

Investment dynamics in Japan

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Statement of Originality

I confirm that the material contained in this thesis is my own original work, and that, to the best of my knowledge, it contains no material previously published or written by another person, except where due reference is made in the text.

Luke Meehan

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Above all this thesis introduced me to my wife, Fiona.

*"... an ever-fixed mark,
That looks on tempests, and is never shaken;
It is the star to every wandering bark,
Whose worth's unknown, although his height be taken."*

Abstract

This thesis contributes to the literature by providing evidence that the drivers and impacts of Japanese private fixed investment change over time.

There is substantial research into aggregate investment, and it remains an active area of investigation. This is particularly the case in Japan, where policy makers and macro-economists alike are encountering novel challenges in the aftermath of the 'Lost Decade'. This is partly because theoretical and empirical aspects of investment are both individually complex and jointly difficult to reconcile. This thesis considers the suggestion such intractability may be due to different models for private fixed investment applying at different points in time.

Chapter 2 evaluates this suggestion in Japan by comparing optimal forecasting models produced by Dynamic Model Averaging. From 1965 to 2014, the optimal forecasting model for investment exhibits substantial composition variation. This variation appears to be linked with known Japanese business cycle and financial crisis events. Chapter 3 explores the Chapter 2 finding that the forecasting utility of uncertainty displays little time variation. This appears true even across the '1980s bubble' and its collapse as well as the Asian and Global Financial Crises. The chapter discusses the potential for 'real options' theory to explain the apparently linear relationship between uncertainty and investment. Using Time-Varying Parameter VAR modelling, this chapter compares realised investment responses to various uncertainty shocks with the canonical response shapes from real options theory. Results differ depending on measure, but domestic, forward-looking shocks appear consistent with the real options theory. Chapter 4 explores the Chapter 2 indication of substantial time-variation in the forecasting utility of investment factors, focusing on one particular component with substantial policy relevance, the yen. Time-Varying Parameter VAR estimates demonstrate a priori unanticipated responses of both the real exchange rate and out-

put to investment shocks. To explain this variation, Chapter 4 derives anticipated sectoral sensitivities from an optimising framework and re-considers the decomposed shock components in a simple non-linear regression format. Results indicate a structural change in the industrial composition of output growth in Japan.

These three empirical analyses are consistent in demonstrating the existence of time-variation in models of Japanese private fixed investment. To re-phrase, this thesis presents evidence that the underlying, data-generating processes behind Japanese private fixed investment change over time.

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Chapter 1

Introduction

Aggregate investment is a major component of changes in output. More variable than hiring, investment is a primary driver of business cycles. There is substantial research into aggregate investment, and it remains an active area of investigation. This is partly because theoretical and empirical aspects of investment are both individually complex and jointly difficult to reconcile. This thesis considers the suggestion such intractability may be due to different models for private fixed investment applying at different points in time.

This thesis makes the following five original contributions to the literature on the drivers and impacts of private fixed investment. First, it is the first work to provide a strong rationale for making time-variation an important consideration when modelling private fixed investment. Second, it is the first work to explicitly demonstrate the likely existence of time-variation in investment private fixed investment drivers, with particular reference to Japan. Third, it is the first work to investigate the time-varying macroeconomic impact of uncertainty in Japan. Fourth, it is the first work to demonstrate that economic uncertainty arising from different sources is likely to differently impact private fixed investment. Fifth, it is the first work to provide evidence of sectoral rebalancing in Japan using evidence from private fixed investment's reactions to currency changes.

Chapter 2 evaluates this suggestion in Japan by comparing optimal forecasting models produced by Dynamic Model Averaging. From 1965 to 2014, the optimal forecasting model for investment exhibits substantial composition variation. This variation appears to be linked with known Japanese business cycle and financial crisis

events. The elements of optimal models that do not seem to change are lagged investment and a measure of uncertainty

Chapter 3 explores the Chapter 2 finding that the degree to which uncertainty is effective at forecasting investment displays little time variation. This appears true even across the '1980s bubble' and its collapse as well as the Asian and Global Financial Crises. The chapter discusses the potential for 'real options' theory to explain the apparently monotonic linear relationship between uncertainty and investment. Using Time-Varying Parameter VAR modelling, this chapter compares realised investment responses to various uncertainty shocks with the canonical response shapes from real options theory. Results differ depending on measure, but domestic, forward-looking shocks appear consistent with the real options theory.

Chapter 4 explores the Chapter 2 indication of substantial time-variation in the forecasting utility of investment factors. Input and output components of private investment variously enter and exit the optimal forecasting model, seemingly in correspondence with external shocks and domestic business cycles. Chapter 4 considers one particular component with substantial policy relevance, the yen. Time-Varying Parameter VAR estimates demonstrate a priori unanticipated responses of both the real exchange rate and output to investment shocks. To explain this variation, Chapter 4 derives anticipated sectoral sensitivities from an optimising framework and re-considers the decomposed shock components in a simple non-linear regression format. There is evidence that investment in different sectors responds differently to variations in the real exchange rate, and the change in relative sectoral composition explains the varying responses of aggregate investment over time.

These three empirical analyses are consistent in demonstrating the existence of time-variation in models of Japanese private fixed investment. To re-phrase, this thesis presents evidence that the underlying, data-generating processes behind Japanese private fixed investment change over time. Satisfying the validity of the motivating question, the discussion now turns to consider its value.

The Japanese economy is a suitable target for the study of aggregate investment given Japan's systematic importance, status as a developed economy, and experience of important macroeconomic phenomena. Corbett (2012) noted that Japan's 'Lost Decade' experience, from growth to 'bubble' to recession, led to significant advances

in macroeconomists' understanding of fragility, deflation, low growth and the policy possibilities surrounding these phenomena. This investigation into Japan was partially motivated by research into real and financial shock transmission (Meehan, Miankhel and Kalirajan, 2011).

Fixed non-residential investment has long been considered an important determinant of a nation's potential rate of economic growth. This is because such investment raises the amount of productive capital and hence, under the assumption that this increase is utilised by a country's labour force, raises aggregate productive potential. Much of the modern support for these theories may have come from the empirical evidence of post-war Japan, where in the late 1950s and early 1960s, the percentage of Gross National Product devoted to domestic fixed investment was in excess of 30% and the corresponding rate of economic growth averaged 9.3% from 1950-1966. During the same period, the U.K. and U.S.A invested less than 20% of GNP domestically, and saw growth rates of 3-4% (data from Lund, 1979).

Hansen (1951) argues that it is only since Keynes' analysis of the global depression of the 1930s that aggregate investment has been seen, not only as a source of long-term economic growth, but a determinant of short-run, cyclical variations in a country's output. In the description by Lund (1979) mid-century Keynesian economists held fixed investment as a determinant of not only potential growth in output, but also the extent to which potential growth was being achieved at any point in time. A casual observer may note the enthusiasm with which Japan's national account statistics are reported in the media, and commented upon by leading economists (consider Governor Shirakawa (2012), who discussed the importance of Japanese private fixed investment to Japan's general economic outlook), and believe investment theories retain their policy-persuasiveness.

The macro-economics of investment, in data and in theory, was a major area of economic research throughout the 20th Century, as summarised by Caballero (1999). The Global Financial Crisis of 2007-9 energised a new wave of business-cycle research, with increased focus on cross-country and cross-sector contagion, financial mediation, risk and uncertainty, and systematic vulnerabilities. The GFC provided economic investigators with new opportunities to evaluate real and financial theories across multiple modern economies, with deep and interlinked data. It also motivated this thesis

– an investigation into the dynamic drivers and impacts of private, fixed investment in Japan.

In investigating the ‘dynamics of investment’, this thesis considers the concept that different models for fixed investment may apply at different points in time – such as before, during and after the GFC. ‘Models’ here refers to explanatory variable sets, their constituents, coefficient signs and magnitudes. The dynamics of investment is an active area of investigation in the economics literature, although it isn’t typically phrased as such. Research into development and associated structural change (Takagi, 2015), financing constraints (Amiti and Weinstein, 2014), uncertainty forms (Bloom 2012), and other areas may variously imply time-variation within sets of investment drivers.

Many standard time-series econometric techniques, such as ‘dummying-in’ structural breaks, state-switching, threshold models or partially non-linear interaction terms may be considered investigations into model dynamics. But they are highly prescriptive techniques, requiring stringent and binding assumptions by the investigator into the timing, degree, consistency and members of the group under analysis. Modern computational Bayesian econometrics offers an alternative, in that per-period evaluations of time-series data are able to be carried out on specific samples (such as a time-varying parameter vector auto-regression, Primiceri (2005)), or broad potential member groups (such as with dynamic model selection, Raftery et al. (2009)). Analyses of these forms may add substantial value both to understanding of the structure of an economy, as well as the relationship between theorised and observed investment sensitivities. Such theory-based, data-driven investigations into the dynamics of private investment either in general or with specific reference to Japan appear to be previously absent from the literature.

Any such evaluation would be strongly dependent upon the data. Such evaluations therefore must be considered for consistency with both the relevant theoretical background, as well as the specific macroeconomic environment. Failure to make such considerations increases the risk of misspecification of questions, misinterpretation of results and the sort of false-relationship discovery that bedevils much ‘big data’ research (see the discussion of ‘Google Flu’ by Lazar et al. (2014)). Consequently, Chapter 2 conducts a deep review of the theoretical and applied investment literature, with

particular attention to literature on the Japanese economy. Chapters 3 and 4 are careful to consider the range of theoretical and observed macroeconomic phenomena that may influence data and estimations.

A further data consideration involves the constitution of investment variables under investigation. In seeking to analyse investment either as a micro-level concept or as an aggregate, the investigator is presented with a series of decisions. Private, fixed investment is frequently summarised as 'plant, property and equipment', but this aggregate is frequently decomposed in line with the purpose of the investigation. The presupposed frequency of the underlying phenomena is a key factor in this decision; including slow-to-adjust information of investment in property is perhaps unlikely to provide insight into the short-term impacts of quickly-adjusting currency markets. A further key factor is the anticipated structural nature of the relationship - when investigating the impact on investment of bank lending to firms, it may not be advisable to include private fixed investment in residential property. This thesis aims to select the appropriate level of aggregation for analysis, and this precise constitution of the aggregate level varies between Chapters. But consistently across Chapters this thesis is interested in the drivers and impacts of firm investment, and consequently excludes private residential investment.

Moving to specific discussion of research motivation and setup, Chapter 2 aims to understand whether different models for Japanese private fixed investment may apply at different points in time. It was motivated by the importance of private fixed investment as a policy target and benchmark in Japan.

Prime Minister of Japan Shinzo Abe has repeatedly aimed to increase private investment and infrastructure exports as part of his strategy to overcome deflation and build economic expansion. A specific, targeted level of 70 trillion yen was indicated by Prime Minister Abe in a May 2013 speech¹. Similarly, the Koizumi Administration's 2002 budget contained 1.8 trillion yen of tax cuts, with the intended result of promoting a rise in corporate investment (Ihori, 2006 Ihori, T. (2006) 'Fiscal policy and fiscal reconstruction in Japan', *International tax and public finance*, 4-13, 489-508).

These two policies were differently focused, but both focused on the suggestion

¹(Bloomberg, 'Abe vows to boost Japan's investment in growth strategy outline, 18 May 2013, <http://www.bloomberg.com/news/articles/2013-05-17/abe-s-growth-strategy-to-support-investment-in-japan-technology>

that private fixed investment could be influenced by an explicit policy. But private fixed investment may be a complex concept; an amalgam of many conflicting factors, some of which will be complex to individually interpret. The possibility that there are actually separate markets for private investment, each with time-varying sensitivities and non-linearities, may not be able to be rejected a priori.

The absence of this rejection is in turn motivated by lively themes in the academic, business and policy literatures: that interest rates may have minimal impacts on investment at the zero-lower bound; that financing constraints may bind more tightly during a credit crunch; that firms may alter fixed investment to 'cater' to equity investors; that uncertainty may only curtail behaviour above a certain threshold; or that oil prices are particularly important during 'oil shocks'.

This first empirical chapter was further motivated by the variation observed in the literature concerning private fixed investment. It discusses later the substantial themes in the literature, notably the apparent tension between q-theory and financing theories of firm capital adjustment. This discussion is important given modern Japan's experience with macroeconomic structural change. The presence of shifts in 'deep' economic behaviour parameters at the aggregate level is suggested by the strong trend variations in output observed across the 'high growth', 'bubble' and 'lost decade' periods.

These competing motivations may jointly suggest an investigation into whether a broadly a-theoretical data mining investigation could be used to reconsider theorised relationships. This chapter is an attempt to take such a suggestion seriously.

Several applicable model classes should be examined, particularly the standard model of investment with convex adjustment costs - Tobin's q theory. This predicts that movements in the investment rate should be entirely explained by changes in a variable: Tobin's q. The theoretical model of q relates a corporate investment rate to the associated ratio of the shadow value of capital and unit price of investment goods. The shadow value is a function of future expectations and is difficult to empirically observe. That there is an empirical attraction of the q model is due to a simple (assumption-based) relationship between this ratio of shadow value to price, or marginal q, and the observable ratio of market valuation to replacement cost value of capital, or average q.

This predicted, strong relationship between q and corporate investment has been challenging to observe in empirical studies. A long series of investigations demonstrate cash flow and other measures of current profitability have a strong predictive power for investment, after controlling for Tobin's q . Many authors view this as *prima facie* evidence of the presence of financial constraints binding on corporate investment activity.

This first empirical chapter goes on to examine the 'Real options', 'Input/Output', and 'Managerial Survey' literatures of investment in detail. These theories, whilst important in the literature and often widely-used across disciplines, are somewhat less prominent in the economic literature. They respectively emphasise the relative importance of uncertainty, factor price variations and manager training, incentives and beliefs.

The strong divergence between the positive and normative investment literatures suggests a theoretically-agnostic investigation may add value. The possibility that structural changes in the relationships between and within underlying variables, together with the possibility of magnitude-based non-linearities in variable impacts, suggest that any investigation method be emphatically flexible.

Dynamic Model Averaging (DMA) is a per-period variant of the familiar Bayesian Model Averaging technique. Raftery et al. (2007) introduced the technique to the statistical literature by forecasting errors and their drivers in the context of an industrial process: a cold-rolling steel mill. Koop and Korobilis (2012) introduced DMA to the econometric literature by comparing the DMA interest-rate forecast effectiveness with that of other modern statistical techniques, notably time-varying parameter models and Markov Chain Monte Carlo Bayesian model averaging. Since the Koop and Korobilis (2012) introduction, DMA has been variously used to forecast commodities, real estate and exchange rate pricing models. The DMA technique avoids the necessity for computationally-intensive simulation of probability transition matrices by inserting a simplifying series of 'windowing' or 'forgetting factor' assumptions. These imply that the observed historical variance will contain useful information as to the forecast variance, and so allows the implementation of a relatively speedy Kalman Filter algorithm.

A substantial contribution of this chapter is to consider the degree to which a per-

period model selection technique may provide useful information as to the relevance, composition and variation of theoretical models. In studying such variation, it is exceedingly important to observe with sensitivity to Japan's modern macroeconomic history. An awareness of the likely structural variations in the economy, together with an understanding of the different geneses, natures and impacts of the various experience crises, may be critical to any model comparison exercise. A further contribution comes from applying the technique in a field in which it has not previously been used.

The results from the DMA exercise indicate substantial variation in the optimal, averaged, prediction model for Japanese fixed investment across the period 1980-2014. Lagged investment is consistently a necessary component of any forecasting model for investment, as is a constant term. Tobin's q , uncertainty and GDP are relatively consistent across the period, used in optimal forecasting models with approximately 50% likelihood. Much more time-variation appears in the tradeable and non-tradeable factors of production, oil and labour, which appear to be respectively linked with periods of internally and externally-driven growth. The predictive utilities of cash from operating and financing activities are very similar until the Japanese financial crisis period of the late 1990s, during which financing cash becomes a very useful predictor of investment.

These results indicate support for this chapter's thesis that different models for investment may apply at different points in time, and that Dynamic Model Averaging is a potentially useful technique for comparing theories of activity against observations embodied in the data.

Chapter 3 takes a closer look at one particular result from the first chapter: that uncertainty is a consistently useful predictor of corporate investment over time. At first blush this is a challenging result, notably because the instinctive association of uncertainty is with crises. Should investment be consistently driven by uncertainty, then that would imply that low levels of uncertainty still alter corporate investment in the same fashion as grand global crises, but their impacts are lesser simply because the magnitudes of uncertainty are smaller.

But this implies a very particular theoretical relationship between uncertainty and investment: real options theory. There are a range of theories by which the psychological, financial and economic literatures suggest uncertainty may impact investment.

This chapter contributes to the literature by suggesting an examination of the shape of impulse responses may aid a distinguishing effort. Most notably, Bloom (2009) and Bloom et al. (2014) suggest that the canonical real options impacts of an uncertainty shock to investment should exhibit drop, rebound and return effects. In this scenario, investment would fall in response to an uncertainty innovation, then rebound as pent-up demand was realised, before returning to trend.

Empirical derivation of specific responses to individual incidents is challenging, but modern computational Bayesian econometrics lessens the associated degree of difficulty. Time-varying parameter vector autoregressive analysis (TVP-VAR), allowing for stochastic volatility (as introduced to the macro-econometric literature by Primiceri, 2005), provides a potential solution. This small-scale, per-period analytic method enables substantially varied investigative scope. Essentially, the investigator is able to compare similar shocks to the same system at different points in time, thereby gaining an insight into periods of structural change or hard-to-observe non-linearities. Most interestingly from the uncertainty-investigation perspective, TVP-VAR enables a comparison of impulse response shapes. This in turn enables a novel examination of the real options theory of uncertainty impacts in Japan.

This chapter used a small q-model variously augmented with three measures for uncertainty, firstly the Chicago Board of Exchange's Volatility Index (VIX), a measure of implied international financial market volatility. Secondly, a measure of the dispersion of Japanese domestic forecaster beliefs derived from the Bank of Japan's 'Tankan' business confidence survey. Finally, a rolling measure of realised sales volatility. These three measures were respectively designed to capture globally-generated uncertainty, domestic forward-looking uncertainty and domestic backwards-looking uncertainty.

Estimation of time-varying parameter VAR models with stochastic volatility indicate domestic uncertainty has the hypothesised drop, rebound and overshoot impacts on Japanese private fixed investment. These findings are consistent with assumptions used in the large-scale modelling analysis by Bloom (2009) and Bloom et al. (2014). Contrary to expectations, such shocks appear linear in time and magnitude. Innovations to an international measure of uncertainty deliver longer-term decreases to investment activity which gradually returns to trend.

The results of Chapter 2 indicated substantial variation in the investment-forecasting

utility of ‘factor’ variables – such as the prices of oil and domestic wages, as well as the real exchange rate. These variables were included in the model-selection analysis by virtue of their association with input-push or output-pull investment drivers, as discussed by Landon and Smith (2009). Such variable sets have the added attraction of potentially throwing light on an area of international political economy debate that was particularly lively when the chapter was being written, namely that of the existence of ‘beggar-thy-neighbour’ monetary policy best known by the dramatic sobriquet of ‘currency wars’. The variation of forecasting utility to these variables indicated by the exercise in Chapter 2 - together with the broader international political economy debate - motivated a deeper look at the investment, growth and exchange rate relationship.

