.

As previously mentioned, incorporating demographic and intergenerational factors (using the BHPS, for example) will be a major improvement on the present methodology. However, the assumption of structurally stable processes may be violated. For example, the proposed higher education bill involves students only paying for their university education once earnings exceed a threshold amount. By removing the present credit constraint it could be argued that the degree of educational intergenerational mobility increases. However, given the data constraints which we face, this is not an issue that can be easily addressed.

An alternative method of modelling education acquisition that was discussed introduces some individual level optimisation which is generally absent from the Pensim2 model. This involves comparing the marginal costs and benefits of educational acquisition. However, an obvious criticism that can be levied against this proposed method is that it ignores non-financial factors (unless it is possible to impute some implicit monetary valuations for these). More generally, the success of such an approach inevitably depends upon how well foregone and potential earnings can be calculated, but at the very least, it will offer a useful robustness check on the present methodology.

Finally, we note that of the pensioners in the 2050 population, many will not have been through the education module since they will have already completed their education when they are observed in the base data set. In this sense, the education module may not be considered as important as some of the other modules, although it does remain a concern should the policy wish to perform analysis that is limited to the younger cohorts.

5.3 Disability

The disability module examines the receipt of Disability Living Allowance (DLA) and Attendance Allowance (AA) for those aged above the state pension age. Data is taken from the Retirement Pensions Widow's Benefit (RPWB) dataset combined with administrative information on receipt of DLA and AA. As the benefits can be either not received, received at the standard rate or received at an enhanced rate an ordered logit model is used. Regressors include age and receipt of income support (interacted with

age). Separate models are estimated for self-employed men, non-self-employed men and women.

*What the disability module **doesn't** model*

The disability module should perhaps really be known as the 'extra cost disability benefits module', as it models the 'extra cost' disability benefits – *Disability Living Allowance* (DLA) and *Attendance Allowance* (AA). As mentioned on page 5 of the respective Pensim2 series paper 'Modelling Disability in Pensim2', disability itself is not modelled due to 'data constraints' and 'classification problems'. Indeed, the module only attempts to estimate receipt of DLA and AA for the pensioner age population. The main reason for not modelling working age disability is due to data limitations at present – the present version of the *Lifetime Labour Market Database* (LLMDB) only goes up to 1996/97, which is not recent enough to capture the large changes receipt of DLA for working age people which have taken place since then. Thus in the current version of the model working age DLA/AA receipt is not modelled. The DWP acknowledge that this is a limitation. Receipt of these extra-cost disability benefits could be an important determinant of working age mortality, as well as perhaps providing additional explanatory power in modelling labour market attachment, over and above incapacity, which is modelled as a possible state in the labour market module (along with receipt of Incapacity Benefit, IB credits and Severe Disability Allowance). Nonetheless, the forthcoming availability of the LLMDB2 dataset should provide an opportunity to model working age DLA receipt.

Lack of a health module

It is clear that DLA and AA receipt are being modelled both to examine the impact on the pensioner income distribution, and as a proxy for health status (in the mortality module). An extension of DLA and AA modelling to working age people, using forthcoming LLMDB2 data, would allow a derived health proxy variable to be used in modelling various dimensions of labour market choice: occupation, the number of hours worked, and the decision to withdraw from the labour market. But even with this extension, the treatment of health in Pensim2 would remain rather crude. There would be no way of assessing the severity of health problems over time, or distinguishing between different types of health problem (physical vs mental health problems, for example).

In defence of Pensim2, it can be argued that there is simply no need to include a fuller treatment of health in the model, as it would not add much to our ability to model the labour market and pensions accumulation over the lifecycle beyond the processes which are already being modelled (chiefly, labour market inactivity due to incapacity). However, it would seem to us that if good data were available, it would make sense at least to experiment with modelling health status directly. Health is potentially important for private pension accumulation and retirement decisions as well as projected state expenditures on disability benefits, and there may be factors associated with health status that are not captured by predicted benefit receipt. Whilst it is certainly true that there are complex causality issues regarding the direction of the link between health and labour market status (for example), this is also true of many of the other relationships modelled by Pensim2. In the short run, it would be useful to investigate the practicality of modelling health status using the BHPS (which appears to be the best source of health data in a panel format currently available). Modelling the evolution of health in the population using the BHPS may well turn out to be impractical due to the small sample size of the survey, but it would be useful to examine this avenue of research in any case.

5.4 Partnership

The partnership module of Pensim2 consists of a number of components governing separation, the custody of any dependent children upon separation, the formation of any new partnerships together with the matching of them, and the move from cohabiting to married, and separated to divorced. Data is used from the British Household Panel Survey.

A difficulty posed in any attempt to model these components of the partnership module is that some of the most important factors that are likely to govern these processes are unlikely to be observed by the analyst. Given this, any attempt at modelling these is limited to a number of demographic and economic influences that are simulated by the Pensim2 model.

