Research Statement of Wouter J. Den Haan

September 2010

1 Themes in past research projects

Below I list the main themes in my research. The list is not exhaustive.[1]

1.1 Frictions

Since the mid nineties, I have been working on macroeconomic models in which agents face "frictions" such as moral hazard, information asymmetries, contracting frictions, financing frictions, and/or search frictions. The current crisis has been beneficial for me in the sense that there has been a surge in this type of research.

Frictions such as moral hazard are intriguing research topics in themselves. For a macroeconomist, there is an additional reason to be interested in these topics. The reason is that the severity of frictions typically depends on economic developments. This leads to fascinating feedback effects, which—in my opinion—are useful in describing observed macroeconomic time series.

For example, suppose the economy is hit by a negative aggregate shock, which leads to a reduction in firms' net worth levels. This usually makes it more difficult for firms to obtain financing, unless financing is frictionless. This would slow down aggregate real activity, which in turn leads to a further reduction in firms' net worth levels. This propagation of shocks is consistent with the persistent effect of shocks observed in the data. Below, I will give more detailed examples of models with such feedback effects.

My research on models with frictions can be split in two groups. The first consists of models in which *financial* markets are subject to frictions and the second of models in which *labor* markets are subject to frictions. I will start with an example from the first

[1] For example, my work on Pigou cycles, i.e., business cycles driven by changes in beliefs about *future* economic growth, is not discussed. See Den Haan and Kaltenbrunner (2009) and Den Haan and Lozej (2010).

group.[2]

In Den Haan, Ramey, and Watson (2003), we built a macroeconomic model in which financial markets are characterized by frictions. We show that in such a model the impact of shocks on the economy is much larger than in the corresponding model with frictionless financial markets. In fact, if the shock is large enough, then the economy would collapse. I will now sketch the model and provide some intuition for our main results.

One of the key elements in our model is that the financing of firms by financial intermediaries is subject to a moral hazard problem. There are also frictions that slow down (re)building relationships between borrowers and lenders. Now suppose that a shock deteriorates the health of the financial system.[3] This deterioration in the health (or efficiency) of the financial system reduces the return on the funds invested by financial intermediaries. This in turn implies that financial intermediaries receive less funds. The reduction in funds does not only lead to reduced activity. Because of the moral hazard problem, it also leads to increased severance of relationships between borrowers and lenders.[4] This further deteriorates the health of the financial system. When the shock is small enough, then this mechanism "only" magnifies and propagates the initial shock, but the system is

[2] There are two other types of models with financing frictions that I have worked on but do not discuss in the main text. First, I have written papers that analyze models with incomplete markets, borrowing constraints, and heterogeneous agents. The focus in these papers is on the ability of agents to smooth consumption and on asset pricing. Second, in Den Haan and Covas (2010) we analyze a financial accelerator model in which—due to information asymmetries—the firm's net worth determines the costs of external funds. Our innovation was to introduce equity finance and to consider nonlinear production functions. This makes the analysis a lot more complex. In particular, the economy can no longer be described by a representative firm. An important benefit of the richer structure is that the model predicts that the cyclical behavior of equity issuance depends on firm size and qualitatively the results match those found in our empirical work on firm financing.

[3] In our model, the "health" of the financial system is characterized by the number of intermediaries that are matched to a borrower. These are the intermediaries that have a profitable use for their funds, at least in a world without the moral hazard problem.

[4] To be more precise, some financial intermediaries do not have enough liquidity to overcome the contracting problems and, thus, cannot ensure cooperation. This leads to unavoidable severance of the relationship.

still able to recover. For a large enough shock, however, the unique solution is a complete collapse of the financial market unless the government pumps enough liquidity into this market. That is, the policy prescription of our model corresponds pretty much with the one followed by central banks during the recent crisis.