But for there to be an investigation worth undertaking, there must be greater evidence than apparent variation in a novel forecasting algorithm and a lively newspaper debate. In consequence Chapter 4 first seeks evidence on the output-investment-real exchange rate relationship in Japan. As with Chapter 3, it uses a time-varying VAR method with stochastic volatility to allow for structural shifts in the relationships between variables. The TVP-VAR analysis indicated the impulse-response relationship between gross domestic product and private investment had changed over time, as had that of investment and the real exchange rate.

In order to grasp the implications of any observed variation in empirical analysis, it is necessary to understand in depth the open-economy literature. This substantial area of research varies from simple and widely-understood models, through to more nuanced ways of thinking about the subject. In these more complex models, the coefficient signs in any estimation of the output, investment, real exchange rate relationship become dependent upon capital account and pricing-to-market assumptions. In turn, substantial empirical literature emphasises the importance of sectoral variations, where industries differently-exposed to international factors exhibit different investment behaviour in response to real exchange rate variations. The initial TVP-VAR examination demonstrated there is a *prima facie* need to consider the more nuanced open-economy models, and what sort of further examination may shed light on the case of Japan.

Chapter 4 continues the analysis by providing a theoretical model for two partic-

ular outcomes from the TVP-VAR estimation: sign changes in the output and real exchange rate responses to investment shocks. A model of open-economy investment is updated to consider FDI, and then estimated in a non-linear framework over the same period. The model is motivated by the suggested importance in New Open Economy Models of the degree to which firms undertake pricing-to-market variations. It derives a long-run investment function for a representative firm able to sell output in foreign and domestic markets using local labour and internationally-traded capital. The model is then extended to allow for firms that can only produce and sell domestically, as with some types of service-sector firms, and extended again to analyse firms that produce internationally and sell in both local and domestic markets - local firms with productive off-shore investments.

The results from non-linear estimates of the three model types indicate Japanese manufacturing investment sensitivity to price variations in external factors of production may aid understanding of the unanticipated TVP-VAR impulses. To further examine this, Chapter 4 conducts separate TVP-VAR analyses of manufacturing- and service-sector investment. This time-varying comparison further suggests the off-shoring of production may play an important role in driving observed Japanese investment and growth dynamics. Chapter 4's results are preliminary, with particular reference to focused examination of medium-term dynamics, and the lack of a long time-series on foreign direct investment.

Chapter 5 concludes by re-examining the central empirical results of this thesis with explicit reference to the motivating question: may different models for investment apply at different points in time? This thesis contends that examining the dynamic drivers and impacts of investment in Japan improves our understanding of the nature of investment, the role of confidence in corporate behaviour, and the structure of the Japanese economy.

All data used in this thesis are available from the author on request. This thesis also includes a Data Appendix, appended following the Bibliography. In the Data Appendix meta-data is provided for all variables on: data adjustment (i.e. differencing), seasonal adjustment, period of coverage, units of measure, source name and identifying hyperlink - active as of April 2017.

Chapter 2

Modelling private fixed investment in Japan

2.1 Introduction

Do different models for aggregate investment apply at different points in time? Such a variation may partially explain the variety of empirical aggregate investment model specifications observed in the literature. This chapter provides a way of drawing information out of a range of different approaches to modelling investment cycles, and demonstrates the core set of factors that have explanatory power across many different approaches. It does so by analysing the possibility that the optimal forecasting model for Japanese private, fixed investment may change over time, and that these changes may contain information about theoretical approaches to modelling investment.

Comparing models for private fixed investment drawn from five strands of literature, the chapter conducts a Dynamic Model Averaging (DMA) exercise over collated variable sets, the results of which indicate substantial time-variation in variable coefficients. This indicates certain variable sets have increased predictive power at different points in time. When compared with the historical macroeconomic record, we gain some insight into how models for aggregate investment may vary over business cycles and rare events. Most notably this chapter finds broad support for: interest rates being poor predictors of investment at the zero-lower bound; financing constraints appear to bind more tightly during a credit crunch; uncertainty does not unusually curtail behaviour during crises; oil prices are particularly important during 'oil shocks', lagged

investment is the most reliable indicator of current investment.

That models for aggregate investment may be differently constituted at different points in time is not novel to the literature, although the issue is rarely phrased in this fashion. There is a large literature in macroeconomics discussing the impact and management of structural changes in time-series variables¹, and dummy variables for unusual periods are a common part of many estimation models.² The estimation of a joint interaction coefficient for variables may also be viewed as efforts to capture changes in preferred models over time³. One recent technique is the time-varying parameter suite of methodologies, in which coefficient values can move over time, a VAR variant of which is applied to investment in this thesis. If variable coefficients can move to and from zero over time, then the correct model specification (with and without these variables) is similarly changing.

Bayesian Model Averaging (BMA) techniques attempt to deal with such model uncertainty by using posterior model probabilities to derive a single, optimal prediction model from a large set of variables. Fernandez et al. (2001) apply BMA to the issue of specification uncertainty in growth regressions, Tobias and Li (2004) apply BMA in the context of returns to education and Cogley and Sargent (2005) to the modelling of inflation. But standard BMA analysis implicitly assumes there is a single, optimal data-generating process: a time-invariant model. DMA (Raftery (2010)) is a recursive Kalman filter technique that allows variable coefficients, and consequently models, to change over time given certain parameters; if those coefficients do not change then DMA is equivalent to a recursively-estimated BMA technique. DMA was introduced to the inflation forecasting literature by Koop and Korobilis (2012)⁴, but does not appear to have yet been generally applied as a model comparison tool, nor specifically to investment.

Aggregate investment is an important component of macroeconomic activity and analysis, albeit a complex component with a range of suggested data-generating pro-

¹Stock and Watson (1996)

²See the oil-shock unit-root dummies in Perron (1989), the application to the impact of debt on investment in Warner (1992) and to Japanese investment in Hoshi et al. (1991) and recently by Kasahara et al. (2014).

³where correctly specified, see the discussion by Balli and Sørensen (2013) and the use in the Japanese investment context by Amiti and Weinstein (2013)

⁴Other forecasting uses include the European carbon market (Koop and Tole (2012)), resource prices (Buncic and Moretto (2014)), US housing prices (Bork and Moller (2015)) and sovereign reserves (Gupta et al. (2014)).

cesses underlying it. Raftery (2010) introduced DMA in analysing complex manufacturing data-generating processes: 'The ... theory underlying the prediction or control problem is often somewhat weak, and may be limited essentially to knowing what the inputs are that could potentially influence the output of a system. In that case we consider a model space consisting of all possible combinations of inputs that are not excluded by physical considerations.' The motivation of the repurposing of the forecasting technique DMA into a model selection technique is that, if the underlying, data-generating model for investment can change over time, then such variation may also be visible in variations to the optimal forecasting model for investment. This chapter essentially suggests the established analytical process of the DMA forecasting technique can be inverted to perform a similar model comparison function to the established analytical processes of BMA from which DMA is derived.

Although investment is much smaller as a fraction of GDP than consumption, investment is much more variable than consumption. So fluctuations in investment spending account for a large proportion of business-cycle frequency fluctuations in GDP (Caballero, 1999). If we think accounting for capital is an important component of explaining macroeconomic outcomes, then we need an understanding of investment. Japan is both a sensible and an important focal point for this investigation. Some of the major events in modern economics were first intensively observed in Japan, from an era of investment and export-led growth, through joint land-equity price bubbles, towards a 'Lost Decade' of zero growth, policy and theory issues with the zero lower bound on interest rates, the complex dynamics of an ageing population and the large-scale foreign direct investment in a rising neighbouring economy in China. Private fixed investment plays a key role in many of these phenomena and, given the existence of both complete mid-frequency data and modern computational econometrics, a better understanding of Japanese investment dynamics is both possible and of potential value to Japanese and international policymakers who are grappling with the management and consequences of variations to aggregate investment.

Evaluating the need and discussing the focus of any such research, Section 2 considers the literature on investment in depth, detailing research into 5 disparate yet connected strands that arose from early models of the nature of capital. Section 3 draws a series of empirical model constituents from the literature and discusses data

sources and treatments for their estimation. Section 4 presents the Kalman filter recursions that enable DMA, and discusses windowing and volatility assumptions. Section 5 details the variations in constituent use probability that are the results from DMA estimation, and discusses their broad implications. Section 6 turns these motivations into a research program that informs the remainder of this thesis.

2.2 Private fixed investment

2.2.1 Foundation research

One of the most influential early works on investment was the ‘The Investment Decision’, a 1957 book by Meyer and Kuh which aimed to provide large-scale, carefully analysed tests of theories of investment behaviour. Meyer and Kuh collected a sample of data from 750 firms over the period between 1946 and 1950, and looked empirically at the determinants of investment, specifically at depreciation expense, age of assets, change in sales, liquidity stock, profits, sales and capacity-utilization. They conclude that the best explanation for their pattern of evidence is that managers are highly reluctant to tap external sources of finance, and are reluctant to change dividends. Their key finding was comparable to a null-theory of investment behaviour, where in the short run investment is set as a residual and therefore moves closely with firms’ internal resources.

Modigliani and Miller (1958) provided the theoretical basis for de-emphasizing the importance of external or internal finance. Motivated by the absence of a theoretical literature on corporate finance, their key capital-structure theorem demonstrates that, in the absence of taxes, bankruptcy costs, agency costs, and asymmetric information, and in an efficient market, the value of a firm is independent of its capital structure. Their result, applied to investment decisions, becomes: in a world without financial imperfections, investment decisions are made by comparing the return promised by the investment to the relevant cost of capital (including opportunity cost). Controlling for investment opportunities, a firm’s investment would, in a world without financial imperfections, be uncorrelated with its cash on hand or current profitability.

The Modigliani–Miller result has no implications for the unconditional correlation between cash flows and investment. If investment opportunities are positively corre-

lated with current cash flows, then investment and cash flows will be correlated even if all of the Modigliani–Miller assumptions hold. Modigliani and Miller say that, in a world without financial imperfections, investment, controlling for investment opportunities, is uncorrelated with cash flows. Meyer and Kuh's empirical analysis highlight the variety of constraints that they perceived to be binding. Largely because of these constraints, in the short run, investment was set as a residual. This behavior necessarily induced a correlation between firms' investment and cash flows.

Jorgenson (1963) developed a model of investment behaviour in which a firm's desired capital stock was derived from the propositions of neoclassical economic theory. This contribution formally based optimising firm behaviour within the neoclassical theory of the demand for factors of production, an important shift from the non-optimising empirical or static theories of investment previously discussed in the literature. Hall and Jorgenson (1967) added significant detail in an important step forward. They constructed a model in which an optimizing firm chooses the level of its capital stock with reference to fundamental features of the economic environment including production function, depreciation rates, a comparison of interest rates to the productivity of the firm's available uses of capital, and particularly tax considerations. The assumptions made by Hall and Jorgensen (1967) were reasonably restrictive and particularly seminal; as a field, the testing and relaxing of these assumptions is a reasonable proxy for the majority of subsequent work in the economics of corporate investment. These assumptions are widely familiar, but due to their importance are listed here and include: the firm operates under perfect competition; there is no uncertainty; there are no adjustment costs or constraints; there is full employment of factors in an economy where prices of labour and capital are perfectly flexible; there is a perfect financial market which allows a firm unlimited borrowing or lending at a given rate of interest; a Cobb-Douglas production function; inputs are employed up to a point at which their marginal revenues are equal to their real marginal costs; there are diminishing returns to scale; the capital stock is fully utilised; the firm maximises the present value of its current and future profits with perfect foresight in relation to all future values, or that expectations of future variation from current pricing are not relevant.

Brainard and Tobin (1968) and Tobin (1969) took to task the assumptions that firms

could instantly and costlessly move their capital stocks to the level that would be justified by the prevailing economic environment, and that expectations had no role to play. In adding an adjustment cost function to the profit function, and suggesting that investment is made until the market value of assets is equal to the replacement cost of assets, Tobin (1969) demonstrated the neoclassical theory was logically equivalent to a 'q-theory'. That is, firms which have a value greater than what it would cost to reproduce their capital should be growing, while firms which are not worth what it would cost to reproduce them should be shrinking. This average Tobin's q became one of the basic tools of financial market analysis and a consistent inclusion in economic models of investment.

That Tobin's q is so consistently utilised in theoretical and empirical models of investment is partially due to the elegant theoretical contributions of Abel (1979) and Hayashi (1982). They showed that the neoclassical model with convex adjustment costs yields a q -model. More precisely, this 'marginal q ' should be interpreted as the marginal value of an installed unit of capital - the shadow value of capital from the firm's optimisation Lagrangian. Hayashi (1982) was particularly influential on the later literature due to his demonstration that, for price taking firms whose production function and adjustment cost function are linearly homogeneous in capital and labor, marginal q is equal to average q . Despite the strong assumptions, this finding was influential due to the great difficulty in empirically identifying marginal q in comparison to the relative ease of average q . Due to their strength, the required assumptions of linearly homogeneous production and particularly adjustment costs rarely hold in practice (see the criticism by Caballero (1999)), and attempts to better separate marginal q from average q have provided a key theme of the simulation-based investment literature's variation to the empirical literature, and the source of much debate.

The debate throughout the 1970s and 1980s centered around the strongly-established positive correlation between business fixed investment and the business cycle, together with the often-zero correlation between the investment and the cost of capital. Shapiro (1986) outlines these pre-1990s debates in some detail in a paper that suggests a hybrid neo-classical and financial accelerator model. That the hybridisation of financial and capital models was deemed necessary was a result of the pro-cyclical

investment correlations entering investment equations strongly in the form of cash from operating and financing activities, sales, depreciation and essentially the other core business-centric variables presented in Meyer and Kuh (1957). Although it also informed future literature investigations into the possibility that high-frequency current variables that appear to drive investment may be artefacts of low-frequency general equilibrium factors, perhaps the greatest contribution by Shapiro's (1986) research was to enable Blanchard (1986) to provide the famous quote in discussion: *"... it is well known that to get the user cost to appear at all in the investment equation, one has to display more than the usual amount of econometric ingenuity, resorting most of the time to choosing a specification that simply forces the effect to be there...."*

Shapiro's (1986) research was also informative in that it was an indicator of the approximate point in time in which a literature divergence occurred. This debate was most notable in the literature's efforts in modelling and empirical efforts to fully identify marginal q , and those investigations into further theory and evidence for financing impacts of investment. The seminal paper of the latter was that of Fazzari et al. (1988); it and the branch of literature following it will be discussed in Section 2.3. Section 2.2 follows the research into q models, Section 2.4 into real options models of investment, Section 2.5 into models focused upon anticipated capital and finally Section 2.6 examines the survey results from the managerial literature.

2.2.2 Deconstructing q

The challenges to q models of investment were largely empiric, and consistent across sectors and economies. Hoshi and Kashyap (1990) presented painstaking estimates of q from 1974 to 1988 in Japanese manufacturing, and found estimated q to be a poor determinant of investment. This was an important contribution, given the estimates of q were within anticipated bounds (i.e. close to unity) and were responsive to taxes as per the Modigliani-Miller (1958) and Tobin (1969) models. Hoshi and Kashyap (1990) were also able to demonstrate low degrees of measurement error in q , up until Japan's stock market boom of the late 1980s, when the estimate became less reliable. This link between stock price booms - and the associated q variation - with private fixed investment represents an important testing opportunity, and is discussed from a business cycle perspective by Kiyotaki and West (1996), a financing perspective by

Chrinko and Schaller (2001) and from a modelled, q -catering perspective by Gilchrist, Himmelberg and Huberman (2005). Essentially, Hoshi and Kashyap (1990) provided strong motivation for further q -deconstruction in more complex modelling.

In response to this challenge, Caballero (1994) advanced q -thinking by noting the presence of adjustment costs would slow the movement of capital stocks to their optimal level, and so estimates of the coefficient of the cost of capital in this adjustment process would be biased towards zero - a bias that disappeared (and returned the cost of capital coefficient to the anticipated negative one) in simulations. This was a high-vs-low frequency argument, and an consequently an early motivation for time-varying analysis.

There is also a long history of research into the association between risk and investment, particularly as investment tends to be to some degree irreversible. Whilst this area will be discussed in depth as part of the real options models in Section 2.4, the 'lumpiness' of microeconomic investment data associated with partial irreversibility has been researched in terms of adjustment costs variations and the presence of fixed costs. Amongst others, Caballero and Leahy (1996) demonstrate that the addition of such non-linear adjustment costs force the firm's value function to deviate from global concavity, and consequently marginal q to become non-monotonic, specifically around the unit value of q . The second main finding, and of particular interest to empirical research, was that the average q becomes a better predictor than marginal q , as firms become less sensitive to small variations in the marginal productivity of capital (or capital stock value) around the unit value of q threshold.

Returning to analysis in the Japanese economic environment, Kiyotaki and West (1996) considered business fixed investment over the pre- and post-bubble period of 1980s and 1990s Japan. Their use of estimates of average q from stock prices to inform present value rules for investment indicated no strong causal relationship. In comparison, a flexible accelerator model constructed with post-tax capital, convex adjustment costs and earnings values was able to usefully match observed investment behaviour during this period. In further q inconsistency, both flexible accelerator empirics and general equilibrium models indicated a small and negative elasticity of capital with respect to the cost of capital.

Abel and Eberly (2002) contributed to the research on investment facing fixed costs

and non-linear adjustment costs by conducting empirical research which allowed for a broad adjustment cost function. By exploiting unobserved heterogeneity of capital (i.e. the rebalancing between different capital types or vintages by firms) they demonstrate the empirical importance of the unitary q threshold, and consequently that the cross-sectional distribution of q affects aggregate investment. They are also able to show business-cycle non-linearities in firm investment behaviour and its responsiveness to q .

A different investigation into the importance of capital adjustment costs was undertaken by Cooper and Haltiwanger (2006), who specify a dynamic optimisation problem for convex, non-convex and irreversible capital adjustment costs. In comparing simulations from the model with plant-level data, they find a combination of non-convex adjustment costs and irreversibility enables a fit of prominent features of observed investment behaviour at the plant level. When matching with aggregate data, the importance of non-convexities decreases, and a model of standard convex adjustment costs fits the data reasonably well, leaving unclear implications for the usefulness of aggregate q .

An alternative explanation for the poor predictive power of q in standard regressions was examined by Cooper and Ejarque (2003), who considered the assumption by Hayashi (1982) that firms were price-takers. The argument made was that any degree of monopolistic power would wedge average and marginal q . By solving a dynamic programming optimisation problem for firms with some degree of market power, they were able to simulate data consistent with results from cash-flow or profit-augmented regressions.

These two simulation papers provide a particularly clear demonstration of the difficulties excluding or including q -theory in theoretical or empirical work; as in much of macroeconomics the existence of multiple cointegration, complex adjustment behaviour and plausibly multi-directional causality cannot be ruled out. Whether q is a true driver of investment behaviour or simply a particularly useful captured indicator of broader economic conditions is difficult to ascertain.

This difficulty, and the strong theoretical basis of q -theory, has persuaded many researchers to fully integrate this capital-optimising behaviour into large-scale models. Christiano, Eichenbaum and Evans (2005) demonstrated that a medium-scale

DSGE model could reasonably match general business cycle activity. They specified a dynamic general equilibrium model with a number of distinct structural features: staggered wage and price setting with partial indexation; habit persistence in consumption; endogenous capital accumulation with higher-order adjustment costs; and variable capacity utilization. This provided the basis for workhorse central bank models and substantial macroeconomic literature. Importantly, this paper used an adjustment-cost augmented investment model that was logically consistent with an average q model.