Specification of the partnership equations

Given the data available, the regressors used appear quite sensible. However, the specified relationships could potentially be improved if non-linear terms were introduced (for example, quadratic of logarithmic terms). For example, relating separation linearly to

the duration of partnership is perhaps too restrictive. Appropriate statistical tests should be performed to establish whether allowing for such non-linear terms significantly improve the fit, and whether the estimates remaining economically meaningful when doing so.

The matching algorithm

The Order of Decreasing Differences (ODD) algorithm used in the partnership matching process is intuitively appealing. However, it may be of interest to relate it to some additional characteristics. The most obvious of which would be the presence (and number) of children. This is likely to be an important determinant of the partnership matching process.

5.5 Fertility

The fertility module consists of a single equation that relates the birth of a child to various demographic and economic characteristics of the mother, estimated using two separate models – one for those without children and one for those with children. Data is taken from the British Household Panel Survey. The variables that have been used are rather uncontroversial, although there are some other potentially important determinants of fertility that could be incorporated into the model. An obvious candidate, would be to include whether all existing children are the same gender (when there is more than one child).

The role of economic factors is currently restricted to whether the mother is in full-time education. A possible extension would be to allow fertility to be related to job characteristics such as earnings interacted with the age of the mother (as high earning women may choose to delay childbirth). Given the order in which the model is run, these would have to be lagged values (however, this might be reasonable here since the decision to parent will presumably take place in the period before birth). A further option would be to relate it to the characteristics of the father (which may be quite important if lagged earnings are included and some degree of income sharing takes place).

From the documentation received, it is unclear whether the number of existing children is given by a continuous variable or a series of dummy variables. Including dummy

variables may be the preferable option. Similarly, a series of dummies may be preferable when capturing the effect of the age of the youngest child.

Finally, it may be of interest to experiment estimating the model separately for singles and couples, provided of course, that the sample of lone parents is of sufficient size. This would therefore involve estimating four models in total here (a model for single women without children; a model for single women with children; a model for couples without children and a model for couples with children). Alternatively, this could be achieved by interacting variables. While we are not necessarily asserting that the relationships are different across these groups, it would be of interest to establish whether it significantly improves the fit.

5.6 Labour Market Status

Pensim2 uses *Lifetime Labour Market Database* (LLMDB) administrative data to generate group or 'cell' transition rates by age, sex, duration in work and length of time spent in work since leaving education. The *British Household Panel Survey* (BHPS) is then used to estimate work probability equations. Predictions of the probability of being in work are then estimated using BHPS. Constructing cells from the BHPS in a similar way to the LLMDB, predicted probabilities of being in work are used to 'rank' individuals in each BHPS cell by their probability of being in work (the ranking includes a stochastic component). Thus, the maximum possible information from the LLMDB (which has only a limited set of covariates) is used to 'calibrate' the BHPS to the transition rates from administrative data. Variables incorporated in the model include information on lagged employment (including occupation), and standard demographic variables such as household composition.

A useful robustness check would be to examine how this process compares with just using the weights in the BHPS to generate transition matrices: how crucial is the LLMDB data here? Another option would be to use a larger survey dataset which has transition information in it. For example, the Labour Force Survey panel is around 10 times larger (per wave) than the BHPS, although it only tracks individuals over a 15 month period.

Joint modelling of couples' labour supply

Pensim2 does not attempt to model male and female partners' labour supply jointly (i.e. taking full account of the fact that the man's labour supply can depend on the woman's labour supply and vice versa). Instead, the labour supply model is sequential: male partner's work status is estimated first, and then the female partner's work status is estimated using the man's work status as an explanatory variable. The interpretation of this sequential model is that in a couple, the woman's labour supply depends on her spouse/partner's labour supply, but not vice versa. For current pensioners or those nearing pension age this may be a reasonable assumption, but for younger cohorts it seems unjustifiable. As the estimation of labour market status transitions in the current version of Pensim2 basically consists of a series of binary choices modelled as probit equations, it would be possible to move towards a joint model by making at least the initial 'in-work some of year' probit (the first box in the sub-system map for the main in-work labour market states presented in Chapter 5 of the Pensim2 documentation) a *bivariate probit*, with the two dependent variables being (male partner in-work some of year, female partner in-work some of year).