Feedback effects also play an important role in my macroeconomic models with frictions in labor markets.[5] In these models, there is a matching friction which means that it takes time for unemployed workers to find employment. In Den Haan (2007), I develop a model in which feedback effects make expectations self-fulfilling, but only after some shocks. In particular, I address the question what would happen when (i) a negative shock has increased the unemployment rate (starting from a low steady state level) but (ii) the values of the exogenous driving processes are back to normal. Because of the matching friction, it would be impossible for the economy to revert back immediately to the situation before the shock occurred. At best, there will be a gradual transition to the low pre-shock level of the unemployment rate. During the transition path, government expenditures such as unemployment benefits are higher than normal. At some point this will have consequences for tax rates and, thus, profit margins. As profit margins drop, then some jobs will no longer generate a positive surplus and these workers will be laid off. This will increase the unemployment rate. This in turn will lead to higher taxes and more layoffs. The question is whether this mechanism is so strong that the gradual return to low unemployment levels is no longer an equilibrium outcome.

For a sufficiently large shock, it is indeed impossible that the economy returns to the previous low unemployment level. Instead, the economy moves to a regime with high unemployment rates and high tax rates. For a small enough shock, however, the economy has to revert back to the original regime with low unemployment levels. That is, optimistic beliefs in case of a large shock and pessimistic beliefs in case of a low shock are *not* self-fulfilling. Whereas self-fulfilling expectations are not an equilibrium outcome for a sufficiently large and a sufficiently small shock, expectations do determine whether

[5] A related paper that is not discussed in the main text is Den Haan, Ramey, and Watson (2000) in which an increase in endogenous job destruction reduces the supply of capital by households, which puts upward pressure on interest rates, which in turn leads to a further increase in the amount of job destruction.

the economy will move towards a low-unemployment or a high-unemployment regime for intermediate shocks.

1.2 Heterogeneous agents

Heterogeneity plays a key role in many of my papers. Both in terms of developing algorithms to solve these models and in terms of using them to address economic problems. I give examples of projects in which heterogeneity is important throughout this research statement.[6]

1.3 Algorithms to solve dynamic stochastic general equilibrium models

The two key aspects of my work on developing algorithms are (i) heterogeneous agents and (ii) taking nonlinearities seriously. The drawback of these two features is that the algorithms are (a bit) more complex and, thus, less user friendly. As the New Keynesian model became the workhorse in macroeconomics, the value of my human capital dropped. The reason is that this model uses the representative agent framework and it is solved using simple linearization techniques. Now that the crisis has renewed interest in models with more volatility, with frictions, and/or with heterogeneous agents, there is also more interest in the types of numerical techniques that I have worked on.[7]

The problem with numerical algorithms is that the descriptions are often quite tedious. Since I give some descriptions of my work on numerical algorithms in the section on work in progress, I will not bother the reader with descriptions of what I have done in the past. To give some idea about the importance of this work, I would simply like to mention that I have been asked to write a chapter on solving models with heterogeneous agents for the

[6] Papers in which heterogeneity plays a role in one form or another are Algan, Allais, and Den Haan (2008, 2010); Algan, Allais, Den Haan, and Rendahl (2010); Den Haan and Covas (2010); Den Haan (1996, 1997, 2007, 2010b,a); Den Haan, Ramey, and Watson (2000, 2003); Den Haan and Rendahl (2010); and Den Haan and Sedlacek (2010);

[7] For example, I have been asked to give workshops at Central Banks. Moreover, in the Summer of 2010 I organized the Amsterdam Macroeconomics Summer School in which I taught a beginners and an advanced course on numerical methods. In total, I had eighty-three participants.

forthcoming handbook on computational economics .[8]

1.4 Empirical

I have always been interested in time series econometrics, mainly in applied time series but also in some theoretical questions.[9] The emphasis in my recent empirical work has been on using *disaggregated* data. This emphasis corresponds with my interest in theoretical models with heterogeneous agents.[10] For example, in Covas and Den Haan (2010) we show that the cyclical behavior of equity issuance depends strongly on firm size and that this size dependence can explain why papers using aggregate data find conflicting results.[11]

Similarly, in Den Haan, Sumner, and Yamashiro (2007, 2009, 2010) we show that the estimated behavior of bank loan *components* following a monetary tightening is quite robust whereas the results for *total* loans are not.[12]

Dealing with disaggregated data is obviously more cumbersome and much more so when—as in Covas and Den Haan (2010)—one works with firm-level data. From my own recent empirical work I learned, however, that it is worth the effort. The reason is that there is a lot to be learned from what happens at the disaggregated level even if one only wants to describe aggregate time series.

---

[8] See Algan, Allais, Den Haan, and Rendahl (2010).