Eberly et al. (2012) provide a full derivation and generalised proof of this q -consistency, and further demonstrate the Christiano et al. (2005) specification also provides a role for both cash-flow and lagged investment. They further demonstrate the empirical value of this specification at the firm level using panel data. As a consequence, they note that non-convex adjustment costs are irrelevant at the firm-level, where lumpiness and irreversibility at the plant level is effectively smoothed out.

The current state of q -theory research suggests that, although difficult to distinguish, and possibly bound up with confusing factors, Tobin's Q (in some average form) may play an important role in driving investment. The most important of these confusing factors are discussed in a branch of the literature concerned with firms' access to capital.

2.2.3 Accessing capital

Empirical analysis of the investment decisions of firms is consistent in identifying as important 'current' variables, particularly cash flow and operating profit, that may fit poorly with q -theory perspectives. Following on from early empirical studies, a number of researchers have investigated extended models of investment that are able to incorporate a role for current variables in terms of alleviating 'financing constraints'. As discussed in seminal work by Fazzari et al. (1988), research into 'financing constraints' essentially investigates the possibility and implications of internal and external sources of finance being imperfect substitutes. Fazzari et al. (1988) establish a research precedent in attempting to find tranches of firms that may be a priori anticipated to experience imperfect information issues in capital markets and consequently face challenges in accessing external financing. Investigating a broad

panel across manufacturing firm sizes and earnings retention practices, they interpret a greater investment-cash flow sensitivity for firms considered more likely to face a larger wedge between the internal and the external cost of funds as evidence that the firms are indeed constrained.

The further evidence and the case of Japanese firms is discussed by Hoshi, Kashyap and Scharfstein (1991). They utilise the unusual industrial structures of linked families of Japanese firms, 'keiretsu', in comparison with firms outside of the keiretsu family grouping. Firms within a keiretsu that has close ties to a major bank are assumed to face lesser financing constraints as a result of the decreased informational challenges associated with a keiretsu grouping. Hoshi, Kashyap and Scharfstein (1991) find that investment by Japanese firms with keiretsu-derived bank links is less sensitive to cash flow than investment by independent firms. They conclude that bank affiliation alleviates underinvestment problems caused by capital market imperfections.

Gilchrist and Himmelberg (1995) demonstrate a similar finding for U.S firms, but with respect to bond market access, as opposed to close banking relationships. They further construct an estimate of 'fundamental q ', a variable designed to capture the best estimates of future marginal q as available from VAR estimates, and show that cash flow remains empirically important, even when forward-looking q data is included in the estimation. This effect appeared stronger for a priori financially constrained firms, as per Fazzari et al. (1988), although in some estimated sub-samples the effect of cash flow disappeared and suggested more complex relationships may be important.

Kaplan and Zingales (1997) influentially find an important role for cash-flow variables in investment estimations that goes beyond financial constraints, notably showing that firms that are less financially constrained exhibit greater investment-cash flow sensitivity. They find that 85% of firm-years in a broad sample of firms show no limitations on access to internal or external funds, and that previous estimates may have been driven by small numbers of outlying results. Their findings suggest an alternative explanation for the importance of current variables for investment.

Inspired by the disconnect between the theoretical value of q and the unclear theoretical value of cash-flow Gomes (2001) notes that, in a fully-specified model, the presence of financing constraints should be accounted for in the market value of the

firm, and thereby be captured by q and that financing constraints are not necessary to obtain significant cash flow effects. Gomes (2001) simulates a general-equilibrium model in which firms can choose when to enter the market for capital, and argues that any correlation between investment, cash-flow and sales is an artefact of underlying technology shocks. From this perspective, reduced-form equations may only capture the spurious relationship portion of the entire environment, and the consequential measurement error may mislead econometric estimates.

The unique situation of the Japanese economy for evaluating the role of current variables in driving corporate investment is explicitly explored by Chirinko and Schaller (2001), whose work motivates the later work by Gilchrist et al. (2005). Both papers consider the possibility that over-valued equity prices may have an impact on private fixed investment, a particularly interesting point in the post 'bubble era' Japanese environment. Chirinko and Schaller (2001) describe two potential mechanisms for an impact to occur: an 'active financing mechanism' whereby firms use the earnings-price ratio as a measure of the cost of capital, consequently over-valued equities may lower the discount rate applied to investment decisions, and an 'inactive financing mechanism', whereby firms realise the arbitrage potential of over-valued equity and react by issuing further stocks and shifting the proceeds into cash and securities. Gilchrist et al. (2005) describe the 'inactive' mechanism as a form of short-selling, in which firms are comparatively unconstrained by regulation. Estimation by Chirinko and Schaller (2001) suggests both that a bubble in Japanese equities existed, and that it had a substantial impact on business fixed investment. Their controls for q suggest this link is from financing, with over-valued equities representing a cheap source of capital. This extra- q suggestion is supported by the VAR modelling of US firms by Gilchrist et al. (2005), although their analysis suggests that firm's position as monopolistic issuers of their own equity is vital.

The finance literature is also actively concerned with the value of cash holdings for financially constrained firms. Denis and Sibilkov (2010) summarise this largely empirical literature and use 3SLS methods to control for endogeneity in their examination of 74,000 US firms, finding cash holdings are positively associated with net investment for financially constrained firms. They further find that financially-constrained firms have low and declining earnings profiles, further constraining external financial

access and increasing the value of internally-retained cash.

The apparent conflict between the often-replicated Denis and Sibilkov (2010) and Kaplan and Zingales (1997) findings is investigated by Lyandres (2007), whose theoretical and empirical analysis considers the possibility of a non-monotonic relationship between the sensitivity of firm investment to cash flow. This analysis depends on the comparative dynamics and statics of high costs of external financing, which in a static analysis impose a high cost on current investment, but when compared across time impose a high cost on the attractiveness of future investment. Lyandres (2007) discusses similar U-shaped empirical findings in the literature, and presents an essentially real-options based model which demonstrates U-shaped investment-cash flow sensitivities arise when comparing whether the relative dynamic and static impacts dominate for constrained and unconstrained firms.

From a policy perspective in the Japanese environment, the usefulness of cash-flow augmented investment analyses and the importance of capital constraints is demonstrated by Kasahara, Sawada and Suzuki (2014). Their counterfactual simulations on firm-level data of the effect of government capital injections into financially troubled banks indicate a substantial alleviating impact of such on Japanese corporate investment. In line with the finance literature, their findings suggest a non-linear impact of capital constraints on both firm investment and firm investment sensitivity to cash-flow.

Amiti and Weinstein (2013) demonstrate a similar importance of bank-loan supply for firm activity in Japan using a loan-linked identification strategy. Although their work demonstrates an odd reluctance of Japanese firms to expand credit lines with alternative, linked, 'main banks' when their primary 'main bank' is hit by a supply shock, they provide evidence that bank shocks have macroeconomically significant impacts via their role in constraining corporate access to capital and consequent investment.

The role of current variables in determining corporate investment is a consistent theme in the empirical literature. Modigliani and Miller (1958) argue that in a frictionless environment, companies can fund all value-increasing investment opportunities. That is, investment and growth do not depend on the availability of internal capital. Once capital market imperfections are introduced, however, firms are not necessarily

able to pursue all value-increasing investment opportunities. The value of internal sources of capital in the face of external capital access variations appears substantial, if possibly non-linear in the face of the real option of opportunities, stock market misvaluation and general equilibrium effects.

2.2.4 Real options

The 'Real options' approach to investment decisions is characterised by three stylised facts. Firstly, most fixed capital investments are partly or completely irreversible, in that the initial cost of investment is at least partially sunk and it cannot be recovered completely by selling the capital once it has been put in place. Secondly, investment decisions have to face uncertainty about their future rewards; the best investors can do is attach probabilities to the possible outcomes. Thirdly, investors can control the timing of an investment, and postpone it in order to acquire more information about the future.

These three facts enable the real option perspective that views an investment opportunity as an option to purchase an asset at different points in time. The optimal investment policy balances the value of waiting for new information with the cost of postponing the investment in terms of forgone returns. When firms commit to an (at least partially) irreversible investment, it kills its option to wait for new information that might affect the desirability of the investment. In consequence, the standard net-present-value investment rule (invest when the anticipated return on the additional capital equals its purchase and installation cost) must be modified: the anticipated return must exceed the purchase and installation cost by an amount equal to the value of keeping the option alive. The literature demonstrates the option value of waiting can be considerable, especially in a highly uncertain environment. As a consequence, uncertainty can become a powerful deterrent for even risk-neutral investors.

McDonald and Siegel (1986) provided the first explicit valuation of investment allowing for irreversibility, incorporating option valuation into investment theory. They analysed a project of fixed size, constraining the timing of the project as the only choice to be made (given stochastic project payoffs and costs), and show the project value includes an option value of waiting which can be valued using option pricing theory. This additional value of being able to choose when to invest is increasing in uncer-

tainty, and consistent with Bernanke (1983) who highlighted the importance of variations in uncertainty in a model of a oil cartel evaluating capital investment. Bernanke (1983, p.91) implicitly discussed the option pricing principle identified by McDonald and Siegel (1986) in his 'bad news principle', which holds "Given the current return, the willingness to invest in the current period depends only on the severity of bad news that may arrive. Just how good is the potential future good news for the investment does not matter at all." This principle can be viewed a result of a decision-delaying threshold within an uncertainty-augmented net present value calculation: a project can be indefinitely postponed but faces finite expansion restraints.

In McDonald and Siegel (1986), the investment is assumed to be lumpy. Pindyck (1988) investigates the opposite case, where the firm can add to its production capacity continuously and incrementally (i.e. the firm chooses both investment timing and size). His analysis shows that, even when demand is subject to mild uncertainty, an optimal investment strategy requires the payoff to be more than twice as large as the investment cost.

Abel, Dixit, Eberly and Pindyck (1996) deepen the uncertainty analysis by providing a general options model of investment irreversibility as symmetric put and call options. They show that even when capital is partially irreversible, uncertainty in the level of future marginal returns has an uncertain effect on current investment if it is costly to expand the capital stock, as the future purchasing price of capital may exceed its current value. They demonstrate that increases in uncertainty may have two opposite options effects: it raises the option value of postponing investment due to limited reversibility, but increases the option value of fast-tracking investment due to finite expansion restraints.

The potential for uncertainty to play a substantial role in aggregate investment decisions in Japan was discussed by Ogawa and Suzuki (2000). They investigate how investment by a panel of 387 Japanese manufacturing firms over 23 years responded to uncertainty in the form of rolling 3-year standard deviations in sales growth. Allowing for firm-specific costs of capital, and including land values, they decompose the constituents of their uncertainty measure into firm-specific and sectoral, finding a negative relationship between uncertainty and investment that is stronger for firms in industries where a greater degree of sunken capital is observed.

Ogawa and Suzuki (2000) argue the magnitude of this uncertainty measure's impact on investment may be downwards biased due to anticipated non-linearity in uncertainty, where a decision is only delayed when uncertainty crosses the option of waiting threshold. But as Bloom (2009) discusses, the impact of uncertainty shocks in a real options framework is magnitude-agnostic - only the increase matters. The intuition behind this logic is that uncertainty causes all investment to be delayed, so firms undertake last period's activity now and this period's next period.

Bloom (2009) and Bloom et al. (2014) use a quantitative RBC model with various adjustment frictions to capital and labour to argue that positive innovations to uncertainty lead to short-run fluctuations, starting with a rapid decline in aggregate activity, then a rebound phase and a prolonged overshoot after approximately six months. This 'wait and see' effect is a direct result from Abel et al. (1996), and involves the logic that, if firms suddenly find themselves in a more uncertain environment they stop investing for a period of time, creating pent-up investment. The simulations in Bloom (2009) deliver the associated drop, rebound, overshoot and mean-revert tendencies such logic implies.

The macroeconomic importance of the findings by Bloom (2009) and Bloom et al. (2014) are challenged by Bachmann, Elstner and Sims (2013), who use the degree of disagreement in surveyed business forecasting data as an uncertainty measure in VAR estimates for the US and Germany. They find that positive innovations to business uncertainty lead to prolonged declines in economic activity, and find no evidence of the 'wait and see' described by Bloom (2009) as a result of real options-based uncertainty shocks. Bachmann, Elstner and Sims (2014) find positive innovations to business uncertainty have effects similar to negative business confidence innovations, and argue that high uncertainty events are epiphenomena of downturns in business cycles.

Gilchrist, Sim and Zakrajsek (2014) attempt to estimate the relative importance of uncertainty shocks in the 'wait and see' forms and as epiphenomena of increased credit spreads in a quantitative general equilibrium model. They find both shocks have large impacts on aggregate investment, with both 'wait and see' and credit spread shocks having quantitatively similar impacts.

The real options theory indicates important, if directionally unclear, investment variations should be associated with uncertainty shocks. The empirical evidence of

these effects is mixed, due in part to the difficulty in extracting uncertainty variations from macroeconomic activity.

2.2.5 Factor sensitivity

The financing stream of the literature strongly suggests that non-q factors may influence aggregate investment decisions. The financing of investment literature specifically focused upon the implications of differentials between internal and external financing costs, but the implication that variations in factor costs could influence investment decisions, separately from anticipated returns to investment, was influential. Inspired by a perceived importance of international factors, a small branch of the investment literature focuses on the influence of specific costs of investment. This rationale involves a standard optimisation approach, but decomposes the costs associated with factors of production. Campa and Goldberg (1995) use this process to develop a measure of export exposure, and in turn identify the degree of investment sensitivity to exchange rate variations across sectors. Further, their theoretical model describes both sales variables and labour cost variables as important determinants. Using 14 years of US manufacturing firm data decomposed into 2-digit sectors, they demonstrate that the higher the external exposure of a sector (i.e. to imported inputs), the greater the investment response to exchange rate variations.

Campa and Goldberg (1999) extend the analysis to a cross-country setting, inclusive of Canada, the U.K. and Japan. Noting that exchange rate variations can cause substantial shifts in relative unit labour costs, influencing prices of goods sold in domestic and foreign markets, they derive a theoretical exchange rate-investment relationship under imperfect competition, and find that industry competitive structure matters for investment responsiveness to exchange rate variations. A final learning is the apparent willingness of Japanese manufacturing producers from 1974-1990 to adjust profit margins (as opposed to levels of labour and capital) in response to exchange rate shocks - a direct contrast to the U.S. or the U.K.

Using micro-level panel data for Italian firms, Nucci and Pozzolo (2001) reinforce these earlier findings in the literature by demonstrating exchange rate variations have important impacts on investment through the cost- and revenue-channels. Swift (2006) conducts a similar exercise for Australian firms, with similar findings. These two pa-

pers focus upon the degree of competitive exposure as a key determinant of factor-price drive variations in investment. Estimated by constructing a 'markup' estimator, essentially operating profit as a percentage of sales, they emphasise that investment in plant, equipment and machinery is most sensitive to exchange-rate variations.

Landon and Smith (2009) examine a variation of the Campa and Goldberg (1999) model that allows for the use of imported capital, whilst also examining revenue factors where output of firms can be sold locally or internationally. Using a long panel of multiple sectors in 17 OECD countries, they estimate a series of wage, capital goods and global income-augmented investment specification, with careful adjustment for the real, local price of both inputs and sales. Their error-correction specification suggests that short-run and long-run impacts of real exchange-rate depreciation for the majority of sectors are negative, although firms in sectors that have a greater likelihood of tradeable outputs are less impacted by cost-channel variations.

Matsubayashi (2011) considers findings of exchange-rate sensitivity from a priced-in- q perspective for Japan. Noting the difficulties in accurately observing marginal q , this paper estimates sector-aggregated marginal q using balance sheet and stock-market data, and includes the results in a similar estimation framework to that of Landon and Smith (2009), albeit estimated as an ordered VAR. The low predictive value of marginal q often found in the literature is replicated here, along with the finding that the cost and revenue channels are important drivers of Japanese private fixed investment, along with estimators of profitability.

This branch of the investment literature began as an investigation into the sensitivity of firm activity to external factors, in line with pricing-to-market theoretical discussions in the open-economy macroeconomic modelling literature. Both aggregate and micro-level empirical estimations suggest that input factor variations, in both the locally- and internationally-priced forms, are important determinants of private investment, along with profitability variables.

2.2.6 Managerial norms

The discussed literature on investment has taken either a theoretical approach derived from optimising frameworks, or an isolated observational approach: asking variously 'what should drive private fixed investment given the implications of production

functions?’ and ‘is there evidence that this factor drives private fixed investment?’. This sub-section discusses the interactive observations of the managerial literature: essentially research into the question ‘How do managers say they make investment decisions?’ From an optimising financial and economic framework, the history of the search for answers to this question is counter to expectations.

The simplest form of managerial estimation is the previous decision, or lagged investment. Bloom et al. (2007) survey 4,000 firms in the U.S., Europe and Asia and find that, when senior managers decide on the investment budget of plant managers, the default is to set it equal to the previous year’s budget. The lower-level managers propose budget augmentations, and the bigger the difference between the plant manager’s proposal and the budget of the previous year, the harder it is to get the revised budget approved.

There are several other key capital budgeting and benchmarking tools frequently examined in the survey literature. The simple payback (SP) criterion is where a project is evaluated based on whether it will pay for itself in a given period, using non-discounted currency. A discounted payback period (DPP) method is identical to the simple method, although it alters the value of currency to current values. An accounting rate of return (ARR) presents the return on investment, in non-discounted currency, as a percentage of its net cost over the project lifetime. The net present value (NPV) of an investment discounts the anticipated costs and returns of an investment over its life time and selects the highest value. The internal rate of return (IRR) is a break-even criterion in which the discounted net present value of an investment is set to zero. It is notable that capital-level optimisation, real-options techniques and firm-level input-output analyses are missing from this list.

An influential survey was carried out by Graham and Harvey (2001), who received surveys from 392 Chief Financial Officers of listed U.S. firms, finding that over 50% of whom used non-discounted (SP, DPP, ARR) methods to aid capital adjustment decisions. Ryan and Ryan (2002) surveyed 205 Fortune 1000 CFOs, finding that payback methods (SP and DPP) are more frequently used than discounted evaluation criteria (NPV or IRR). For Japan, Takahashi et al. (2003) discuss responses from 192 firms, of whom less than 20% ever used discounted criteria, and of whom 15-20% used no formal criterion at all.

The absence of a formal decision mechanism conforms with Hallikainen et al. (2006) who investigated the I.T. project purchasing decisions of approximately 500 Swedish, Danish and Finnish firms. Their results indicate that, although a majority of firms consider the use of formal IT project evaluation procedures to be very important, only a third of projects are formally evaluated at all, and only 10% face a formal evaluation criterion. This finding is given context by the analysis of Brounen et al. (2004), who received responses from 312 manufacturing firms from the Netherlands, the U.K., Germany and France. Their regression analysis of results indicated that smaller firms conduct little formal analysis, whilst larger firms implement discounted criteria, often with CAPM-adjusted discount rates. Returning to Japan, Shinoda (2010) surveyed 225 managers in charge of capital budgeting decisions of Tokyo Stock Exchange-listed firms, finding little use of CAPM-informed discount rates, and a heavy reliance on payback period evaluation methods.