Treatment of "individual effects" in the labour market transition equations

The BHPS panel data used to estimate the labour market transition equations has several waves and so can be used to estimate a random effects probit model of labour market transitions, which allows some characterisation of the heterogeneity in the degree of mobility between individuals which remains even after conditioning on observable factors. (Individuals in future cohorts could be given a random draw to preserve the distribution of heterogeneity). This is econometrically more appealing than the present methodology used to control for individual heterogeneity, which involves 'taking predictions from the model for the historical period on which the data is estimated, then producing quartiles of the difference between the actual years in a labour market state and the predicted number of years worked'. The random effects probit has been ruled out at the moment on the grounds that the sample size is too large (in the LLMDB presumably). Yet given that the BHPS is used to determine who actually makes the transitions between labour market states each year, it should be possible to estimate the random effects probit just on the BHPS. This would certainly be a useful improvement to the model.

5.7 Earnings

Information on factors such as work history (including occupation, industry and sector) and year of education are taken from the British Household Panel Survey. These are used to estimate an earnings equation using Generalised Least Squares (GLS).

Which panel data estimator should be used in the earnings equation?

Pensim2 uses a random effects (GLS) panel data estimator to estimate the earnings equations on the *British Household Panel Survey* (BHPS) panel data. This is preferred over a fixed effects model on the grounds that:

a) the model needs to predict an individual effect for new entrants into the labour market and this is easier to do with a random effects model than with a fixed effects model.

b) The fixed effect would 'mop up' any time-invariant effects in the estimation of the earnings equation, which is problematic because most of the explanatory variables used in Pensim2 are time-invariant and we would then have no way of knowing what the total effect of (for example) education on earnings was.

Whilst we concur with the view that the fixed effects model is probably not a good model to use in this case, it should be possible to exploit the multi-wave structure of the BHPS data to provide more robust estimators of earnings effects than the GLS estimator. For example, the dynamic panel data GMM estimator developed by Arellano and Bond (1991) and refined by Blundell and Bond (1999), which does not rely on strict exogeneity of the lagged regressors in the earnings equation, is likely to produce more robust results than GLS. The trade-off here is that the GMM estimator will be more computationally intensive to implement, but given the small sample size of the BHPS, this should not be a problem.

5.8 Housing

In the first version of the Pensim2 model, housing is only allocated to those aged 60 and above. The outputs from this module are then used in the modelling of entitlement to Housing Benefit, Council Tax Benefit and Income Support Mortgage Interest, using the DWP's Policy Simulation Model. The various components of this module are estimated using data pooled from the *Family Resources Survey* (FRS) from the years 1999/2000 – 2001/02. A two step model is estimated – first whether or not the individual rents and if

not whether or not they own their home outright (see section 4.6). These are estimated using a logit model. Characteristics incorporated in the model include education, job tenure, marital status and whether in receipt of private pension income. Further models estimate council tax payments and rent levels or mortgage payments where appropriate.

One of the most potentially worrying aspects of the housing market module is its treatment of Council Tax. The assumption of 6.8% growth in Council Tax may be reasonable for a few years ahead, but is less so as we look fifty years into the future, especially considering some of the recent debate. The implied real increase in Council Tax over the models timeframe would be enormous. A more conservative assumption to make would be that it initially increases at this rate [6.8%], but over time it eventually only increases with average earnings. Ideally, this should also be available as a user specified parameter so that sensitivity analysis can be performed.

From the microeconometric modelling that has been undertaken, it is found that the husband's characteristics are important for married women's housing tenure type (housing tenure type is allocated to the first individual in the household reaching age 60), but the converse is not true. This is what we would expect for the current cohort of pensioners, but the relationship may be very different for future pensioner cohorts. In other words, the assumption of structural stability may be violated. However, as has already been stated, this is not something that can feasibly be addressed. In any case, while the model does allow for an average effect for married women who have been widowed, it does not do so for those who separated/divorced and didn't remarry. This is constraining all parameters of those who never married to equal those who divorced, not even allowing for an average effect. Appropriate statistical tests should be performed to ascertain whether this is indeed the case.

Many of the estimated models yield plausibly signed coefficients, however, there are still some possible modifications to the specifications that could be considered (some of these may have already been experimented with by the Pensim2 team during the development of the model). These include allowing the number of years worked to enter the specification non-linearly (*e.g.* a quadratic term). Furthermore, it may be of interest to consider some more detailed educational disaggregation rather than simply including an indicator variable for whether an individual possesses a degree or not, as well as trying to capture economic influences by inclusion of lagged income. Finally, in the Pensim2 series documentation, made available to the IFS, the specification for the private versus

non-private rental sector model does not appear to include an indicator for "widowed". This appeared as an important determinant in other housing market equations, and we may expect that it would continue to do so here.

Empirically, the distribution of tenure types, together with associated variables, varies considerably by region. For example, the rental sector is much more important in London than it is elsewhere in the country. This is therefore another module where modelling region would prove useful insofar as it may provide a useful explanatory variable, both in terms of the tenure type and the amount of council tax paid, and mortgage and rental payments. "Region" could therefore be considered as a potential process to be simulated in a future revision of the Pensim2 model.