[9] For my interest in theoretical questions see Den Haan and Levin (1997).

[10] Even without such a theoretical motivation, there are good reasons why models with disaggregated data provide better empirical models. For example, in Cai and Den Haan (2009) we compare two strategies to forecast GDP. The first strategy (i) uses models that generate separate forecasts for the components of GDP and (ii) obtains the forecast for GDP by aggregating these forecasts of the components. The second strategy obtains forecasts from a univariate model for GDP. We find that the first strategy performs better.

[11] The cyclical behavior of equity issuance of the very largest firms turns out to be quite different from that of the other firms. With equity issuance being countercyclical for one type of firm (the largest firms) and procyclical for the other type of firm (all except the largest firms), then the cyclicality for the average firm turns out to depend on particular choices made by the researcher such as which sample is used and how equity issuance is exactly defined.

[12] The loan components are consumer loans, mortgages, and commercial and industrial (C&I) loans.

2 Work in progress - plans for future research

I think it is fair to say that the financial crisis has made my 2003 *Journal of Monetary Economics* paper on financial crises more relevant to the profession. More generally, the financial crisis has increased interest in the ingredients I put in my models (heterogeneous agents, frictions, and an explicit role for unemployment) and in my solution algorithms (that can deal with nonlinearities and heterogeneous agents).

In terms of tools, I therefore seem well equipped to participate in macroeconomic research in the coming years. But the financial crisis and the discussion on how to do macroeconomic research has led me to do quite a bit of rethinking on how to build macroeconomic models. The first two topics I discuss in this section are the fruits of this process of soul searching.

2.1 Heterogeneous beliefs and non-rational agents

Models with rational agents are very popular in macroeconomics. The motivation for such models is typically that they are a useful benchmark or that one could expect the economy to behave like the predictions of the rational expectations model if agents have had time to learn the dynamics of the system. These are sensible views. But given that it is hard to believe that all agents are always rational, it is clear that we should consider other models as well.

While behavioral economics has become quite influential in many fields, there are still not many macroeconomic models that incorporate elements from behavioral economics. The most popular type of behavioral macroeconomics follows the agent-based framework of Brock and Hommes (1997) in which agents behave according to *fixed* rules.

In my opinion, there are two drawbacks to this framework. First, it often seems arbitrary why a particular rule is included in the analysis. That is, there is not yet a good underlying principle or laboratory evidence to prefer one behavioral rule over another. This is especially problematic since there are many rules to choose from. Second, the behavioral rules considered are typically *all* passive backward looking rules. One would think that at least some agents are as smart as the model builder and try to think through the economic system in which they live when making forecasts. That is, one should allow for some agents to be forward looking and not ignore knowledge about the economy that the model builder has. Allowing for this possibility seems especially important when important changes occur, for example, when there is a considerable cut in the interest rate set by central banks or when the government announces that tax rates will be adjusted.

To deal with the second problem, I include (truly) rational agents in my framework.[13] These agents are forward looking and fully take into account the presence of the other types of agents. One contribution of this research project is to make clear that solving these models is not that difficult, which implicitly means that the problem the rational agent faces is also not that difficult.[14]

It is probably impossible to fully deal with the first problem of having many types of non-rational behavior to choose from. But I think the problem can be alleviated by focusing on specific research questions. The focus of my analysis is the following question. Suppose that one group of firms is *overoptimistic* about their own future profitability. The other group of agents has rational expectations, not only about their own profitability but also about the actions and expectations of the overoptimistic agents. What will happen? Will the response of the rational investors partly or completely *undo* the exuberance of the overoptimistic firms? Or are there situations in which rational investors will follow the overoptimistic firms and also invest more? Of course, there are still multiple ways in which one can model how agents are "overoptimistic", but I think that some general lessons can be learned from this setup.

To address these questions, I have been looking at simple labor market matching models in which expectations about future profits determine the decision of firms to invest in creating new employment opportunities. In particular, I am interested in the question

[13] In this literature, one occasionally encounters forecasting rules that are referred to as "rational", but the terminology is then often not consistent with the standard definition of rational agents. The reason is that these "rational" agents typically only have a bit more information, e.g., about fundamental asset values, but they are not rational in the traditional sense and in particular they do not make forecasts that are consistent with the structure of the model.