The incoherence of these survey results with the suggestions of the theoretical literature is a consistent theme in the literature, and raises challenges in estimation for empirical and policy analysis. The importance of lagged investment and discount rates may be emphasised, but estimation of anticipated returns to individual investments is challenging - to say nothing of off-the-cuff decision making. The argument by Shapiro (1986), that many strong empirical findings are effectively driven by underlying business cycle variations has great appeal, which demonstrations of the utility of q-theory further support. Whether the demonstrated importance of firms' access to capital (and implicated cash flow) for investment purposes is an artefact of general economic conditions is difficult to determine, as is (for identical reasons) the importance of exchange rates and factor costs. Similarly, the strong theoretical underpinnings of real-options theory suggests that associated uncertainty measures be included in any estimating activity, although the empirical evidence of their extra-cyclical importance is mixed.

The strong divergence between the theoretically- and observationally-derived investment literature streams suggests a theoretically-agnostic investigation.

2.3 Variable Selection and Data

This chapter undertakes a dynamic comparison of investment model constituents with the aim of identifying whether different models of investment may apply at different points in time. The literature discussion identified a series of models previously used in theoretical and empirical analyses; selected component variables that constitute the search population of source variables are discussed here. This section details the source and nature of variables used in the DMA analysis described below, as well as necessary transformations. Tables 2.1 and 2.2 display summary statistics and correlations.

Before discussing the nature of DMA, it may be best to discuss the motivation for introducing this novel technique to a literature already featuring a very broad range of econometric analyses. The challenge to these extant, mostly regression-based, econometric analyses lies in two phenomena potentially associated with aggregate investment - time variation in variable coefficients, and time variation in model specifications. DMA is a forecasting tool designed to be flexible to models that change over time as model constituent coefficients change.

The model sets under evaluation are, in broad terms:

A q-model for investment as per Section 2.2.2, where

$$I_t/K_t = f(\text{MarketValueofFirmAssets}/\text{BookValue}, \text{CostofCapital}, I_{t-1}/K_{t-1}) ,$$

noting that theory does not dictate a specific function form for a q equation and the Eberly et al. (2012) demonstration of a theoretically-sound motivation for the inclusion of lagged investment.

A capital availability model of investment as per Section 2.2.3, where

$$I_t = f(\text{DesiredInvestment}, \text{AccesstoCapital}) ,$$

noting that the literature places heavy emphasis on the role of cash flow in decreasing the impact of differing internal and external capital costs.

A real options model of investment as per Section 2.2.4, where departures from investment trends are some function of uncertainty innovations.

A factor cost model of investment as per Section 2.2.5, where

$$I_t = f(\text{Demand}, \text{TradeableInputs}, \text{NonTradeableInputs}, \text{RealExchangeRates}).$$

The manager-heuristic results of the survey literature in Section 2.2.6 most strongly

conform to either a lagged-investment (Bloom 2009) or general equilibrium (Shapiro 1986) specification, which should be captured by the above variable sets.

A decision must be made as to whether to analyse investment as a stand-alone variable, or as in the form of the investment-capital ratio. The literature is divided on the issue, with a majority of q-theory investigations using the theory-informed ratio, whereas much corporate finance, real options and managerial survey literature focuses solely upon the independent investment amount. The choices exemplified by this division are rarely explicitly discussed, with a functional form typically presented as appropriate for the situation under analysis. To further confuse the issue, a variety of lagged forms are specified in the literature (i.e. I_t/K_t , I_t/K_{t-1} , I_t/K_{t-2}) and the precise timing of lags is uncertain. Following much of the recent financing of investment literature (including Lyandres (2007), Hennessy, Levy and Whited (2007), Hackbarth (2009) and Denis and Sibilikov (2010)) this chapter considers the non-ratio, dependent investment variable. This dependent variable has the benefit of being well-established in finance and corporate finance literature, possibly due to the low degree of built-in structural theory as compared with estimations of I_t/K_t , or I_t/K_{t-1} , which both imply a constancy of investment-capital relationship.

Data for this dependent variable of investment is chosen to minimise sectoral variations (as discussed in Section 2.5) whilst maximising power and availability. Japan's Ministry of Finance's, 'Financial Statements Statistics of Corporations by Industry, Quarterly' release provides detailed balance sheet information on domestic companies. Investment data is 'Investment by manufacturing firms in plant and equipment, excluding software', seasonally adjusted with the X12 ARIMA method, and analysed on log first differences, with a constant added to force positivity. The constant differs between variables whilst remaining fixed within - an addition required for logarithmic transformation. This alteration method represents the chapter's standard transformation concept applied to all variables: remove seasonality, transform log-form, ensure stationarity (all where appropriate). Per-variable details are available in Table 2.1.

There are two key implications of evaluating only investment by manufacturing firms in plant and equipment. Firstly, property is not included - a choice motivated by both Japan's experience of a property value boom in the 1980s, and the incidentally-productive nature of property which fits poorly into the five model archetypes de-

scribed above. Secondly, the exclusion of service-sector firms implies this analysis may not be fully generalisable across the economy, but ensures that sector-derived variations are minimised - a point made in Section 2.5 and evaluated in further detail in Chapter 4.

Substantial portions of the investment literature have been devoted to analysing Tobin's Q , in particular the difference between marginal and average q . Given the difficulty in statistically accessing firms' marginal q , even at the aggregate level, this chapter follows much of the literature in using average q in estimations, a decision partially indicated by the analyses of Hayashi (1982) and Caballero (1999) discussed in Section 2. Average q is here instrumented as 'Net assets of all manufacturing firms' as the book value of firm assets (from the same source as investment data) as the divisor of the Nikkei 255 Index (from Thomson-Reuters Datastream), representing an estimate of the market value of firm assets.

The literature on the importance of financing investment suggests that cash flow acts as a vital buffer to firms' investment capacities should external capital be costly. One implication of this Modigliani-Miller breakdown is that the impact of cash from operating activities and cash from financing activities may be important jointly (in that they represent internal capital availability) and separately (in that cash from financing may be indicative of changes to external capital availability). Using the same Ministry of Finance source as above, cash flow from operating activities is constructed as being 'Operating Profits' with subtracted changes to 'Accounts Receivable' and 'Inventories', with added 'Accounts Payable' and 'Net Interest Received'. Cash flow from financing activities is constructed as being the change in 'Short Term Borrowings', 'Long Term Borrowings' and 'Value of Bonds Issued'. All definitions as per source.

Uncertainty is constructed in a similar fashion to Bachmann et al. (2013), in that a dispersion indicator of forecaster beliefs is calculated from the Bank of Japan's 'Tankan' index of firm sentiment. Each forecaster is sampled as to their opinions of business conditions in 6 months time, and are able to indicate improvement, stasis or decline. This chapter uses as an uncertainty indicator the cross-sectional standard deviation of forecasters who indicate improvement and decline.

To capture external sensitivities, as per Landon and Smith (2009), the demand indicator of Japan's GDP, a tradeable capital input indicator in the WTI Spot price

of oil to 2010, thereafter WTI Cushing and the nominal Yen/USD exchange rate are all included in the DMA estimation, and sourced from the FRED economic statistics database. Further, the real interest rate (as per the Bank of Japan's 'Basic rate' net of the long-running PPI) and the non-tradeable factor input estimator 'Wages expense' from the MOF data source are included.

This data constitutes the starting-point for the DMA investigation of investment, modelled as:

$$I_t = f(I_{t-1}, I_{t-2}, Q_t, Y_t, U_t, O_t, X_t, W_t, RI_t, COps_t, CFin_t) \quad (2.1)$$

i.e. fixed investment by Japanese manufacturing firms is some time-varying function of at least one of the variables: lagged investment, average aggregate Tobin's Q , Japanese GDP, uncertainty, oil spot, yen/USD spot, manufacturing wages, the real interest rate, cash received from operating activities and cash received from financing activities. All data cover the period Q2:1965-Q1:2014 inclusive, with the exception of the Tankan-based uncertainty indicator which is available from Q3:1974. 2 lags of investment are selected as indicated by AIC. AIC was chosen as a selection criterion over alternatives given the high computational requirements for high lag dimensions. This suggests that a potential false negative should be penalised more strongly than a potential false positive, and consequently suggests the use of AIC, as outlined by Dziak et al.(2012).

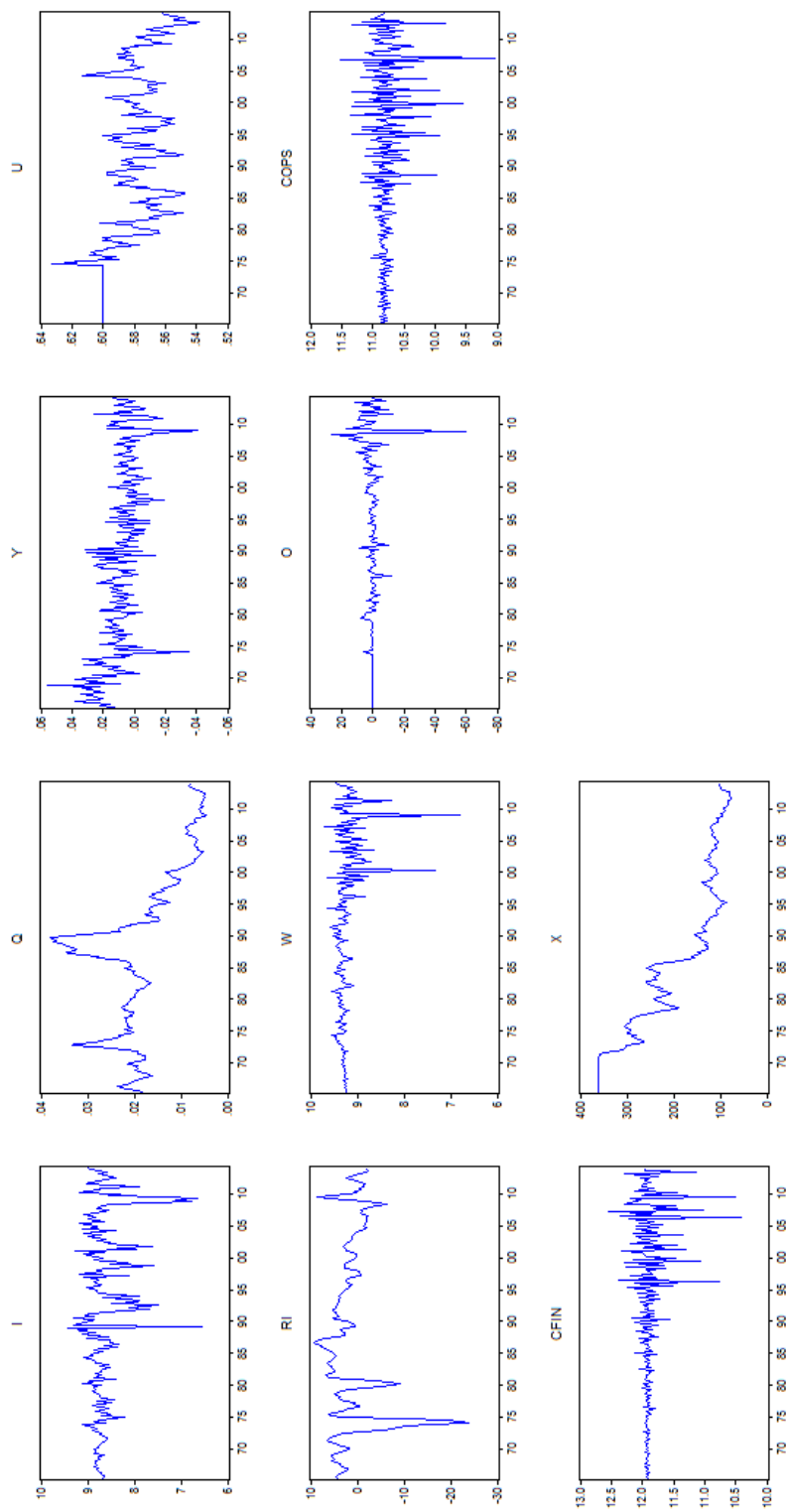


Figure 2.1: Time series of key variables (Manufacturing firm investment, aggregate Tobin's average Q , Tankan forecaster disagreement, Japanese GDP, WTI Oil spot price, the real interest rate, firms' wages expense, yen/USD spot, cash received from financing and operating activities respectively), quarterly Q4:1965-Q1:2014. Adjustments made as per the information in Table 2.1

	Mean	Maximum	Minimum	Std.Dev	Adjustment	Obs
I	8.654	9.436	6.537	0.421	3,C,A	196
Q	0.016	0.037	0.004	0.008	1,S	196
U	0.581	0.633	0.538	0.017	1	196
Y	0.008	0.055	-0.041	0.012	1	196
O	0.488	26.01	-59.613	6.203	1	196
RI	1.642	9.066	-23.833	4.673	1	196
W	9.243	9.705	6.801	0.294	3,S	196
X	188.624	360	77.34	94.443	1	196
CFIN	11.89	12.532	10.407	0.257	3,C,A	196
COPS	10.787	11.527	9.033	0.298	3,C,A	196

Table 2.1: Summary statistics of key variables (Manufacturing firm investment, aggregate Tobin's average Q, Tankan forecaster disagreement, Japanese GDP, WTI Oil spot price, the real interest rate, firms' wages expense, yen/USD spot, cash received from financing and operating activities respectively), quarterly Q4:1965-Q1:2014. Adjustment codes are: 1) No change, 2) First difference 3) First difference of natural logarithms, C) Constant added to force non-negative values, S) Seasonal adjustment by author with X12 ARIMA mutiplicative, A) Seasonal adjustment by author with X12 ARIMA additive

	I	Q	U	Y	O	RI	W	X	CFIN	COPS
I	1									
Q	0.214	1								
U	0.169	0.352	1							
Y	0.399	0.392	0.263	1						
O	0.204	-0.038	-0.003	0.116	1					
RI	-0.145	0.123	-0.193	0.246	-0.068	1				
W	0.348	0.348	0.089	0.342	0.184	-0.011	1			
X	0.163	0.466	0.552	0.489	-0.040	0.067	0.197	1		
CFIN	0.063	0.082	0.07	0.047	-0.184	-0.028	0.138	0.090	1	
COPS	-0.001	0.071	-0.005	0.082	0.047	0.048	0.079	0.087	-0.295	1

Table 2.2: Correlation table of key variables, quarterly Q4:1965-Q1:2014.

2.4 Econometric Model

Time-varying parameter methods are widely used in empirical economic analysis, see for instance Primiceri (2005), Cogley and Sargent (2005), Koop, Leon-Gonzalez and Strachan (2011), Korobilis (2013) and Gerber and Hauzenberger (2013). In the conext of Japan these methods have been specifically applied to monetary policy by Nakajima et.al (2011) and to private fixed investment dynamics in this thesis. TVP methods are typically specified for $t = 1, \dots, T$ as with the state-space representation:

$$y_t = x_{t-1}\beta_t + u_t \quad (2.2)$$

$$\beta_t = \beta_{t-1} + \epsilon_t \quad (2.3)$$

where y_t is the dependent variable (investment), x_t is some $1 \times m$ vector of predictors, including intercepts and lag terms, β_t is a $m \times 1$ vector of coefficients, $u_t \sim N(0, H_t)$ and $\epsilon_t \sim N(0, Q_t)$ are the variance and covariance matrices of the measurement and state equations respectively, assumed to be mutually independent across time.

In any model averaging exercise the vector x_t is not concretely specified at the outset, but rather a result of the estimation method. In a dynamic setting, this is extended to allow the selected set of predictors x_t to vary over time. These sets of predictors - linear combinations of explanatory variables - may be thought of as varying models, represented here by the index $\{m = 1, \dots, M\}$. The associated state-space representation is:

$$y_t = x_{t-1}^{(m)} \beta_t^{(m)} + u_t^{(m)} \quad (2.4)$$

$$\beta_t^{(m)} = \beta_{t-1}^{(m)} + \epsilon_t^{(m)} \quad (2.5)$$

From relatively standard state-space models of this type, given knowledge of H_t , Q_t and for some set model $M_t = m$, time-varying parameters can be extracted by Kalman-type recursions:

$$\hat{\beta}_{t|t-1}^{(m)} = \hat{\beta}_{t-1|t-1}^{(m)} \quad (2.6)$$

$$P_{t|t-1}^{(m)} = P_{t-1|t-1}^{(m)} + Q_t^{(m)} \quad (2.7)$$

$$\hat{y}_{t|t-1}^{(m)} = x_{t-1}^{(m)} \hat{\beta}_{t|t-1}^{(m)} \quad (2.8)$$

$$\hat{u}_t^{(m)} = (y_t - \hat{y}_{t|t-1}^{(m)}) \quad (2.9)$$

$$F_t^{(m)} = x_{t-1}^{(m)} P_{t|t-1}^{(m)} x_{t-1}^{T(m)} + H_t^{(m)} \quad (2.10)$$

$$G_t^{(m)} = P_{t|t-1}^{(m)} x_{t-1}^{(m)} / F_t^{(m)} \quad (2.11)$$

$$\hat{\beta}_{t|t}^{(m)} = \hat{\beta}_{t|t-1}^{(m)} + G_t^{(m)} (y_t - \hat{y}_t^{(m)}) \quad (2.12)$$

$$P_{t|t}^{(m)} = P_{t-1|t-1}^{(m)} - G_t^{(m)} x_{t-1}^{(m)} P_{t-1|t-1}^{(m)} \quad (2.13)$$

where $\hat{\beta}_{t|t-1}^{(m)} = E_{t-1}(\beta_t^{(m)})$, $P_{t|t-1}^{(m)}$ is the MSE $\hat{\beta}_{t|t-1}^{(m)}$, and $E_{t-1}(\cdot)$ is the expectation from information set L_{t-1} . $\hat{y}_{t|t-1}^{(m)}$ is the forecast dependent variable estimate using model m and information set L_{t-1} . The state-space form of the Kalman Filter algorithm, as set out above for some model m , can be fully informed by time-series data with the exception of the variance/covariance matrices H_t and Q_t . As per the discussion in Koop and Korobilis (2012) the estimation of Q_t can be simplified by a ‘forgetting factor’ specification:

$$P_{t|t-1}^{(m)} = \frac{1}{\lambda} P_{t-1|t-1}^{(m)} \quad (2.14)$$

for $0 < \lambda \leq 1$. This approach minimises computing overhead in an intuitive fashion: tomorrow’s data partially determines today’s data, at a decreasing rate. The ‘forgetting factor’ λ weighs past observations by decaying their impact on current observations. A λ value close to 1 would indicate coefficients in the distant past retained similar predictive power to last periods’. A λ value of 0.95 would weigh 5 year old observations at 35% of last periods’, whilst a λ value of 0.9 would weigh a 5 year old observation at 13%. Selecting a lambda parameter of 0.8 results in year-old observations receiving 50% of the last period’s weighting. In comparison, a lambda parameter of 0.99 weighs a 4-quarter old observation by 93%, as are depicted in Table 2.3.

The selection of this factor represents a choice for the investigator insofar that it represents an assumption on lag structure in how firms make investment decisions. For instance, how quickly is bad news replaced with good, or good with bad? This is both a theoretical and empirical question, and a full investigation is beyond the scope

of this chapter. Koop and Korobilis (2012), in their comparison of forecasting models US inflation, test a range of values and note the variance in predictive power for each. They finally set a λ value of 0.99, which in the Japanese investment context would suggest long decays, where data 20 years old still factors into purchasing decisions - as is perhaps appropriate for systems with minimal trend-reversion. This chapter compares results at λ values 0.9, 0.95 and 0.99 and notes the evident variations between these estimations. Table 2.3 demonstrates the rates of decay associated with various λ values, and the value at each point in time should be interpreted as the weighting applied to past data. Evidently, a lower λ value creates a higher rate of decay, and weights more historically-distant data at a lower weight than more recent data. These weightings have substantial impact on the final estimations in consequence.