Some of the estimated relationships are extremely simplistic. Most notably of which, only a single regressor is included in each of the equations estimated for private rent. Omitted variable bias is likely to be severe in this case, although admittedly this is not an equation that is easy to estimate. One possible candidate to include would be lagged earnings.

5.9 Savings

Currently Pensim2 uses information from the *Family Resources Survey* (FRS) to model whether an individual has financial assets at age 60 and if so the level of those financial assets. Information from the *British Household Panel Survey* (BHPS) is used to model the evolution of savings from age 60 onwards. For whether or not an individual has financial assets at age 60 four different models are run – for men and women with and without current accounts. Regressors include age, marital status, education, years of work and whether currently contributing to a private pension. A similar set of regressors is included in the model for the amount of savings except whether currently contributing to a private pension is excluded.

The modelling of saving is extremely constrained by both the availability of data and also the intrinsic complexity in modelling saving decisions. While it should be possible to make some improvements in the short and the medium term to the way in which saving behaviour is modelled, it is likely that this will remain a relatively weak part of Pensim2 for a considerable period of time. In particular the current model does not take into account possible income or substitution effects that might affect the level of private savings. This means that the impact of reforms to the tax or benefit system that affect

either direct state support for pensioners or the expected returns from private saving might be particularly inaccurately measured. In the longer term trying to explicitly model such impacts, while difficult, is probably one of the areas where Pensim2 could be most enhanced. Until such modelling can be incorporated it would be sensible to always carry out, and publish, sensitivity analysis to the estimated effects of different reforms to the assumption that the level of private savings will always grow in line with average earnings. This would help give an idea of whether the assumption is likely to be important for a particular reform that is being modelled.

In the short term the modelling of savings behaviour could probably be improved by making some changes to the specifications used. Currently the only characteristics included in the modelling is the number of years in full-time work, number of years in part-time work, their current marital status and whether they are currently contributing to an occupational or a personal pension. It would sensible to include other characteristics available in the FRS in this model such as housing tenure type and education. The interest rate should also be included in the model (although as this is not determined in the model for simulations it would need to be added as a user parameter). In addition currently the savings of married couples is assumed to depend only on the characteristics of the male. It would seem sensible to include some of the characteristics of their partner in this model.

Furthermore, a potential problem when using ordinary least squares regression for modelling the level of savings (conditional upon having positive savings) is that the estimator can be seriously distorted by outlying observations in a relatively small sample. An estimator which is much less affected by such extremities is the Least Absolute Deviations (LAD) estimator. Rather than minimising the squared distance between the observed and fitted values, this involves minimises the absolute distance between fitted and observed values. Although it is at the expense of greater computational cost, it is perhaps a worthwhile exercise to establish the extent to which the estimated coefficients are sensitive to the estimation technique used.

The interpretation of the positive co-efficients of whether or not someone is currently contributing to a private pension (either occupational or personal) should also be used carefully when modelling reforms. Currently the inclusion of these variables is picking up an association between a preference for choosing to save in one form and a preference to choose to save in another form. Reforms that changed the options

available to individuals – for example modelling a world in which employees were compelled to join an employers pension scheme if one were offered – would be expected to change this relationship. Otherwise individuals that were forced into occupational pension schemes would also be thought to be more likely to save more in other forms, whereas in practice forcing individuals to save more in one form might be expected to lead to an offsetting reduction in savings (or an increase in debts) elsewhere. If such reforms are to be modelled using Pensim2 then this component of the modelling will need to be revisited.

The possibility has been raised that in the medium term the modelling of savings in Pensim2 should use the information on capital income data in the BHPS. This would have the advantage of being able to take into account past income. However a major concern with this approach is that this would be subject to considerable measurement error. The ONS is currently consulting on the possibility of carrying out a household wealth survey. If this does go ahead then a more sensible medium term strategy for Pensim2 would be to use this data instead. This would also have the advantage of allowing debts to also be modelled, which are currently completely excluded from Pensim2 due to the lack of microdata. In terms of building an evidence base for future Government policy making, it seems that collecting comprehensive data on financial assets and debts, for example through a regular large scale sample of households, could prove extremely beneficial in this area. In the meantime it might be possible that the Inland Revenue holds data that could be used in Pensim2 (although this would be unlikely to be as good as having survey data as information held at the Inland Revenue is likely to be at an individual rather than family or household level).

5.10 State and private pensions

Back simulation of existing state and private pension rights

This module uses information from the *Lifetime Labour Market Data Base* (LLMDB), *Government Actuary's Department* (GAD) and the *General Household Survey* (GHS) to obtain an estimate of existing rights to the Basic State Pension, SERPS and occupational pensions among the working age population. (As information on earnings is not available prior to 1975 earnings equations for these years are estimated using Generalised Least Squares on the GHS. Separate equations are run for men and women).