[14] For further details see Section 2.5.

whether it is possible that rational firms will go along with the overoptimistic investors and *also* increase their employment levels. One possible mechanism would be that the increased demand for workers by the overoptimistic firms increases aggregate demand including the demand for the products produced by the rational firms. In simple models, these effects are not strong enough to lead to an increase in the demand for labor by the rational firms.[15] But I suspect (hope) that it is possible to generate these types of effects if workers cannot insure themselves (fully) against unemployment. In that case the increased demand for workers by overoptimistic firms is important not only because it increases the expected labor income of the average household, but also because it reduces uncertainty by lowering the unemployment rate.

2.2 Interaction between disequilibrium in labor & commodities markets

During the seventies and eighties, macroeconomic models were developed in which the presence of disequilibrium in one market would interact with disequilibrium in other markets.[16] The way newspapers describe recessions captures the underlying idea: firms do not hire workers because they do not expect to sell their products and consumers do not buy because they are concerned about their job prospects. Note that the newspaper reasoning does not seem to rely on sticky prices, whereas the existing models that focus on this type of interaction between markets typically rely on sticky prices. I am interested in the question whether it is possible to write down models that capture the newspaper reasoning without relying on sticky prices.

I think that models with search frictions can generate these types of interaction between "disequilibrium" in different markets even when prices can adjust.[17] In particular, I have developed very simple models in which search frictions in labor and consumer markets

[15] Unless one puts in features such as firms caring about market share. Such general equilibrium effects are still interesting because they make clear that it is less costly if many firms are overoptimistic then when an individual firm is overoptimistic.

[16] As in the disequilibrium theories of Benassy.

[17] I have put disequilibrium in quotation marks because in models with search frictions phenomena such as unemployment are strictly speaking *not* disequilibrium outcomes of the model even though unemployed workers are willing to work at the current market wage rate.

interact. Prices are flexible in the sense that participants are free to bargain when they meet. I am currently working on finding the right approach that allows the idea to be incorporated in a full macroeconomic model.

2.3 Cost of business cycle fluctuations

It is a widely held belief, by those inside as well as those outside our profession, that business cycles are a serious nuisance. In most of our models, however, the presence of business cycles creates only a minor loss in utility for the economy as a whole. It is of course possible that this widely held belief is wrong. But it is also possible that our models miss something important.

Together with Petr Sedlacek, I explore the latter possibility.[18] In particular, we have developed a model in which relatively small aggregate fluctuations are much costlier than in standard models. The innovative element in our model is that frictions (such as contracting or financing frictions) make it impossible for firms to simply average out the good times and the bad times. That is, some projects have to be terminated during economic downturns, which means a shortening in the expected duration of a project. This property together with entry costs imply that the presence of fluctuations deter entry, which in turn implies that fluctuations have *level* effects. That is, the more aggregate volatility there is, the lower the average level of real activity.

Firms are heterogeneous in this model with respect to their productivity level and the value of their entry costs. Calibrating models with heterogeneous agents is typically difficult for the following reasons. First, one needs information about a cross-sectional distribution. Second, the properties of the model typically do not depend on moments such as means and variances but on how much mass is located around the cut-off levels. That is, one has to know the mass of projects just above the cut-off level, i.e., the number of marginal existing projects, and the mass of the projects just below, i.e., the number of potential projects. This type of detailed information is hard to find. Using a German panel data set and some structure imposed by the theoretical framework, we provide the

[18] See Den Haan and Sedlacek (2010). This paper will be substantially revised.

kind of empirical justification for the calibration that I did not manage to obtain in my earlier quantitative exercises with models with heterogeneous agents.

2.4 Expected recoveries during recessions

This is a relatively small project, but it reveals my continued interest in time series econometrics. It is well known that GDP is either an I(1) process or close to such a process. This means that (some) shocks have permanent effects. In fact, there is evidence suggesting that GDP is described well with a random walk (with drift). These properties have played an important role in the discussion on the long-term consequences of the current financial crisis. In particular, prominent economists like Greg Mankiw have argued that the random walk property implies that the best prediction about the long-term consequences of the crisis is that the drop in GDP is permanent.