Lacking a fully-researched framework, comparison with the literature appears a sensible means of progression. The Koop and Korobilis (2012) λ value of 0.99 was selected to optimise the forecasting of US inflation. But in the Koop and Korobilis (2012) estimates, a λ value of 0.95 demonstrate decreased mean squared forecasting errors in comparison with that of 0.99 for the GDP deflator over 4 quarters. From the perspective of a substantially different stream of investment-linked literature, Bloom (2009) implements uncertainty and volatility shocks on US prices and output in a VAR framework, and finds the impacts of these shocks appears largely decayed after 5 years and, although the duration is sensitive to adjustment cost specifications and shock magnitude, are relatively consistent with the 35% weighting of 5 year-old data the λ value of 0.95 implies. Consequently, this chapter presents estimations run using a λ value of 0.95 in the results section.

The second simplifying assumption concerns the time-varying error variance term H_t . This chapter examines private fixed investment in Japan over a relatively long time-series, which includes periods of rapidly re-industrialising economic growth, an accelerating 'bubble' period, and a long low-growth phase. It is therefore inappropriate to follow Raftery et al. (2010) and much of the engineering state-space literature in specifying a constant H : the error variance of private fixed investment in Japan is plainly not constant over time. An exponentially weighted moving average estimate (or integrated GARCH (1,1) model, with a fixed intercept at 0) may more appropriately model investment volatility in Japan:

$$H_t^{(m)} = \kappa H_{t-1}^{(m)} + (1 - \kappa) u_{t-1}^{2(m)} \quad (2.15)$$

where the decay term $\kappa = 0.98$ is set as is appropriate for quarterly data (Riskmetrics 1996).

Model selection and averaging (DMS/DMA) is carried out by weighting forecasts with their respective model probabilities; how well any given set of variables (or model) predicts the outcome of investment at the target time is directly linked to the weight associated with that model in the optimal forecasting setup. Consider $\pi_{t|t-1}^{(m)}$ to be the probability of model m given information to $t - 1$ as:

$$\pi_{t|t-1}^{(m)} = \Pr(M_t = m | L_{t-1}) \quad (2.16)$$

DMS proceeds by selecting the model with the highest predictive probability (i.e. $\pi_{t|t-1}^{(m)}$). DMA uses the probabilities as model weights to compute the average of m forecasts. Recursive forecast calculations of y_t using information sets $E(y_t | L_{t-1})$ are a weighted average of the forecasts from all possible models, with the averaging weights being the predictive probabilities:

$$\hat{y}_{t|t-1}^{(DMA)} = \sum_{m=1}^M \hat{y}_{t|t-1}^{(m)} \pi_{t|t-1}^{(m)} \quad (2.17)$$

These DMS/DMA forecasts require model predicting and updating recursions. Let $p_{jm} = \Pr(M_t = m | M_{t-1} = j)$ indicate the probability of moving from model j at time $t - 1$ to model m at time t , and let $f_N^{(m)}(y_t | L_{t-1})$ represent the Normal predictive density of y_t , with mean and variance $\hat{y}_{t|t-1}^{(m)}$ and $F_t^{(m)}$. For some initiating prior $\pi_{0|0}^{(m)}$, the model prediction and updating equations are:

$$\pi_{t|t-1}^{(m)} = \sum_{j=1}^M \pi_{t-1|t-1}^{(j)} p_{jm} \quad (2.18)$$

$$\pi_{t|t}^{(m)} = \frac{\pi_{t|t-1}^{(m)} f_N^{(m)}(y_t | L_{t-1})}{\sum_{j=1}^M \pi_{t|t-1}^{(j)} f_N^{(j)}(y_t | L_{t-1})} \quad (2.19)$$

The prediction equation requires the probability p_{jm} , which implies comparison of $M = 2^m$ models. For large variable spaces the probability transition matrix becomes

computationally challenging, and Raftery et al. (2010) replace the prediction equation with the forgetting-factor specification:

$$\pi_{t|t-1}^{(m)} = \frac{\pi_{t-1|t-1}^{\alpha(m)}}{\sum_{j=1}^M \pi_{t-1|t-1}^{\alpha(j)}} \quad (2.20)$$

for $0 < \alpha \leq 1$. As with forgetting factor λ , the α parameter weighs historical model transitions by decaying their impact on current observations, and, similarly to the λ value decision, represents an important choice for the empiricist. But where the λ value question implied an assumption on the usefulness of old observations compared with new (and consequently the nature and magnitude of shocks), the α parameter refers to the rate at which the implicit or explicit modelling frameworks of investment decision-makers are discarded and updated. Sensitivity analyses indicate the results are substantially sensitive to these choices. There is an interesting ontological question embedded in this sensitivity: to what degree are means of interpretation of information similar or dissimilar to the information itself? The α parameter essentially reflects the means of interpretation, in that it embodies the weight applied to an optimal model for forecasting at an earlier point in time. Assigning the α parameter to a value of 1 would imply that decision-makers in Q2:2009 would place the same value on a set of variables that successfully forecast investment in Q1:1981 as they would place on the set of variables that successfully forecast investment in the previous period, Q1:2009. This may be unreasonable, particularly if there is a human tendency to forget distant learnings at a greater rate than recent learnings.

Without a reliable theory of informational-model decay rates, there may be some justification in the treatment of information about information in an identical manner to the information itself. In treating meta-information and information alike, this chapter follows the Koop and Korobilis (2012) in setting the α parameter identically to the λ parameter, to 0.95. Evaluation of the meanings and impacts of these variables may be an interesting area for future research, with particular potential for cross-disciplinary literature on decision theory, learning and behavioural psychology in general to inform the parameter values.

Prior values of the state variable are initiated at a mean of 0 and variance of 100 as in Raftery et al. (2010).

Alpha / Lambda	0.99	0.97	0.95	0.92	0.9	0.85	0.8
Quarters							
1	1	1	1	1	1	1	1
2	99.0%	97.0%	95.0%	92.0%	90.0%	85.0%	80.0%
3	98.0%	94.1%	90.3%	84.6%	81.0%	72.3%	64.0%
4	97.0%	91.3%	85.7%	77.9%	72.9%	61.4%	51.2%
5	96.1%	88.5%	81.5%	71.6%	65.6%	52.2%	41.0%
6	95.1%	85.9%	77.4%	65.9%	59.0%	44.4%	32.8%
7	94.1%	83.3%	73.5%	60.6%	53.1%	37.7%	26.2%
8	93.2%	80.8%	69.8%	55.8%	47.8%	32.1%	21.0%
9	92.3%	78.4%	66.3%	51.3%	43.0%	27.2%	16.8%
10	91.4%	76.0%	63.0%	47.2%	38.7%	23.2%	13.4%
11	90.4%	73.7%	59.9%	43.4%	34.9%	19.7%	10.7%
12	89.5%	71.5%	56.9%	40.0%	31.4%	16.7%	8.6%
13	88.6%	69.4%	54.0%	36.8%	28.2%	14.2%	6.9%
14	87.8%	67.3%	51.3%	33.8%	25.4%	12.1%	5.5%
15	86.9%	65.3%	48.8%	31.1%	22.9%	10.3%	4.4%
16	86.0%	63.3%	46.3%	28.6%	20.6%	8.7%	3.5%
17	85.1%	61.4%	44.0%	26.3%	18.5%	7.4%	2.8%
18	84.3%	59.6%	41.8%	24.2%	16.7%	6.3%	2.3%
19	83.5%	57.8%	39.7%	22.3%	15.0%	5.4%	1.8%
20	82.6%	56.1%	37.7%	20.5%	13.5%	4.6%	1.4%
21	81.8%	54.4%	35.8%	18.9%	12.2%	3.9%	1.2%
22	81.0%	52.7%	34.1%	17.4%	10.9%	3.3%	0.9%
23	80.2%	51.2%	32.4%	16.0%	9.8%	2.8%	0.7%
24	79.4%	49.6%	30.7%	14.7%	8.9%	2.4%	0.6%
25	78.6%	48.1%	29.2%	13.5%	8.0%	2.0%	0.5%

Table 2.3: Observation weighting decay table for alpha / lambda parameters. Selecting a lambda parameter of 0.8 results in year-old observations receiving 50% of the last period's weighting. In comparison, a lambda parameter of 0.99 weights a 4-quarter old observation by 93%. Alpha parameters' decay weights model transitions.

The final decision required of the DMA-using analyst is the period of forward prediction desired. As models are selected on the basis of their ability to predict dependent variable future values, the point in the future at which the variables should be judged is highly important: it is quite possible to envisage a variable set that has embodied a high degree of future information over short-term variations but a low degree of future information over long-term variations; short-term market liquidity in comparison with long-term productivity trends in evaluating financial markets is perhaps an intuitive example. But this is an over-simplification given the α and λ forgetting factors discussed above; when models are slow to change and old data remains relevant the distinctions between short-term, business-cycle and productivity-scale forecasting sets becomes blurred and unclear, particularly when cointegrating

relationships and general equilibrium factors may be in play. This chapter arbitrarily selects 4 quarters ahead as a prediction horizon, but notes the potential research value in clarifying this question.

2.5 Results

This chapter conducts a Dynamic Model Averaging exercise to simultaneously compare and evaluate models for aggregate investment by manufacturing firms in Japan: do different models for investment apply at different points in time? Consequently, the key result of interest from the DMA exercise is the probability that an independent variable will be used in the optimal prediction model for the dependent variable at any point in time. The entire scope of the search variables for the DMA investigation of investment is:

$$I_t = f(c, I_{t-1}, I_{t-2}, Q_t, Y_t, U_t, O_t, X_t, W_t, RI_t, COp_{st}, CFin_t) \quad (2.21)$$

i.e. fixed investment by Japanese manufacturing firms is some time-varying function of at least one of the variables: a constant, lagged investment, average aggregate Tobin's Q , Japanese GDP, uncertainty, oil spot, yen/USD spot, manufacturing wages, the real interest rate, cash received from operating activities and cash received from financing activities.

There are 12 estimated potential predictor variables, leading to a very large number of potential model sets for predicting investment variation at every point in time. Displaying the posterior inclusion probabilities of each of these on a single graph is a challenge, made somewhat easier by the consistent utility of the constant and both lagged investment terms. These three variables are estimated with a probability coefficient stable and close to '1'. This is regardless of the forgetting factor specification selected, and is consistent with the literature on the subject, notably Bloom (2009) and Eberly et al. (2012). The line plots of the constant and both lagged investment posterior inclusion probabilities displays no variation over time, and so overlap and not displayed in the Figure 2.2 plot of quarterly, averaged variable posterior inclusion probabilities, 1965-2014. As discussed in Section 4, this is a 4 quarter-ahead analysis, with α and λ forgetting factors set to the implied medium-term value of 0.95.

The interpretation of these graphs is made challenging by the absence of an equivalent to the confidence-interval boundaries frequently drawn with, for instance, VAR models. As a result, the interpreting analyst must ‘eyeball’ the posterior inclusion probabilities of individual variables without a familiar surety heuristic. The key issue to focus on is that these inclusion probabilities represent the likelihood of a variable being used in the averaged optimal prediction model for investment at any point in time. Thus the plotting of 0.5 probability for Tobin’s average Q in Q1:1986 is consistent with a 50% likelihood that the optimal prediction model for Japanese private fixed investment included Tobin’s average Q at Q1:1986 (noting the assumptions regarding the information decay and model averaging decay factors λ and α respectively). Variables that display substantial posterior inclusion probability volatility should be interpreted as frequently entering and leaving optimal predication models, conversely variables exhibiting stable probability paths have consistent inclusion likelihoods.

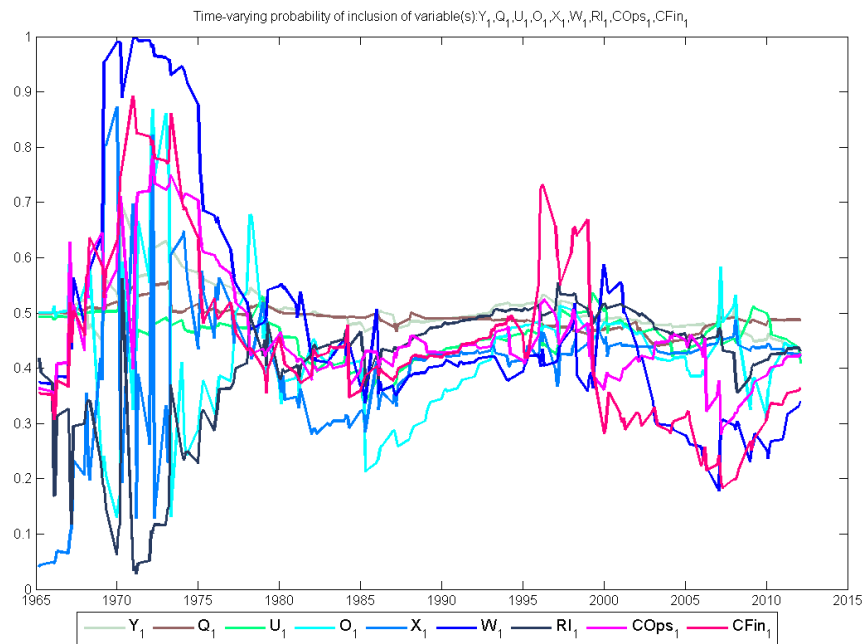


Figure 2.2: Plot of probability of variable inclusion in DMA-optimal prediction model for Japanese manufacturing firm investment, Q4:1965-Q1:2014. Predictions are 4 quarters ahead, with α and λ of 0.95. Variables in legend correspond to: Y~GDP, Q~Tobin’s Average Q, U~Uncertainty, O~WTI Oil Spot, X~Nominal exchange rate, W~Wage expenditure, RI~Real interest rate, COps~Cash from operations, CFin~Cash from financing. Not shown: a constant term and the first and second lags of investment: their constant probability of 1 indicates consistent use in all optimal models.

The y-axis on Figure 2.2 is the probability from 0 to 1 of a variable (denoted in the

legend) being included in the optimal forecasting model at a point in time depicted on the y-axis, noting that these models are averaged and decayed as per the DMA and α specifications in Section 4. The first observation from this plot is the difficulty in distinguishing individual lines. The second is the high degree of variation associated with the 1965-1980 period in comparison with the post-1980 period. This is potentially symptomatic of the Kalman filter algorithm ‘burning-in’, and so Figure 2.3 depicts only the 1980-2014 period, noting that as this is a 1 year in advance prediction exercise, the data drawn for Q1:1980 will be based on models averaged and decayed to Q1:1979, and consequently the last period drawn is for Q1:2013 as there is no observed data beyond Q1:2014.

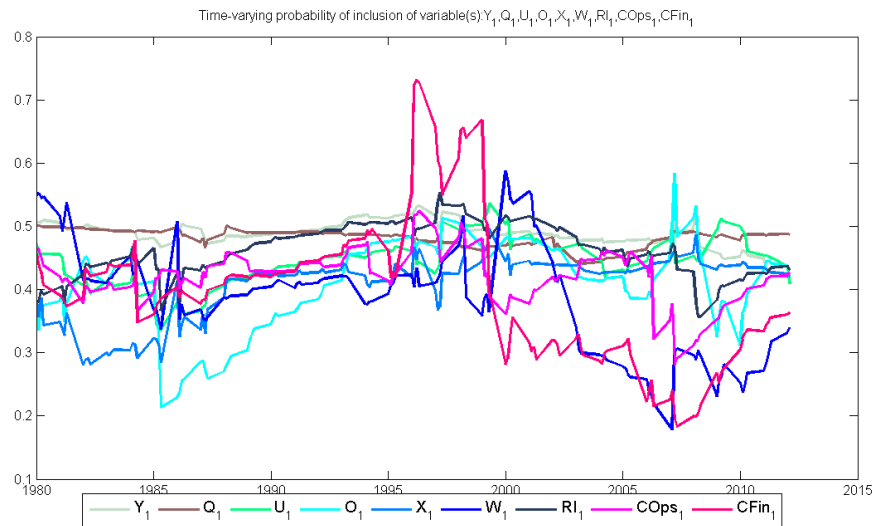


Figure 2.3: Plot of probability of variable inclusion in DMA-optimal prediction model for Japanese manufacturing firm investment, Q1:1980-Q1:2014. Predictions are 4 quarters ahead, with α and λ of 0.95. Variables in legend correspond to: Y~GDP, Q~Tobin's Average Q, U~Uncertainty, O~WTI Oil Spot, X~Nominal exchange rate, W~Wage expenditure, RI~Real interest rate, COps~Cash from operations, CFin~Cash from financing. Not shown: a constant term and the first and second lags of investment: their constant probability of 1 indicates consistent use in all optimal models.

Figure 2.3 demonstrates several points of relevance to the investigation aim, primarily that there is some evidence that investment model components become more or less useful predictors of behaviour at different points in time. Noting the y-axis has been compressed to 0.1-0.8 to zoom-in and examine variation, consider the 0.5 y-axis threshold which represents a 50% probability that the variable will be used in the optimal, averaged forecasting model. A number of variables appear to cross this threshold in different directions, notably the input factors of oil prices and wages ex-

pense. Moreover, these movements can be quite sudden and large - consistent with the consideration of model variation. Cash from financing appears to be a very strong predictor during the late 1990s, a period associated with 'credit crunch' conditions during a financial crisis (see Kashara et al. (2014)). Other variables, notably average q and the demand-instrument GDP, are both close to 0.5 and display little variation over time, indicating the models with these components may be consistently useful predictors. The diagram is very busy, and as a result unclear, but there does appear to be evidence in support of this chapter's original question: that different models of aggregate investment apply at different points in time.

This point is more starkly made in Figure 2.4. This displays the sum of the probabilities of all variables displayed in Figure 2.3, recalling that there were 12 potential variables of which 3 (a constant, and two lagged investment terms) had a sum probability of 3. The plot displays substantial time-variation in the expected number of predictors in a forecasting exercise, appearing to peak during the financial crisis of the late 1990s, and troughing during the high-growth mid 1980s and late 2000s. With approximately 1.3 extra predictors entering an optimal forecasting exercise between peak and trough, there is substantial evidence of time-variation in investment model constitution. That the preferred investment prediction models also exhibits strong, multiple-year trends is also interesting. Figure 2.4 can be interpreted as demonstrating that 3 and 5 independent variables enter and leave the optimal forecasting exercise for 1 year ahead across the 1980-2014 period.