It seems clear that these are the most sensible data sources for this analysis, and it is difficult to see what improvements could be made to this modelling in the short-term. However, the main source of error in this modelling is likely to be in incorrectly assessing pension tenures, which will be an important determinant of accrued defined benefit pension wealth. This is a feature of the typical design of defined benefit pension schemes in the UK and arises due to the interaction of a standard real wage profile with the fact that pensionable earnings are usually heavily dependant on salary towards the end of a pension tenure. Hence in the medium-term consideration should be put as to whether better data sets exist for measuring pension scheme tenure: for those individuals aged 50 and over the *English Longitudinal Study of Ageing* (ELSA) could be used, particularly given that this survey does contain some information on scheme details.[9] Pension tenures of younger working age individuals could be modelled using the *British Household Panel Survey* (BHPS). In order to establish whether these alternative data sources are worth pursuing it would definitely be worth estimating the private pension incomes among the current retired population and comparing the distribution of the simulated state and private pension incomes with those actually observed amongst those aged over the State Pension Age in the *Family Resources Survey* (FRS). A similar exercise has been done in work examining simulated pension rights in the *British Retirement Survey* (BRS) – see Blundell, Meghir and Smith (2003) for more details.

Future simulation of future state and private pension rights

Whether an employee is offered the opportunity to join an employers pension scheme, whether they accept that offer and whether they choose to join a personal pension is modelled using data from the *Family Resources Survey* (FRS). Information on scheme rules is assigned using data from the *Employer's Pension Provision Survey*, GAD survey of occupational pensions and the NAPF survey.

A probit model is used to estimate whether or not someone is offered the chance to join an occupational pension scheme. Regressors include age, job tenure, pay, occupation, industry and interactions of pay and industry. Whether or not some joins an occupational pension is also estimated using a probit model. Regressors include: age, education, marital status, job tenure, occupation, industry and interactions of occupation

[9] Respondents have also been asked for the names of their pension schemes so in principle it would be possible to combine all details of each providers most common scheme.

and tenure. Scheme rules are assigned using information on industry and sector. Whether or not some joins a personal pension is also estimated using a probit model using similar regressors.

The FRS data contains the required dependent variables has a large sample size and very detailed information on income. An alternative would have been to use the *British Household Panel Survey* (BHPS). This contains the same dependent variables with a smaller sample size but would have allowed transitions between types of pension schemes to be modelled. Furthermore it contains more covariates so that, for example, information on the sector of work could have been included. It is not clear which approach would have been better. For the same reasons as discussed above in the medium term it will be worth investigating using data from the ELSA to model future state and private pension accruals among those aged 50 and over.

In terms of improvements to the modelling that could be implemented in the short term it would seem sensible to consider including, where relevant, the characteristics of an individuals partner. With the modelling of the annuity market it seems more sensible to assume that 75% of voluntary private pension saving is used to purchase an annuity rather than the 100% assumed at the moment. In addition the annuity rate offered should also decline over time as life expectancies increase.

As with our discussion of the savings module (see Section 5.9) there is no automatic feedback of the tax and benefit system on the private pension decisions of individuals or their employers. Indeed there is no direct feedback from macroeconomic variables such as stock market levels and interest rates into pensions or savings decisions. Including such links would be extremely hard, but it will be important to be explicit about this weakness when presenting any results that might be particularly sensitive to the assumptions made.

6. Recommendations

Based on the analysis in the previous section, we have compiled a list of recommended improvements and revisions to Pensim2. We have divided the list into two sections:

- *Short-term recommendations*. These are 'action points' which could be carried out in the near future with little or no reprogramming required.

- *Medium/long term recommendations.* These are recommendations where a more substantial investment of time and resources would be necessary. In some cases the feasibility of a proposal is also contingent on the availability of new data sources (ELSA, for example).

Table 6.1 gives our short term recommendations. The first column shows the part of the model which the suggestion applies to – either an existing module or modules, a proposed new module, or in some cases suggestions which affect the whole model. It also gives the section number where the recommendation is first discussed. The second column gives details of the proposal.

Table 6.1. Short term recommendations for Pensim2

Module	Section	Recommendation
all modules	4.3	Present a complete econometric specification of the model with full variable listing
several modules	4.5	Introduce controls for business cycle effects. These are most obviously applicable for modelling earnings and labour market status, but could also be useful in modelling other processes which are sensitive to cyclical conditions, e.g. savings.
Mortality	5.1	(a) Allow the impact of relative income on mortality to vary by age (b) Experiment with different age splits in the mortality regression
Partnership	5.4	(a) Do more investigation of the specification of the partnership equation to improve the fit of the model. (b) Investigate additional matching variables for the matching process
Fertility	5.5	Try separate fertility regressions for single people and couples, with and without children
Labour market status	5.6	(a) Check what the importance of the LLMDB/BHPS calibration process is by running the transitions equations on BHPS alone (b) Random effects probit model for labour market transitions
Earnings	5.7	Try using a GMM estimator for the earnings model
Housing	5.8	(a) Experiment with different assumptions about council tax growth over the longer run (b) Check the specification for widowed women vis-à-vis divorcees.
Savings	5.9	Improve specification of savings equation: for example including housing tenure and education in the model.
Pensions	5.10	Refinements to annuity modelling (in the future pensions simulation)

Table 6.2 gives our longer-term recommendations.