In Cai and Den Haan (2009), we show that this reasoning is not correct. The reasoning of Mankiw is based on the assumption that one only observes output. But it is easy to construct multivariate systems such that (i) the univariate representation for GDP is a random walk and (ii) the richer multivariate representation allows for predictable changes. We show the relevance of this insight for the behavior of US GDP. In particular, we document the following. In past recessions, (simple) multivariate time series models predicted that a substantial fraction of the loss in GDP would be recovered, which in fact turned out to be the case in most recessions.[19] The estimated univariate model, however, often grossly overestimated the long-term loss.

2.5 Numerical solution methods

There are two projects that fall in this category. In both cases, the motivation for starting these projects came out of my work on solving models with heterogeneous agents. But the techniques developed in the second project should be useful in other settings as well.

[19] For each prediction we use a forecast that is based on a model estimated using only data up to the forecasting point.

Solving models with heterogeneous beliefs. As mentioned above, I started working on models in which some agents have rational expectations and some do not. The idea of these models is that the rational agents take into account that there are different types of agents in the economy. One might think that these models are terribly difficult to solve, especially when the fractions of the different types are time varying. The purpose of this project is to explore whether this is true.

In terms of developing algorithms to solve these models, the concern is definitely not true. For example, the algorithm of Den Haan (1996) or the algorithm of Krusell and Smith (1998) can be used with only minor modifications. The key insight is that rational agents do not have to exactly understand how all these other agents in the economy behave. They only need accurate descriptions of the laws of motion for the variables that the rational agents are interested in. Examples of such variables are prices, wage rates, job finding probabilities, tax rates, and so on. As long as one can find accurate representations for these laws of motion, then one can obtain accurate solutions for the complete model.

Whether this will be the case in a wide class of models remains to be shown. But it definitely is feasible in some cases. In fact, the techniques themselves are relatively simple and in the Amsterdam Macroeconomics Summer School I let students solve a prototype model in which some agents are rational and some are not.

Improved perturbation analysis. Perturbation analysis is a popular numerical solution technique that is especially suited for larger systems. An important practical problem is that time paths generated using higher-order perturbation solutions are often explosive in models with a substantial amount of underlying volatility. In models with representative agents, the volatility is low enough to avoid this problem. This is not the case in many models with heterogeneous agents when agents face a realistic amount of volatility, e.g., because they can become unemployed and face a serious drop in income.

The source of the problem can be explained intuitively as follows. Suppose that the true (unknown) solution is a contraction mapping and thus has a unique fixed point. Now consider a second-order perturbation solution. This second-order approximation will have another fixed point and will, thus, not be globally stable. More generally, the fact that perturbation techniques rely on polynomial approximations means that at some point one has to deal with undesirable oscillations. That is, the problem will not disappear by going to higher-order approximation. In fact, it can easily get worse. The troublesome aspect of perturbation solutions is that one cannot control how close to the steady state these oscillations will occur.[20]

Together with Joris de Wind and Ken Judd, I have been exploring solutions to this problem.[21] Some solutions are straightforward like using weighted combinations of stable first-order solutions and higher-order solutions.[22] Some solutions are more complex like replacing the standard monomials by alternative basis functions. The key underlying idea behind both of our suggested improvements is that the perturbation principle, i.e. using an approximating function that is such that its derivatives up to the k^{th}-order are identical to the true derivatives, allows for many solutions, not just polynomials.

References

Algan, Y., O. Allais, and W. J. Den Haan (2008): "Solving Heterogeneous-Agent Models with Parameterized Cross-Sectional Distributions," *Journal of Economic Dynamics and Control*, 32, 875–908.

——— (2010): "Solving the Incomplete Markets Model with Aggregate Uncertainty Using Parameterized Cross-Sectional Distributions," *Journal of Economic Dynamics and Control*, 34, 59–68.

Algan, Y., O. Allais, W. J. Den Haan, and P. Rendahl (2010): "Solving and Simulating Models with Heterogeneous Agents and Aggregate Uncertainty," in *Handbook of*

[20]In contrast, with projection methods one can avoid these problematic oscillations either by widening the grid (when using polynomials) or by using splines.