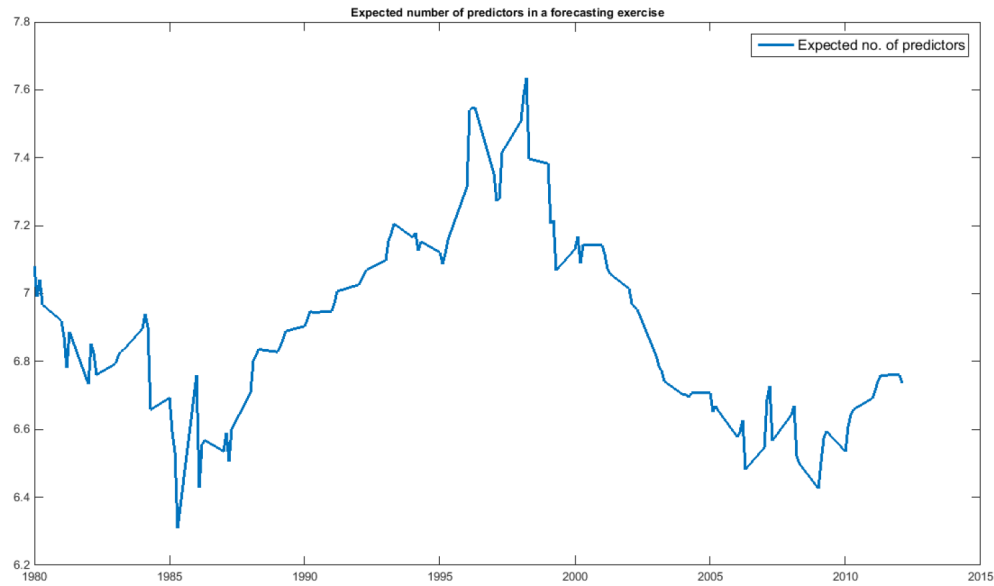


Figure 2.4: Plotted summed probabilities of all variables in the DMA-optimal prediction model for Japanese manufacturing firm investment, Q1:1980-Q1:2014. Prediction are 4 quarters ahead, with α and λ of 0.95. The constant term and the first and second lags of investment have constant values of 1, indicating consistent use in all optimal models.

To clarify the question of time-variation in investment models, the following charts plot separate sets of variables. Figure 2.5 below displays the probabilities of using average aggregate q and the Tankan-based uncertainty measure. The utility of q is close to 0.5 and constant, indicating there is a 50% probability that the optimal averaged forecasting model at any point in time will contain the current or historical (see forgetting factors) value of q . The uncertainty plot indicates much more variation in the utility of forecaster disagreement as a predictor of manufacturing investment. While the plot is below the 0.5 line throughout the bubble and crash period of 1985-1995, it rises to above 0.5 during the domestic Japanese financial crisis period of the late 1990s and the global financial crisis period of the late 2000s. But given the value is close to 0.5 from the mid-1990s to 2010, and there is no facility for calculating standard error-equivalent spreads, the possibility that the predictive value uncertainty is linear in time (as per real options theory) should not be discounted.

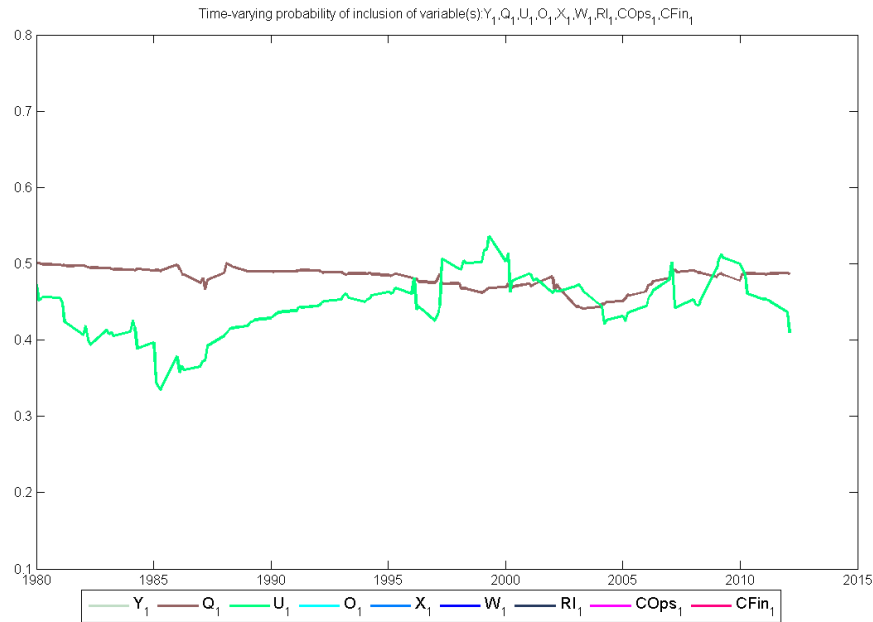


Figure 2.5: Plot of probability of variable inclusion in DMA-optimal prediction model for Japanese manufacturing firm investment, Q1:1980-Q1:2014. Predictions are 4 quarters ahead, with α and λ of 0.95. Variables in legend correspond to: Y_1 ~GDP, Q_1 ~Tobin's Average Q. Not shown: a constant term and the first and second lags of investment.

Figure 2.6 displays the plots for the input and demand factor variables. As with q , Japanese GDP displays little time-variation and is consistently close to 0.5. This raises questions about the degree to which the aggregate q instrument is simply capturing business-cycle variations: Table 2.2 indicates a 0.39 q -GDP correlation. Greater variation is visible in the real interest rate probability plot, which peaks at over 0.5 in the late 1990s and troughs at the beginning and end of sample periods at below 0.4. This hump-shaped variation is reminiscent of the expected number of probabilities plot in Figure 2.4, and raises questions about general equilibrium effects and cyclical-ity. The input factor instrument inclusion probability plots of oil and wages display substantially greater volatility still. The WTI oil spot price appears a useful predictor in the global crisis period of 2007-2009, possibly indicating increased sensitivity of manufacturing investment to international factors during this time, a point worthy of further investigation in consideration of the contagion literature. The Japanese domestic macro-economic growth periods of the early to mid-1980s and the early 2000s are the points at which wages expense are at their maximum investment-predictive potential, further indicating a separation between periods of internal and external sen-

sitivity. In comparison, the nominal yen/USD exchange rate inclusion probability plot displays lesser volatility than the factor inputs and without crossing the 0.5 threshold, suggesting the exchange rate's transmission and moderating role may make it a poor investment predictor.

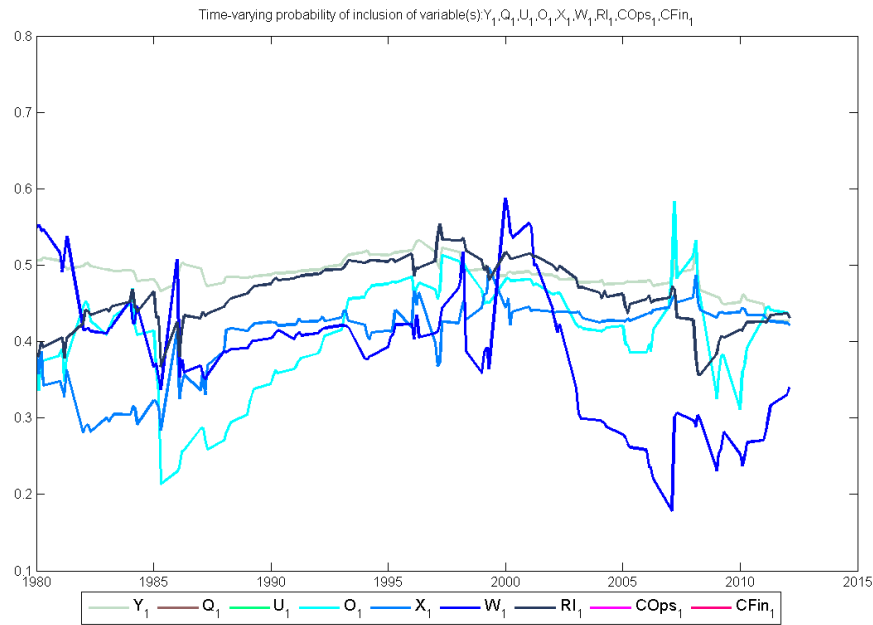


Figure 2.6: Plot of probability of variable inclusion in DMA-optimal prediction model for Japanese manufacturing firm investment, Q1:1980-Q1:2014. Predictions are 4 quarters ahead, with α and λ of 0.95. Variables in legend correspond to: O~WTI Oil Spot, X~Nominal exchange rate, W~Wage expenditure, RI~Real interest rate.

Finally, the comparison in Figure 2.7 of the probability of including cash received from operating and financing activities by Japanese manufacturing companies in a the preferred prediction model. The plots are interesting in that they confirm several important themes in the access to capital literature, notably the Modigliani-Miller theory of the irrelevance of internal and external capital to firm value. discussions by Amiti and Weinstein (2013) and Kasahara et al. (2014) of the importance of the late 1990s credit-crunch in constraining Japanese private fixed investment. Cash from operating and financing activities have very similar probability inclusion plots until the advent of the financial crisis in late 1990s Japan, whereupon the predictive power of cash receipts from financing activities increases dramatically to the highest non-lag inclusion probability of the investigation. This suggests the sudden fall in cash from financing activities during this period coincided with large falls in investment, and is consistent with the narrative that firms who were able to access cash from financing

activities were less constrained in investing activities. Cash from operating activities is a more consistent predictor than financing throughout this period, consistent with the suggestion that internal capital is more reliable and less costly than external.

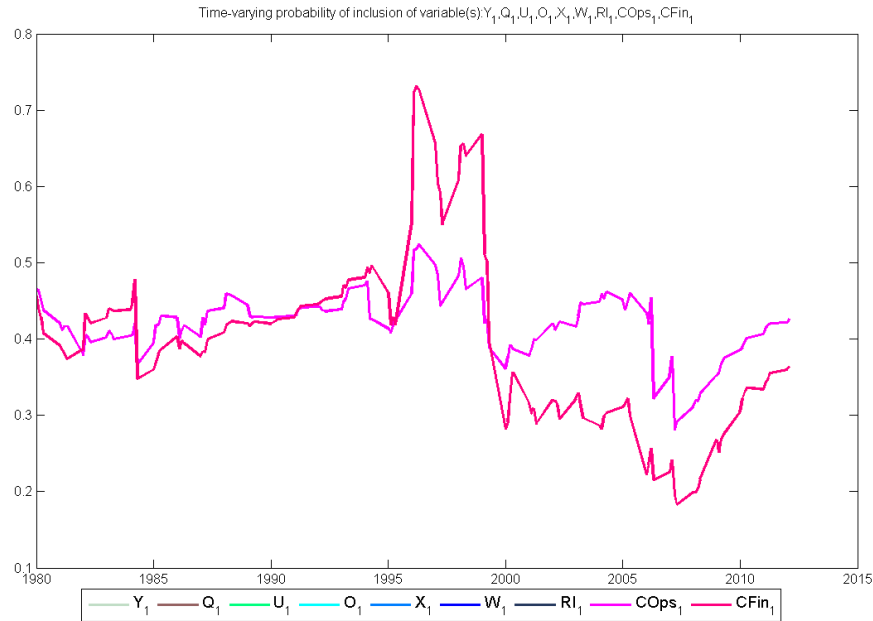


Figure 2.7: Plot of probability of variable inclusion in DMA-optimal prediction model for Japanese manufacturing firm investment, Q1:1980-Q1:2014. Predictions are 4 quarters ahead, with α and λ of 0.95. Variables in legend correspond to: COps~Cash from operations, CFin~Cash from financing.

The results from the DMA exercise indicate substantial variation in the optimal, averaged, prediction model for Japanese fixed investment across the period 1980-2014. Lagged investment is consistently a necessary component of any forecasting model for investment, as is a constant term. Tobin's q , uncertainty, GDP and (to a lesser degree) the real interest rate are relatively consistent in the period, used in optimal forecasting models with approximately 50% likelihood. Much more time-variation appears in the tradeable and non-tradeable factors of production oil and labour, which appear to be respectively linked with period of internally- and externally-driven growth. The predictive utilities of cash from operating and financing activities are very similar until the Japanese financial crisis period of the late 1990s, during which financing cash becomes a very useful predictor of investment, and after which becomes a very poor predictor.

These results indicate support for this chapter's thesis that different models for investment may apply at different points in time, and that Dynamic Model Averaging is

a potentially useful technique for comparing theories of activity against observations embodied in the data.

2.6 Conclusions

Private fixed investment is a key component of developed macroeconomies, and consequently an important economic indicator and policy goal. The literature on investment exhibits a range of theoretical and empirical divergences, from the theoretically-satisfying-but-empirically-inaccessible marginal q , to the fascinatingly ad hoc indications of the managerial survey literature. Motivated by recent literature that explicitly or implicitly consider models for investment with time-varying components, this chapter suggested that a novel empirical method from the forecasting literature could be re-purposed as a model comparison tool. Dynamic model averaging is a technique that aims to select some combination of current and lagged models that have maximised forecasting value at any point in time.

Using models drawn from four strands of economic and financial literature, this chapter used DMA as a data-mining tool to evaluate whether the optimal forecasting models changed over time. The time-variation of these models was then linked back to known events in modern Japanese economic history, in an attempt to understand how and why models for investment may change over time.

The evaluation presents evidence of substantial model variation over time. This variation appeared driven by expenditure on input factors and by the availability of external finance. There appeared little time-variation in uncertainty, GDP and average q . These results are consistent with their anticipated priors from their relevant literatures, and indicate the usefulness of DMA as a data investigation tool.

Chapter 3

Uncertainty and investment through the 'Lost Decade'

3.1 Introduction

Does uncertainty matter for Japanese investment? Does this impact vary over time, particularly in periods of crisis? Could uncertainty shocks have contributed to the 'Lost Decade'? This chapter finds that uncertainty shocks caused Japanese private fixed investment to fall steeply in the short-term, rebound, overshoot and return to trend in the medium term throughout the 'Lost Decade' period.

This finding is a result of comparing the theoretical impacts of real-options driven uncertainty to investment using time-varying parameter VAR models with stochastic volatility (TVP-VAR). The econometric analysis considers five hypotheses concerning private fixed investment in Japan over the period 1990-2011: 1) uncertainty has some non-zero impact on investment, 2) that an increase in uncertainty leads to a short-term fall in investment, 3) an increase in uncertainty leads to a medium-term increase in investment, 4) these impacts vary over time and 5) these impacts are greater during periods of peak uncertainty. All results are consistent in confirming hypotheses 1, 2 and 3. Hypotheses 4 and 5 find little support in the data.

Boltho and Corbett (2000) discuss the competing suggestions that the 'Lost Decade' was either a result of a series of unfavourable shocks, or the result of deeper-seated structural issues. Examining these suggestions, Horioka (2006) examines key components of economic output in Japan, and identifies low levels of private fixed invest-

ment as the underlying cause of the 'Lost Decade', together with inventory investment and government investment. His finding regarding private fixed investment is particularly strong in terms of a plummeting rate of growth. These low levels of investment and associated high levels of corporate cash holdings remain imperfectly understood in the literature (Kasahara, Sawada & Suzuki, 2014).

Politicians, economists and policymakers frequently identify uncertainty shocks as culpable for the falls in output and investment during the great recession. Summers (2009) summarised the issue well: "... unresolved uncertainty can be a major inhibitor of investment. If energy prices will trend higher, you invest one way; if energy prices will be lower, you invest a different way. But if you don't know what prices will do, often you do not invest at all." A key paper in support of these hypotheses is that by Bloom (2009), whose time-series analyses and real business cycle models indicated uncertainty could be a primary driver of business cycles.

Real options theory suggests increases in uncertainty should have negative impacts on investment. Bloom et al. (2014) suggest the non-linear impacts of these shocks are key drivers of investment activity and the business cycle. Theoretically, these wait-and-see shocks should drive investment temporarily lower, followed by a heightened recovery. Recent work by Bachmann, Elstner and Sims (2013) throws doubt on this theory by showing that short-term uncertainty innovations have long-term impacts in Germany and the US. Their work supports that conducted by Ogawa and Suzuki (2000) who found significant negative impact of uncertainty shocks in Japan on annual panel data. Choi (2013) further finds that the empirics in Bloom (2009) may be sample period dependent.

3.2 The how and why of uncertainty

The term 'Uncertainty' has spent the last decade competing with 'austerity', 'crisis' and 'quantitative easing' for the title of 'Macro Buzzword de Jour'. The impact of uncertainty shocks is a controversial topic in the macroeconomics literature¹. This is due to both the difficulty in separating the impact of changes in anticipated returns from mean-preserving spreads in anticipated returns distributions (or 'Panglossian'

¹see the detailed summary of the academic literature by Bloom (2014), and a summary of the U.S. political debate by Konczal (2012)

uncertainty shocks) and due to the difficulty in accounting for the time-varying impact of uncertainty shocks.

Whilst the empirical literature remains uncertain about the impacts of increases in uncertainty, the proposed depressive role of uncertainty remains extremely popular in the policy arena. Central bankers “A black cloud of uncertainty is hanging over investment” (Mervyn King, Bank of England, 2012), IMF economists “Uncertainty is largely behind the dramatic collapse in demand,” (Blanchard, 2009) and politicians (Lerer, 2012) who discusses the Barack Obama quote that “[policy] uncertainty is already having an effect”, have consistently identified uncertainty as a vital macroeconomic shock with a negative influence on activity.

Perhaps a portion of the attractiveness of uncertainty as a driving force is its contemporaneity with episodes of sudden recession. Figure 3.1 shows the levels of the Japanese private fixed investment, in the form of machinery purchases against the calculated Tankan forecaster dispersion data, with an apparent negative correlation supporting such concepts.

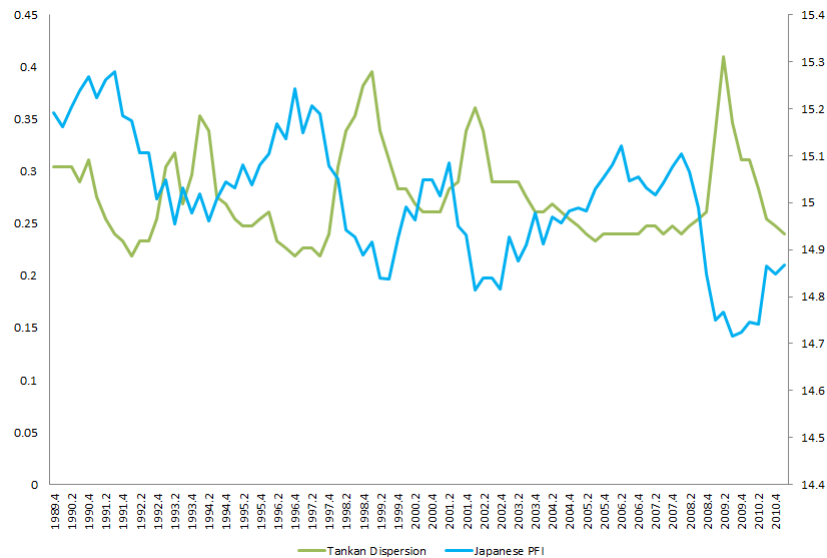


Figure 3.1: Time series of Japanese machinery investment (RHS, log-levels) and Tankan forecaster dispersion (LHS, levels).

But these shocks are also associated with real falls in global activity. Trade, currency, investment, financing and demand all decline post-shock (Fry et al. 2011). Disentangling the impacts of a mean-reverting uncertainty shock requires careful, theory-consistent, analysis.

One particular theoretical relationship between investment and uncertainty mo-

tivates substantial recent micro- and macroeconomic investigation - notably the literature following Bloom (2009). The theory is known as the 'real options' theory of investment, and it anticipates two epiphenomena in 'wait-and-see' and 'caution'. In discussing these epiphenomena, this section provides a benchmark for estimation and motivates the use of time-varying VAR models.