Table 6.2. Long term recommendations for Pensim2

Module	Section	Recommendation
All modules	4.4	Given the investment made in the model it might be useful to make it available for a range of purposes (e.g. modelling tuition fees, savings gateway & child trust fund, etc.) That is, it's not just a 'pensions model'.
New health module	4.4	Useful to investigate the possibility of detailed modelling of health status using BHPS (or ELSA for those aged 50 and over once the data become available). This would improve mortality and disability modelling considerably
New housing wealth module	4.4	Modelling the accumulation of housing wealth and the decision to move house seems important as it is one of the key forms of wealth holding in the UK. It is also possible that housing wealth will be used as a substitute for pension accumulation by some UK citizens in the future.
Mortality	5.1	Take recent changes in the Income Support / Pension Credit system into account when modelling the future relationship between mortality and Income Support / Pension Credit eligibility. This will be particularly important for policy simulations.
Education	5.2	(a) Allow assignment of educational characteristics to new cohorts of young people in the model to vary by observable characteristics. In effect, this would introduce an element of intergenerational linkage into the model. (b) Allow the future proportions of young people achieving different levels of educational attainment (GCSE, A Level, university degree etc) to be set as a user parameter in Pensim2.
Disability	5.3	Model receipt of Disability Living Allowance amongst working age people (contingent on the availability of LLMDB2 data).
Labour market status	5.6	Move towards joint modelling of couples' labour supply rather than having the female partner's labour market decisions being conditional on the male partner's.
Housing	5.8	Introduce region as an explanatory variable (obviously this could affect other modules as well, e.g. earnings and labour market status)
Savings	5.9	(a) Try to incorporate income or substitution effects which might affect the level of private savings – in particular the impact of tax and benefit reforms which might affect support for pensioners or the expected returns to private saving. (b) Improve the analysis of policy simulations which introduce elements of compulsion (e.g. compulsory contributions to employer pension schemes) – the existing framework may be inadequate to analyse these changes. (c) Use information from the prospective household wealth survey (contingent on when and if such a survey is conducted)
State and private pensions : Back simulation	5.10	(a) Exploit ELSA to improve modelling of pension scheme tenures (contingent on a reasonable time series of ELSA data becoming available) (b) Use BHPS to model pension tenures for younger individuals not covered by ELSA
State and private pensions: Future simulation	5.10	(a) Try using BHPS for the simulations, as this allows us to model transitions between different types of pension scheme. (b) Allow feedbacks to pension scheme decisions from the tax/benefit system and the macroeconomy.

7. The future – towards "Pensim3"

The lists of short term and medium term of recommendations in Section 6 map out a possible development and improvement strategy for Pensim2 over the next two to three

years or so. In this section we attempt to look beyond that horizon to ask what might be possible in the much longer term – say ten years from now. This section is divided in to two parts. To start with, we talk about the possibility of new data sources, both those currently planned and where we believe unfilled gaps exist in the UK's data resources. Secondly, we discuss probable technical and technological advances and their role in improving and extending the scope of Pensim.

7.1 New data sources

Pensim as it stands makes use of several primary data sources:

i) the LLMDB

ii) various administrative data on benefit receipt

iii) the British Household Panel Survey

iv) the Family Resources Survey.

There are several other potential data sources which could be used to improve Pensim2. Some of these are surveys which are already in existence, or which plans have been drawn up for. Others are more speculative. We discuss several possibilities below.

English Longitudinal Study of Ageing (ELSA)

ELSA is a longitudinal panel study of just over 11,000 men and women aged 50 or over. As its name suggests, ELSA focuses on collecting data on several aspects of ageing, including: work and retirement; social activity; health; physical and cognitive function; physical and social environment; and socio-economic and socio-demographic characteristics. The survey is funded by the US National Institute on Aging, and by several UK government departments, including DWP. So far only one wave of the survey has been completed and released (based on interviews in 2002). Further waves of interviews are planned every two years.