[21]See Den Haan and De Wind (2009, 2010). We are currently in the process of revising Den Haan and De Wind (2010) that discusses pruning and the simple solution to preserve stability. When this revision is finished we want to come back to the bigger problem on shape-preserving perturbation. This last project would be joint with Ken Judd.

[22]For the weighted average to be consistent with the perturbation methodology, it cannot simply be an ad hoc weighted average. But our proposal is still very simple to implement.

Computational Economics, ed. by K. L. Judd, and K. Schmedders. Elsevier, Amsterdam, The Netherlands, forthcoming.

Brock, W. A., and C. H. Hommes (1997): "A Rational Route to Randomness," *Econometrica*, 65, 1059–1096.

Cai, X., and W. J. Den Haan (2009): "Predicting Recoveries and the Importance of Using Enough Information," CEPR Discussion Paper No. 7508.

Covas, F., and W. J. Den Haan (2010): "The Cyclical Behavior of Debt and Equity Finance," *American Economic Review*, forthcoming.

Den Haan, W. J. (1996): "Heterogeneity, Aggregate Uncertainty and the Short-Term Interest Rate," *Journal of Business and Economic Statistics*, 14, 399–411.

——— (1997): "Solving Dynamics Models with Aggregate Shocks and Heterogeneous Agents," *Macroeconomic Dynamics*, 1, 355–386.

——— (2007): "Shocks and the Unavoidable Road to Higher Taxes and Higher Unemployment," *Review of Economic Dynamics*, 103, 348–366.

——— (2010a): "Assessing the Accuracy of the Aggregate Law of Motion in Models with Heterogeneous Agents," *Journal of Economic Dynamics and Control*, 34, 79–99.

——— (2010b): "Comparison of Solutions to the Incomplete Markets Model with Aggregate Uncertainty," *Journal of Economic Dynamics and Control*, 34, 4–27.

Den Haan, W. J., and F. Covas (2010): "The Role of Debt and Equity Finance over the Business Cycle," Unpublished Manuscript, Board of Goverenors of the Federal Reserve System and University of Amsterdam.

Den Haan, W. J., and J. De Wind (2009): "How Well-Behaved are Higher-Order Perturbation Solutions?," Unpublished manuscript, University of Amsterdam.

——— (2010): "Pruning and Higher-Order Perturbation Solutions," Unpublished Manuscript, University of Amsterdam.

Den Haan, W. J., and G. Kaltenbrunner (2009): "Anticipated Growth and Business Cycles in Matching Models," *Journal of Monetary Economics*, 56, 309–327.

Den Haan, W. J., and A. Levin (1997): "A Practioner's Guide to Robust Covariance Matrix Estimation," in *Handbook of Statistics 15*, pp. 291–341. Elsevier, Holland.

Den Haan, W. J., and M. Lozej (2010): "Pigou Cycles in Closed and Open Economies with Matching Frictions," *NBER International Seminar on Macroeconomics*, forthcoming.

Den Haan, W. J., G. Ramey, and J. Watson (2000): "Job Destruction and Propagation of Shocks," *American Economic Review*, 90, 482–498.

——— (2003): "Liquidity Flows and Fragility of Business Enterprises," *Journal of Monetary Economics*, 50, 1215–1241.

Den Haan, W. J., and P. Rendahl (2010): "Solving the Incomplete Markets Model with Aggregate Uncertainty Using Explicit Aggregation," *Journal of Economic Dynamics and Control*, 34, 69–78.

Den Haan, W. J., and P. Sedlacek (2010): "ŢInefficient Employment Decisions, Entry Costs, and the Cost of Fluctuations," Unpublished manuscript, University of Amsterdam.

Den Haan, W. J., S. W. Sumner, and G. Yamashiro (2007): "Bank Loan Portfolios and the Monetary Transmission Mechanism," *Journal of Monetary Economics*, 54, 904–924.

——— (2009): "Bank Loan Portfolios and the Canadian Monetary Transmission Mechanism," *Canadian Journal of Economics*, 42, 1150–1175.

——— (2010): "Bank Loan Components and the Time-Varying Effects of Monetary Policy Shocks," *Economica*, forthcoming.

Krusell, P., and A. A. Smith, Jr. (1998): "Income and Wealth Heterogeneity in the Macroeconomy," *Journal of Political Economy*, 106, 867–896.