Real options investment theory emerged from the empirical failures of Tobin's q and Jorgensen's neoclassical approaches. Strongly associated with the book 'Investment and Uncertainty' by Dixit and Pindyck (1996), as well as Abel and Eberly's (1996b) work, real options theory is based on three key features of investment decisions. Firstly, most capital investments are to some non-trivial degree irreversible – sunk costs exists. Secondly, investment decisions are made in the reality of uncertainty in terms of future returns – outcomes are probabilistic. Thirdly, investors control the timing of investments – postponement to acquire information is possible.

Real options theory associates innovations to uncertainty with 'wait-and-see' and 'caution' effects. 'Wait-and-see' refers to the tendency of firms, when suddenly in a more uncertain environment, to delay expenditure. 'Caution' effects occur when uncertainty increases, rendering firms less sensitive to other changes, such as input prices and demand.

'Wait-and-see' effects are simple and intuitively satisfying, being a consequence of the option approach in which an investment decision is an opportunity to purchase an asset at different points in time. The optimal investment policy balances the value of waiting for new information with the cost of postponing the investment in terms of forgone returns. When a firm makes the decision to invest, it forces the expiration of the option to wait for new information regarding the investment return mean and distribution. As Abel and Eberly (1996) note, the anticipated return to investment must therefore exceed the purchase and installation costs by an amount equal to the value of keeping the option alive. If there is a mean-preserving spread in the distribution of returns, the option value of waiting increases and current-period investment falls. From Bachmann et al. (2013), "why pay a fixed cost now when a highly uncertain future means one will likely have to pay the fixed cost again?"

'Caution' effects are similarly straightforward. If a firm need weigh up several factors in making a decision, then any large increase in one factor will comparatively

decrease the importance of all others; a large increase in the cost of capital – as is demonstrated during credit-crunch periods – may well decrease a firm's sensitivity to labour cost changes. If the option value of waiting associated with uncertainty is a factor in a firm's decisions, then uncertainty spikes will lower price-sensitivity in other factors.

These real options effects are the basis of the modelling of uncertainty-driven business cycles by Bloom (2009) and Bloom et al. (2014). This body of work argues positive innovations to uncertainty lead to short-run falls in investment and hiring, in turn leading to short-term falls in activity. When the waiting period is finished, pent-up demand leads to a medium-term increase in activity, as depicted by the capital responses in Figure 3.2.

Bloom (2009) and Bloom et al. (2014) implement RBC and DSGE models, respectively, augmented with uncertainty shocks. Bloom (2009) also implements a range of VARs evaluating the role for stock market volatility in driving US macroeconomic outcomes. These models indicate volatility shocks have short-term (less than 12 months) depressive impacts on industrial production, but medium-term (more than 12 months) positive impacts. These results fit the wait-and-see typification of uncertainty shocks well (Figure 3.2). Bloom et al. (2014) develop micro-level measures of uncertainty that are strongly counter-cyclical at the national and sector levels. Their simulations of uncertainty shocks show investment falling steeply in a short-term response, before recovery to a positive effect in the medium-term.

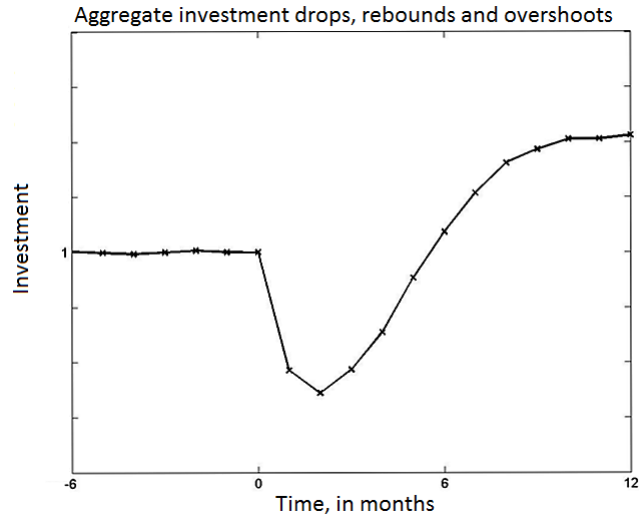


Figure 3.2: Canonical real options impacts of uncertainty on investment, as discussed by Bloom et al. (2014)

This time-varying nature of uncertainty is key to the relationship identified by Bloom (2009) between uncertainty and business cycles. But the non-linear nature of the relationship makes this stochastic volatility famously difficult to empirically evaluate. Testing of the relationship requires a method capable of allowing parameters to vary over time.

Two recent papers have tested the short-term fall, medium-term recovery result from Bloom (2009) and Bloom et al. (2014). Bachmann et al. (2013) test this on US and German data. Using business confidence survey data, they construct an uncertainty measure consisting of the degree of forecaster disagreement – a dispersion index. They further construct an aggregate dispersion index and a micro-level, sectoral robust index and find the measures are positively correlated with impacts on economic activity that are often statistically indistinguishable.

Bachmann et al. (2013) use two-variable SVARs to identify the impact of uncertainty on manufacturing production, general business activity and manufacturing employment. Their impulse response analysis indicates that uncertainty shocks have protracted negative impacts on economic activity that are quantitatively small on impact. They further show that innovations to business confidence (a strongly pro-cyclical measure) have similar impacts to uncertainty innovations. An attempt to identify the time-varying impact of uncertainty shocks is made via Blanchard-Quah decomposition restrictions, which has similar results.

The work of Bachmann et al. (2013) could have been improved in three key areas. Firstly, the dependent variable choices – activity, employment and production – are open to debate. Employment is famously sticky, particularly in Germany - see Siebert (2005). Production may also be a function of existing orders rather than anticipated business conditions and their combined impact may render general business activity comparably murky. Moreover, the real options literature deals particularly with investment as this may be both easier to alter than staffing or extant orders as well as more susceptible to changes in anticipated returns (Dixit and Pindyck 1996).

Second is the absence of effective time-varying analysis: the SVAR impulse responses are based on coefficient averages throughout the sample period, not at periods of peak uncertainty. Finally, the use of more global uncertainty measures may have allowed business-cycle exogenous analysis.

Choi (2013) repeats Bloom's (2009) time-series analysis with sub-period divisions. Division of the VAR data into pre- and post-1982 delivers markedly different results. The earlier period displays theoretically-familiar wait-and-see fall-rebound effects. Impulse responses during the post-1982 period show no short-term impact and positive medium-term impacts. These contra-theory results suggest a need for further investigation.

3.3 Japanese private fixed investment

The choice of Japan as the focal point of this analysis is motivated by the global importance of the Japanese economy, the key role of Japanese Private Fixed Investment in the 'Lost Decade' (Horioka, 2006) and the similarity between Bloom's simulated 'wait-and-see' capital response to uncertainty shocks (as per Figure 3.2) and the Japanese investment time-series in Figure 3.1.

With specific regard to Japan, Horioka (2006) identified low levels of private fixed investment as the underlying cause of the 'Lost Decade', together with inventory investment and government investment. His finding regarding private fixed investment was particularly strong in terms of a plummeting rate of growth.

There is a deep literature using Tobin's q and neoclassical models to investigate the cause of these falls in investment. The model developed by Kiyotaki and Moore (1997)

was motivated by Japan's post-bubble fall in output and places private fixed investment as a major constituent of business cycle variations, albeit one that responds only to output and cost-of-capital variations. Ando (1998) and Bayoumi (1999) discuss the slowdown as a consequence of a low return to further capital investment following previous over-investment, although this gives primacy to wealth effects by assuming an absence of wealth-creating investment opportunities. Hayashi and Prescott (2002) conduct a growth accounting exercise and find that low investment was a causal factor which was in turn driven by low Total Factor Productivity (TFP), but fail to unpack what the relevant constituents of TFP may be (Hoshi and Kashyap, 2004). More recently, Tyers & Zhang (2011) attempt to explain the declining investment share of GDP in a multi-sector dynamic model and in turn Japan's economic recovery of 2002-2007, finding an important role for the impact of an ageing population. This finding is consistent with the broad, long-term downtrend in investment displayed in Figure 3.1.

An important field of Japanese fixed investment research places financing constraints at the centre of investment investigation. Financing theories of investment focus primarily on the degree to which private fixed investment is aided or constrained by the availability of liquid investment capital. These theories also attempt to explain the empirical importance of cashflow to investment; the absence of which is a major failing of neoclassical theories (Caballero 1999). The Japanese experience with financial excesses in the 1980s and financial crises in the 1990/2000 decades resulted in deep literature investigating how these events may have driven private fixed investment and consequently business cycles. Hoshi, Kashyap and Scharfstein (1991) take advantage of the 'keiretsu' industrial organisation idiosyncrasies of Japan to evaluate the investment influence of reliable credit. They found support for a credit protection effect, with investment less sensitive to cashflow in keiretsu-protected firms. Kaplan and Zingales (1997) extend the cashflow discussion by noting the absence of theory or empirical evidence for investment-cashflow sensitivities to increase with financial constraints. Their paper - when considered with Hubbard's (1998) and Bernanke, Gertler and Gilchrist's (2000) provision of evidence and theory, respectively, of a preference to finance investment with internal rather than external funds - is a major motivator of this thesis' investigation into investment variations.

The current state-of-the-art in financing investment theory is demonstrated by Kasahara, Sawada and Suzuki (2011). Their dynamic structural model of the Japanese economy indicates that, following Japan's financial crisis of 1997, there was a sharp decline in bank loans to firms followed by a fall in corporate investment in 1998-9. They found support for the theories of low bank health leading to low firm investment and, accordingly, for some exogenous financial constraint to indicate low firm investment. Their model under-predicts investment of low TFP firms and over predicts investment of high TFP firms, potentially signalling a channel for non-fundamentals based decision making. The authors note the potential for further mechanisms in the paper: "The large variance of idiosyncratic shocks indicates that there are unobserved factors for investment that are not fully explained by the observed state variables in the model, which is not surprising because empirically explaining a large portion of the cross-sectional variation in investment by observed variables has been found to be difficult in the literature."

Little research has been conducted into the role uncertainty may have played in the post-bubble falls in Japanese investment. Ogawa and Suzuki (2000) evaluate the conditional standard deviation in the growth rate of sales as a driver of Japanese manufacturing firms' investment. They find uncertainty has a significant negative impact on investment which is closely related to the degree of irreversibility of capital. Their panel analysis is unable to decompose impacts of uncertainty across time and magnitude and may suffer from using measures of uncertainty partially endogenous to Japanese business-cycles.

3.4 Uncertainty measures and data

This section discusses the selection logic behind the variables used in my empirical analysis. It also identifies data treatments and sources.

Precise data on the individual uncertainty distributions of decision-makers is unavailable for Japanese enterprises. The use of a proxy for these distributions is necessary; these are most accessible in aggregate. But all empirical work is weakened by use of proxies, with vulnerabilities stemming from weakly-associated proxies, system endogeneity or omitted variable bias. This chapter takes these vulnerabilities seriously

and uses conceptually, sectorally and geographically separate proxies for uncertainty.

Firstly, I follow Bachmann et al. (2013) in the construction of an uncertainty measure based on the Bank of Japan's Short-term Economic Survey of Enterprises in Japan, or 'Tankan': the standard deviation of a Tankan diffusion measure. This measure represents the degree of disagreement between managers of Japanese firms as to their 6-month forecast of business conditions. This measure is selected as a measure robust to the 'weakly associated proxy' vulnerability. The sample size, history and external weight placed upon the Tankan Index suggests that it will be strongly associated with actual business uncertainty. But a diffusion measure may represent naturally heterogeneous variation in opinions (i.e. from sectoral variations) and therefore be susceptible to omitted variable bias.

In order to move into a more pure uncertainty space, I investigate the Chicago Board Options Exchange Market Volatility Index (VIX) - a popular measure of the implied volatility of S&P 500 index options. Widely used in the financial uncertainty literature it represents a measure of the US equity market's expectation of stock market volatility over the next 30 day period. This measure is chosen for its resilience to endogeneity criticisms, but due to separation in geography and economic systems may be a weak instrument for firm-level uncertainty in Japan.

Finally, I repeat the uncertainty measure analysed by Ogawa and Suzuki (2000) - the rolling 1-year standard deviation in the growth of sales. Ogawa and Suzuki take the view that when the structure of the output market is imperfect, and thus firms face a downward-sloping demand curve, uncertainty shocks may be demand shocks. They therefore argue sales growth volatility is an important component of the real uncertainty firms face. This inclusion of sales growth volatility aids this chapter's analysis in several way. Most notably it is a backwards-looking measure, as opposed to the more forwards-looking VIX and Tankan forecaster dispersion measures. Its inclusion is appropriate and useful in the unclear decision environment of firm-level investment; whether managers are backwards- or forwards-looking is theoretically and empirically uncertain (see the empirical importance of lagged investment in driving investment in Eberly et al. (2012) compared with the forward-looking modelling by Bloom et al. (2014)).

The Tankan is a statistical survey of private enterprises conducted by the Bank of

Japan. The survey aims to provide an accurate picture of business trends of enterprises in Japan, thereby contributing to the appropriate implementation of monetary policy and is conducted quarterly in March, June, September, and December. The population of the survey is approximately 210,000 private enterprises (excluding financial institutions) in Japan with at least 20 million yen in capital.

The Tankan has several notable strengths as an uncertainty measure, primarily its statistical coherency and reputation. In terms of reputation, the Tankan is one of the key financial measures in Japan and has substantial influence on asset prices and monetary policy. Its coherence is well-documented by Bank of Japan records and has been imitated by Spain national statistics organisation. Further, the Tankan is widely used as a business confidence, and business cycle, measure in the macroeconomic literature on Japan.

The survey question of interest for this analysis is the first question in the 'Judgment Survey' section. In this section, responding enterprises are asked to choose one alternative among three as the best descriptor of prevailing conditions, excluding seasonal factors at the time of the survey and three months hence. The question of interest requests 'Judgement of general business conditions of the responding enterprise, primarily in light of individual profits.' Potential answers are: 1) Favorable. 2) Not so favorable. 3) Unfavorable.

The 'Tankan Index' is the 'Business Conditions Diffusion Index'. This diffusion index is calculated by subtracting the percentage share of enterprises responding '(3) Unfavorable' from that of '(1) Favorable.' There is no weighting measure: each respondent has one vote. Respondents answer both an 'Actual result' and a 'Forecast' question, where the forecast pertains to the next quarter's business conditions. As the literature frequently features forecaster dispersion as an uncertainty metric (Bachmann et al. (2013) I use 'Forecast' responses.

To transform this diffusion index into an uncertainty measure I undertake the standard method (Bachmann et al. 2013, Ballantyne et al. 2016) for evaluating response disagreement in the survey data literature by indexing 'Favourable' responses as +1 and 'Unfavourable' as -1, then calculating the cross-sectional standard deviation.

VIX is the ticker symbol for the Chicago Board Options Exchange (CBOE) volatility index, which represents market volatility expectations over the next thirty days, as

well as the popular measure of implied volatility for the S&P 500 index option. Since its introduction in 1993, VIX has become a preferred forward-looking indicator of investor sentiment and market volatility, and is often referred to as the “investor fear gauge”. It is derived without reference to restrictive option-pricing models.

3.4.1 Data sources

Data cover the period Q1:1990 - Q1:2011, the longest period available at the time of writing. This relatively short period is a result of VIX index data being available from 1990, and a change in the measurement and collation of Japanese private fixed investment limiting that data to Q1:2011. Regardless of availability this period is of substantial interest, being the two 'Lost Decade/s' post-bubble, and free of confounding factors in the destructive Tohoku earthquake of March 2011 and the novel policies of Abenomics.

Japanese Private Fixed Investment (JPFI) data are taken from the Economic and Social Research Institute of the Cabinet Office of Japan (ESRI) from the publication 'Orders Received for Machinery'. Data are from the sub-section 'Machinery Orders by Sectors, Sales and Remainders (Seasonally adjusted, Quarterly)' and represent private sector purchases. These data are used in calculations under the assumption that they are representative of fixed investment variations across the Japanese economy. The machinery classifications included are 'Boilers and power units', 'Heavy electrical machinery', 'Electronic and communication equipment', 'Industrial machinery', 'Metal cutting machines', 'Rolling machines', 'Motor vehicles (over 5000kg)' and 'Aircraft'.

There are three key implications of evaluating only orders received for machinery as a proxy for investment. Firstly, property is not included - a choice motivated by the difficulty in matching long-term property purchase decisions with medium-frequency variations in uncertainty indicators. Secondly, the effective exclusion of service-sector firms implies this analysis may not be fully generalisable across the economy, but ensures that sector-derived variations are minimised - a point evaluated in further detail in Chapter 4. Finally, the decision to evaluate orders received as opposed to final investment was made to better-align with the behavioural concepts and comparative frequency of uncertainty above. Should uncertainty changes occur at higher frequen-

cies than variations in machinery orders (as may be possible given the lag time between, for example, aircraft order and delivery in comparison with the appearance of financial market variations) then the order may be withdrawn and the final investment fail to materialise in official statistics. This would be a situation in which the response phenomena had occurred following the stimuli, but would not appear in the econometric analysis. Evaluating orders received avoids this potential issue.

Accumulated, seasonally adjusted, quarterly capital stock data are sourced from Japan's Ministry of Finance 'Financial statistics of corporations by industry'. To limit multi-collinearity with machinery investment and the Nikkei 225, capital stock is defined as the sum of 'Cash and deposits', 'Bills and accounts receivable', 'Inventories', 'Finished goods and merchandise', 'Works in process', 'Raw materials and goods supplies', 'Bonds and debentures', 'Other securities', 'Land', 'Intangible fixed assets' and 'Construction in process'. Data are collected from all Japanese firms with capital assets in excess of 10 million yen, excluding the Finance and Insurance sectors.

Tankan data are from the Bank of Japan time-series 'Tankan' data release.

Nikkei 225 Index and VIX data are taken from Thomson Reuters' Datastream. VIX data considered in this study are the quarterly maxima of the daily VIX data. The quarterly maxima instead of the quarterly average are chosen to ensure differentiation between short periods of high uncertainty and prolonged periods of moderate uncertainty, the import of which is described in Bloom (2009).

Where appropriate, all data are seasonally adjusted using the X12 ARIMA method. Investment, Capital, Nikkei 225 are examined on first-differenced log-levels. Sales volatility, Tankan forecaster dispersion and VIX Index data are evaluated on levels.