ELSA is a very exciting potential source of data for Pensim2 in the future, as data builds up. Whilst the survey will only contain data on men and women aged 50 and over, the breadth and depth of data available on health status, disability, wealth and assets and pension arrangements for those surveyed outstrips anything available in the existing datasets used for Pensim2. Moreover, ELSA is a panel, which allows for far more robust

econometric techniques to be used than in cross-sectional studies. We would anticipate the ELSA data being particularly useful in the following modules:

- mortality (for modelling mortality and morbidity among the over-50s)
- disability (indeed the ELSA data may facilitate the construction of a health module for older people within Pensim2)
- Labour market status (older people's work and retirement decisions)
- Savings
- Pension scheme tenure, retirement and pensions receipt amongst the over-50s
- Housing tenure, housing transactions and accumulation/ running down of household wealth
- Long term care

Disability survey(s)

There is currently no large scale micro-level survey of a representative population sample in the UK which focuses specifically on disability. Existing surveys such as the Family Resources Survey, the Labour Force Survey and the British Household Panel Survey all contain some information on health and disability but the number of questions asked is very limited, and hence there is very little 'in-depth' information. The most detailed large-scale disability survey in recent memory was a one-off follow-up to the 1996-97 FRS which asked a much greater range of disability-related questions to a subsample of individuals who had been identified as disabled in the main FRS interview round. Because the 1996/7 FRS follow-up was a one-off survey, and is somewhat out of date now, it is not very useful for Pensim2 in itself. However, if the disability follow-up were made into a permanent feature (perhaps as an 'extension questionnaire', which could operate every other year, or every third year of the sample) it would provide very useful extra information which could be used to model the onset and severity of disability amongst the Pensim2 population. This would be particularly useful for the working age population, as the information available in ELSA would provide possibilities for modelling disability amongst retired people (as noted above), but ELSA only covers those aged 50 and over.

Alternatively, the DWP could commission a completely new survey on disability. This has advantages and disadvantages. On the plus side, focusing on disability as the key topic in the survey would permit a wide range of questions on health and disability to be asked whilst still retaining a questionnaire of acceptable length, and the resulting data would hopefully be very detailed and of good quality. The survey could also be carried out as a panel if desired, which is particularly useful for analysis to be used in Pensim2, as it would allow researchers to focus on the dynamics of disability – i.e. changes in disability for individuals over time. This is more useful than static 'snapshots' of disability for modelling the dynamic processes which characterise Pensim2. However, if a new survey of disability were commissioned it would be important to make sure that it contained enough variables common to other datasets used in Pensim2 – for example, demographics, employment and income information – to enable it to be used in conjunction with the other datasets which make up the model.

Inland Revenue data

DWP has made good use of its own administrative data in designing Pensim2, drawing on the LLMDB2 data on earnings and NICs, data on State Pension entitlements, and benefit receipts data. In the future, it would be useful to make use of data from the Inland Revenue to improve the performance of the model even further. There seem to be two obvious areas where Inland Revenue data could help:

- **Tax credit data.** The child tax credit and working tax credit form an important part of the government's financial support package for families with children and working people on low incomes respectively. Tax credits are an important part of the Pensim2 model for two reasons. First, the availability of and generosity of tax credits may affect the decision to work or not, which will affect pensions contributions and perhaps the date of retirement (as modelled in the labour market module of Pensim2). Secondly, the aggregate numbers of people working and the demographic structure of the population will affect the government's financial position by determining the amount of tax credits that have to be paid out in a given year, and this may have a bearing on the fiscal viability of a given combination of tax rates, benefit rates, tax credits and the state pensions system. Whilst micro-level surveys such as the FRS and the BHPS feature some information on tax credit receipts and eligibility, the Inland

Revenue maintains administrative data samples which are far larger and would allow much more accurate modelling.

- **Pension contributions data.** The Revenue keeps a database of pensions contributions collected as part of its PAYE and tax return records could be a useful supplement to the DWP's LLMDB data (particularly if data on different pensions held by an individual could be linked). Most importantly, the Inland Revenue administrative data would allow a detailed analysis of contributions to private pension plans, whereas LLMDB is most useful for modelling state pension accumulation through National Insurance contributions records (although any IR data is still likely to be hampered by the fact that the information is likely to only be available at the individual rather than the family or the household level).

7.2 Technical improvements

The role of technical progress in expanding the boundaries of possibility as regards simulation models like Pensim2 cannot be overstated. After all, twenty years ago, the state of the art desktop computer was the IBM PC-XT, featuring a maximum of 640 kilobytes of RAM, and an Intel 8086 CPU. Today, even a run-of-the-mill desktop PC will ship with at least 256Mb of RAM, and an Intel Pentium 4 or AMD Athlon XP processor thousands of times faster than the 8086. The rate of technical progress in computing is roughly approximated by Moore's law, which states that computing power doubles roughly every 18 months. If correct, this suggests that the average desktop PC will be around 100 times more powerful in 2014 than the 2004 model. The increase in computer power will certainly benefit Pensim2 greatly, particularly as given the resources available to DWP, there exists the option to run the model on high-powered servers (as indeed is the case at present) rather than on the desktop.

Technical progress over the next decade should, with any luck, give the Pensim2 programmers more options for modelling strategies. These seem to divide into two broad strategic areas, listed below.

Improving and augmenting the existing modelling framework

During conversations with DWP programmers in the writing of this report, one of the main concerns expressed about the model as it currently stood was the length of time it takes to run. At the time of these conversations (late 2003) the programmers were still

trying to get the model to run fast enough to produce results over a 40-year time horizon with acceptable run times ('acceptable' being defined here as the full model running in a matter of days, rather than weeks). Many of the short-term and medium term recommendations that we make in Section 6 would increase run time even further. Whilst the DWP were confident that they could refine the programming of the model so that it was capable of executing at an acceptable speed, any assistance offered by faster computers over the next few years will be very welcome.

Experimenting with more ambitious modelling frameworks

As discussed in Section 4.1, Pensim2 is not a 'structural' dynamic model in the sense that many economists would use this term. Rather than modelling behaviour by estimating the underlying parameters of individual agents' utility functions, Pensim2 estimates relationships at the individual level between observable variables (earnings, pension contributions, housing tenure, savings, benefit claims, etc) and then projects forward via extrapolation, subject to simulated stochastic components and some user-specified parameters. This 'non-structural' approach has the primary advantage of being less computationally intensive than a structural approach, and given that the current non-structural approach is only just feasible to estimate given current technology, a fully structural pensions simulation model is an impossibility at the current time. However in the future this need not be the case. It is entirely possible that technological improvements, coupled with advances in applied econometric techniques, will make a structural model of most or all of Pensim2's processes viable in the future. In the meantime it is possible to estimate a much more parsimonious structural model which could help give some further insight (see, for example, French, 2000), albeit at the expense of ignoring many of the processes included in Pensim2.

This does not necessarily mean that the current approach should be discarded and a full structural approach adopted as soon as it is feasible to do so; as we show in Section 4.1, there are arguments both for and against structural modelling. However, in the long run it would certainly be useful to compare the results of Pensim2 with an equivalent model or models estimated using structural modelling. This would provide a useful opportunity to assess what difference a structural or non-structural approach makes to the predictions which Pensim2 and other dynamic models arrive at. Given that Pensim2 is conveniently divided into modules, it may be possible to test certain individual modules against comparable structural approaches. A good candidate for testing would be a

module which is not too complex in terms of the number of processes being modelled and the amount of data being used. Perhaps the savings module would be a good example of such a test candidate.

8. Conclusions

In this audit report we have tried to give as thorough and balanced an assessment of the Pensim2 model as we are able to, given our relevant expertise. In the main, our assessment of Pensim2 is very positive. It represents the first large-scale dynamic microsimulation model for the pensions system available in the UK. Crucially, it makes use of administrative micro data in many of its modules. And it models a very wide range of processes – not just pensions, saving and the labour market, but such areas as education, housing, migration and institutional care.

Most of our short term recommendations are to do with robustness analysis and slight tweaks to the specification of given equations in the various modules. These could mostly be implemented without too much difficulty. Some of our medium term recommendations – in particular those which involve the construction of entire new modules, or the use of new datasets – will be much more time consuming and expensive to implement. So obviously it will be for the DWP to decide whether the additional investment of resources is worthwhile. Our view would be that given that the lion's share of the work has been done already, in getting the model to its current state, it would make sense to carry out the marginal extra investment necessary to implement such improvements as a health module, analysis of housing wealth accumulation, and intergenerational linkages. Given that these improvements would make the model very useful to other government departments (for example, DfES for educational policy analysis, DoH for analysis of the links between economic variables and health in the long term, and the Inland Revenue and Treasury for long term analysis of tax policy and housing), there may be some scope for the DWP securing financial support from other departments for developing the model.

In the very long run it is to be hoped that some of the technical constraints which currently constrain the complexity of the analysis that can be carried out in several key areas will ease, which should enable a complete re-evaluation of the model's structure and scope. In particular, the capacity for fully structural modelling of dynamic economic processes at a micro level will be there, available for use if it is felt that this would

improve the usefulness and realism of the model. Also, new data sources from both within and outside the DWP's remit should help considerably. It is crucial that the Pensim2 team has an input into the design of any new surveys planned by DWP (the disability survey, for example) or other Government departments (such as the proposed ONS wealth survey) so that it can be ensured that these surveys collect data which is of maximum usefulness for estimating future versions of the model.

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Appendix: Pensim2 flowchart

This flowchart, adapted from a DWP original, shows the order in which modules are estimated in Pensim2 to advance the model on one year. Modules in green are covered in this audit report; modules in black are not.