	MCH	K	NIKK	SALE	TANK	VIX
Mean	-0.003	0.001	-0.015	0.043	0.276	26.745
Median	0.001	-0.001	-0.002	0.042	0.261	23.87
Maximum	0.122	0.085	0.198	0.091	0.41	80.86
Minimum	-0.142	-0.06	-0.29	0.015	0.219	12.67
Std. Dev.	0.058	0.021	0.099	0.011	0.042	11.154
Observations	85	85	85	85	85	85

Table 3.1: Summary statistics

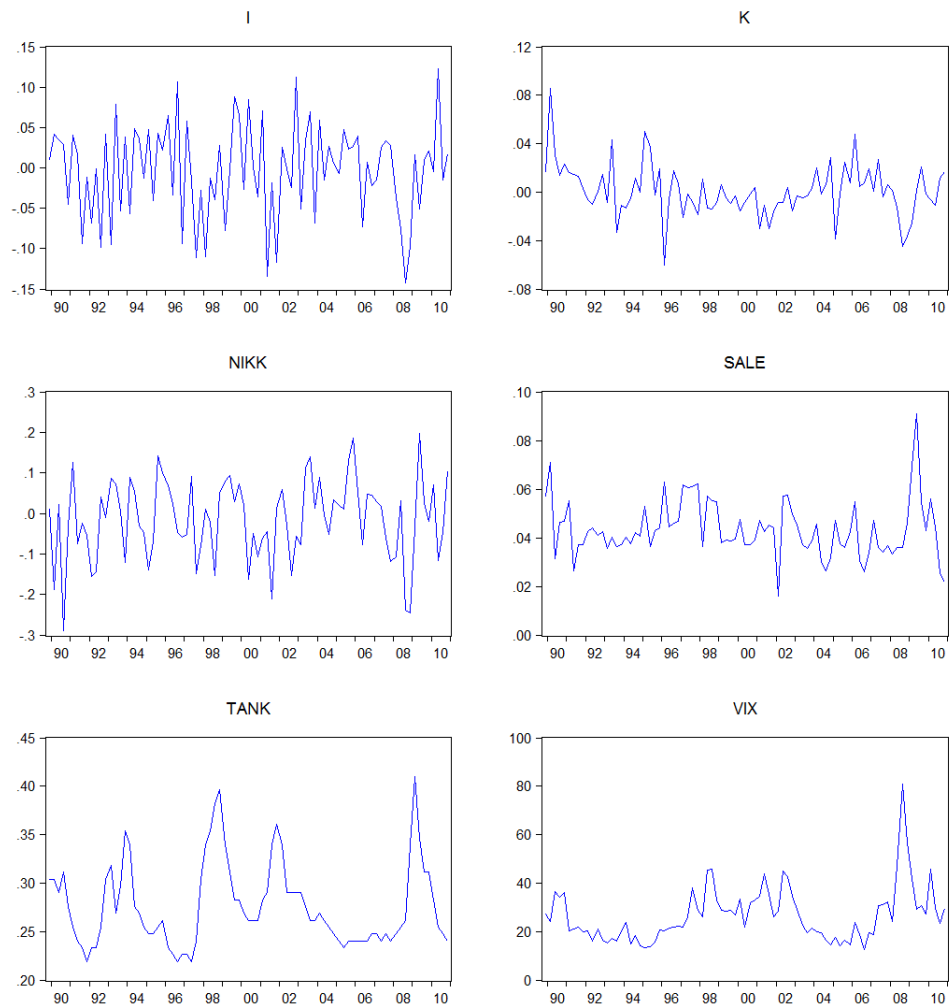


Figure 3.3: Time series of key variables. Investment, Capital, Nikkei 225 are first-differenced log-levels. Sale is the rolling 1-year standard deviation of Japanese non-financial company sales growth. Tankan forecaster dispersion is levels and VIX Index levels of monthly maxima.

Correlation/Covariance	MCH	K	NIKK	SALE	TANK	VIX
MCH	1					
	0.003					
K	0.196	1				
	0.000	0.000				
NIKK	0.154	0.106	1			
	0.001	0.000	0.010			
SALE	0.028	-0.06	-0.036	1		
	0.000	0.000	0.000	0.000		
TANK	-0.143	-0.214	-0.052	0.283	1	
	0.000	0.000	0.000	0.000	0.002	
VIX	-0.313	-0.359	-0.386	0.233	0.378	1
	-0.201	-0.085	-0.422	0.030	0.179	122.949

Table 3.2: Correlation and covariance statistics of estimated variables

3.5 Time-varying Parameter VAR

The time-varying nature of the impact of uncertainty and its stochastic volatility is key to the identification the impact of uncertainty on economic activity as discussed by Bloom (2012). The steady-state of uncertainty is small, and so comparative statics exercises (Dixit and Pindyck 1996, Abel and Eberly 1999 or the CAPM work of Baum et al. (2008) tend to show little impact. This indicates that, whilst OLS/VAR methods are potentially useful, they will not identify the full impacts of individual variable innovations on the system as a whole.

Accordingly, this chapter uses a multivariate approach: a multivariate vector autoregressive model which allows for time-varying parameters and stochastic volatility - a TVP-VAR as introduced by Primiceri (2005). A substantial theme in the macroeconomic literature is the allowance for structural breaks in time-series analysis, where coefficients can change in value (Stock and Watson, 1996). TVP-VAR analysis is a per-period extension of structural break analysis. Such techniques do not appear to have previously been applied to the question of investment under uncertainty.

An historical problem with incorporating time-varying parameters into VARs was the proliferation-of-parameters concern, especially considering the already large size of most macroeconomic models. Allowing the error-covariance matrix to change over time with the incorporation of stochastic volatility increases the proliferation issue (see Koop and Korobilis (2010) for a full discussion). Bayesian methods utilising prior information allow for the shrinking of parameter influence (either via restrictions or

shrinking towards zero).

The estimation setup is informed by a standard Tobin's q setup, where corporate investment is equivalent to the ratio of the marginal productive value of additional capital to its marginal acquisition cost. Given the difficulty in empirically accessing marginal values of q , this chapter follows substantial literature (Caballero and Leahy (1996), Eberly et al. (2012)) in evaluating implied average q using the market value of the firm as an indicator of the average productivity of capital, and the book value of the firms to indicate the acquisition cost of capital: numerator and denominator of average q respectively. But given the role of costly capital-adjustment in driving real options behaviour (as per Abel et al. (1996)), necessary is a specification that recognises the importance of capital adjustment-costs: the importance for q -analyses was demonstrated by Abel and Eberly (1996a) and Cooper and Haltiwanger (2006). Consequently this chapter considers a 4-variable system in which the constituents of average q are separated as:

$$I_t = f(K_t, V_t, U_t) \quad (3.1)$$

where I_t is private fixed investment at time t , K_t is the capital stock of the firm V_t is the value of the firm and U_t is uncertainty. The model is evaluated at the aggregate level, with the Nikkei 225 Index acting as an aggregate firm value instrument.

The TVP-VAR analysis is ordered as I_t, K_t, V_t, U_t . This ordering broadly indicates that investment does not respond fully to capital, whereas capital does fully respond to investment. This is problematic, particularly as the Christiano et al. (2005) treatment of investment explicitly holds investment to be the means by which capital is optimised, as opposed to driving activity. The empirical weakness of such assumptions (from Blanchard (1986) '... it is well known that to get the user cost to appear at all in the investment equation, one has to display more than the usual amount of econometric ingenuity') motivated a long empirical literature on managerial decisions (for instance Brounen et al. (2004), Hallikainen (2006) and the Japanese case presented by Shinoda (2010)) where managerial investment decisions are based on capital availability and simple payback accounting.

A second justification for this controversial ordering concerns the specific nature of

Japanese corporate asset holdings in the post-1990 period. Koo (2011) notes the very high levels of capital holdings by Japanese companies during this period were heavily weighted by 'bubbly' assets, particularly land and stocks. These asset holdings were not typically held for the purpose of conducting business, but often for speculative or corporate alignment (the so-called cross-holdings of company shares). As such, they may not be a primary driver of presumably productive investment (as per the data definition in Section 6.4).

3.5.1 Setup

Following Nakajima (2011), consider the representation of a TVP-VAR model:

$$y_t = c_t + B_{1t}y_{t-1} + \dots + B_{st}y_{t-s} + e_t \quad (3.2)$$

$$e_t \sim N(0, \Omega)$$

for $t = s + 1, \dots, n$ where y_t is a $(k \times 1)$ vector of observed data, $B_{1t}, \dots, B_{st}$ are $(k \times k)$ time-varying coefficient matrices and Ω_t is a $(k \times k)$ time-varying covariance matrix. This chapter follows Primiceri (2005) in assuming a recursive identification, where the simultaneous relations of the structural shock e_t are decomposed as $\Omega_t = A_t^{-1} \Sigma_t \Sigma_t' A_t^{-1}$, where A_t is a lower-triangular matrix with the diagonal elements equal to one, and $\Sigma_t = \text{diag}(\sigma_{1t}, \dots, \sigma_{kt})$. This allows the covariance of the errors to vary in time.

By this definition, the model allows for three time-varying parameters: β_t , a_t and h_t , where β_t is the stacked row vector $B_{1t}, \dots, B_{st}$, $a_t = (a_{1t}, \dots, a_{qt})'$ is the stacked row vector of the lower-triangular elements of A_t and $h_t = \log(\sigma_{it}^2)$ allows volatility to follow a stochastic process. These parameters follow a random walk process, so the three state equations and their error terms are modelled as:

$$\beta_{t+1} = \beta_t + u_{\beta t} \quad (3.3)$$

$$a_{t+1} = a_t + u_{a t} \quad (3.4)$$

$$h_{t+1} = h_t + u_{ht} \quad (3.5)$$

$$\begin{pmatrix} e_t \\ u_{\beta t} \\ u_{\alpha t} \\ u_{ht} \end{pmatrix} \sim N \left(0, \begin{pmatrix} I & 0 & 0 & 0 \\ 0 & \Sigma_\beta & 0 & 0 \\ 0 & 0 & \Sigma_\alpha & 0 \\ 0 & 0 & 0 & \Sigma_h \end{pmatrix} \right)$$

for $t = s + 1, \dots, n$, with $e_t = A_t^{-1} \Sigma_t \epsilon_t$, where Σ_α and Σ_h are diagonal, $\beta_{s+1} \sim N(\mu_{\beta 0}, \Sigma_{\beta 0})$, $\alpha_{s+1} \sim N(\mu_{\alpha 0}, \Sigma_{\alpha 0})$ and $h_{s+1} \sim N(\mu_{h 0}, \Sigma_{h 0})$.

This setup implies several assumptions, the first being Cogley and Sargent's (2005) specification of A_t as a lower-triangular matrix with ones on the diagonal. In following Primiceri (2005) by allowing for time-variance this assumption allows recursive identification of the VAR system and is relatively standard in the literature. But as Chib, Nadari and Shephard (2006) note, this can lead to highly autocorrelated MCMC draws, requiring a large number of draws to achieve accurate estimates. This estimation uses 50,000 draws instead of the Chib, Nadari and Shephard algorithm: a choice justified by Figure 3.4, which demonstrates minimal draw autocorrelation and appropriately-shaped parameter distributions.

A second assumption is that the parameters follow a random walk. This no-trend assumption in the time-varying coefficient, simultaneous relations and volatility stacked vectors allows further parameter shrinkage and is not unreasonable given the samples' paths depicted in Figure 3.4. A third assumption is that Σ_α and Σ_h are diagonal, which is relatively standard in the literature following Cogley and Sargent (2005).

The Markov Chain Monte Carlo sampling algorithm used is the stochastic volatility variant of the Gibbs Sampler from Nakajima (2011). The posterior estimates are computed by drawing 50,000 samples after a 5,000 sample burn-in period. Two lags are used for in all VAR and TVP-VAR estimations, as indicated by AIC (see logic for AIC selection in Chapter 2). The following priors are assumed for the i -th diagonals of the covariance matrices:

$$(\Sigma_{\beta})_i^{-2} \sim \text{InverseWishart}(25, 10^{-4}I) \quad (3.6)$$

$$(\Sigma_{\alpha})_i^{-2} \sim \text{Gamma}(4, 10^{-4}) \quad (3.7)$$

$$(\Sigma_h)_i^{-2} \sim \text{Gamma}(25, 10^{-4}) \quad (3.8)$$

Figure 3.4 displays the estimation results from one typical TVP-VAR analysis. These results show the MCMC algorithm is functioning efficiently, covering all parameter distributions with minimal residual autocorrelation.

3.6 Results

This section discusses the TVP-VAR impulse response analyses for all three uncertainty specifications: Tankan dispersion, Chicago BOE's VIX, and Japanese corporate sales growth volatility.

As these are time-varying estimates, a decision must be made as to from which time an impulse is to be simulated. This chapter's motivating questions suggest that shocks be simulated generally across the estimation period, at the beginning of the 'Lost Decade' and at periods of unusually high and unusually low volatility. Consequently, impulse response analyses are conducted at periods of unusually high and unusually low equity market volatility that span the estimation period: High-{Q4:1990, Q3:1998, Q4:2008} and Low-{Q2:1992, Q1:2000, Q4:2007}. Results from the shock simulation are presented at the end of this section.

Reading TVP-VAR impulse response diagrams differs from standard VAR impulse response diagrams due to the number of coefficients estimated and the concomitant myriad response vectors to be drawn. The standard method is to draw the n-period response lines across time. This is opposed to drawing the system response line across n-periods. A useful metaphor to bear in mind in reading these charts is the leaves of a book: a normal impulse response diagram is a single page, a TVP-VAR impulse response is drawn across the edge of all the leaves. Note that the variable set {MCH, K, NKK, TNK, VIX, SALE} corresponds to private fixed investment (machinery) pur-

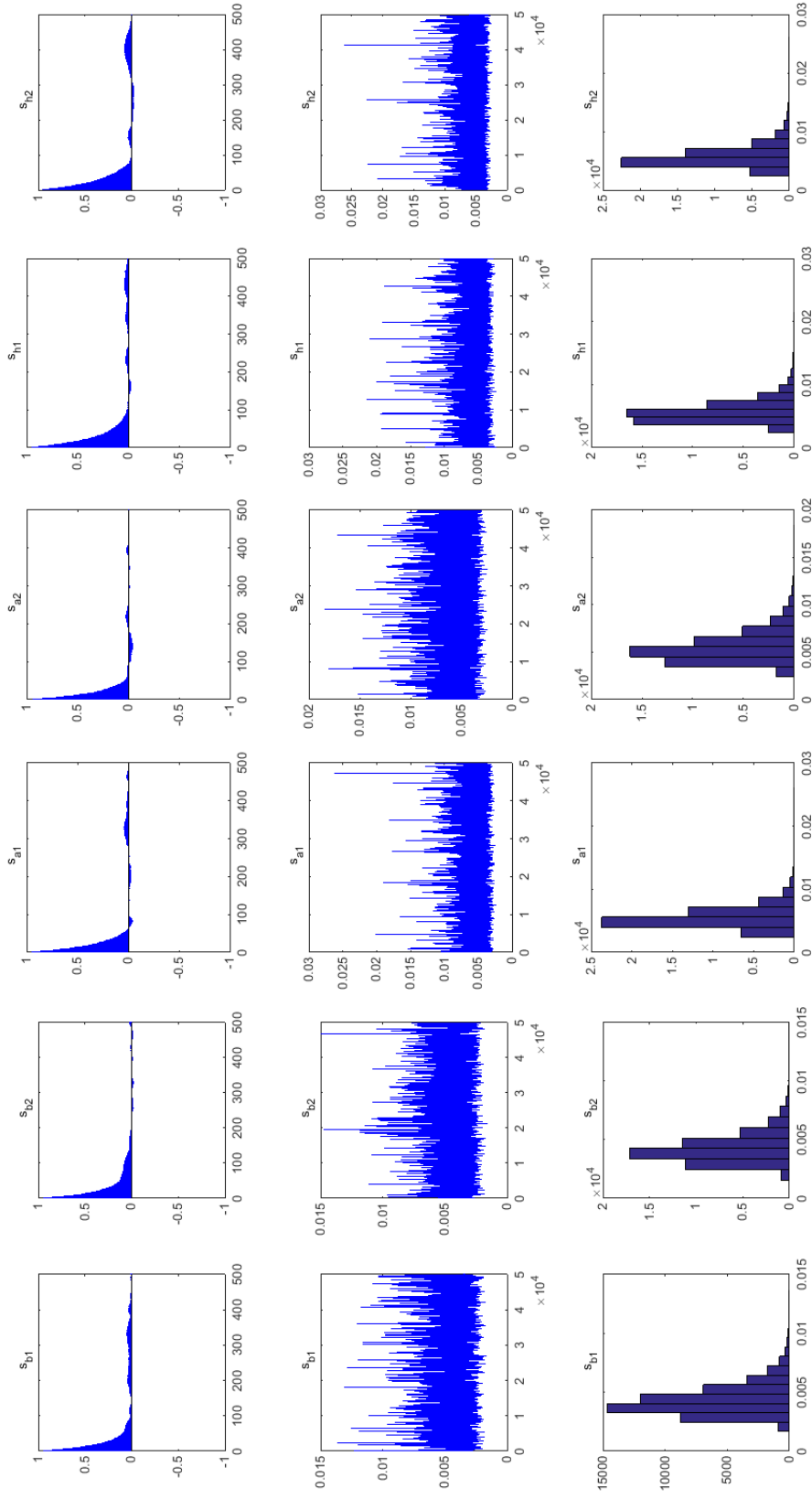


Figure 3.4: Parameter autocorrelation, distribution and densities, TNK specification.

chases, corporate capital stock, the Nikkei 225 Index, the Tankan forecast dispersion, quarterly maxima of the VIX Index and 1-year rolling Japanese corporate sales growth volatility.

The first general observation on the TVP-VAR impulse response estimations of the 4-variable set is that they contain more variation between periods than the 3-variable setup utilised in the following Chapter 4: 'Investment, output and the yen'. This is to be anticipated given the estimation strategy, and is in fact a desired outcome of this form of Bayesian simulation. All variables are simulated conditional on other variables in the system, and by increasing the variable count the information density of coefficients is also increased. That the VIX system appears more irregular than either the Tankan or sales measures may be a meaningful artefact of the dissimilarity between domestic and global uncertainty, or real and financial uncertainty, or it may be an indicator of poor algorithmic performance. All VIX-augmented system results are interpreted with some caution.

The direction, shape and persistence of impulse-response diagrams are relatively consistent for domestic uncertainty systems, both in comparison with each other and across time. This is a substantial finding, in that there is little evidence that uncertainty innovations have greater impact on corporate investment activity during periods of unusually heightened or flattened uncertainty. To rephrase, the impacts of uncertainty appear linear in time and magnitude. This is a novel finding to the uncertainty and investment literature, which has broadly followed the assumption in Dixit and Pindyck's 1996 book and by Abel and Eberly (1999) that low levels of uncertainty have comparatively far smaller impacts than high levels. I find no evidence supporting this assumption, but rather that high levels of uncertainty have large impacts on activity simply because the levels of uncertainty are high.

All three specifications provide evidence broadly supporting the Tobin's Q theory of investment used by Christiano et al. (2005) and transformed to explain the lagged investment effect by Eberly et al. (2012), in that positive shocks to firm value in Nikkei 225 innovations have a consistent short-term positive impact on investment. Positive shocks to firm capital also have short-term positive impacts on investment.

The seemingly similarity between the two domestic measures of uncertainty (forecaster dispersion (Tankan) and rolling 1-year sales growth volatility) is interesting.

Both sets of variables appear to have similar real options effects on investment. This suggests that forwards-looking and backwards-looking indicators are similarly derived, and may form the basis for interesting uncertainty measure comparison research.

Shocks simulated in the early 1990s suggests that uncertainty had a drop, rebound and overshoot impact on Japanese private fixed investment at the start of the 'Lost Decade'. Given the absence of either an obvious rebound or overshoot impact in the investment time-series, together with Horioka's 2006 finding that investment falls caused the 'Lost Decade', it seems incorrect to attribute to uncertainty shocks entire causation of a long-term recession.

3.7 Summary

This chapter sought to answer three questions: Does uncertainty matter for Japanese investment? Does this impact vary over time, particularly in periods of crisis? Could uncertainty shocks have contributed to the 'Lost Decade'?

These questions in turn generated five hypotheses: 1) uncertainty has some non-zero impact on investment, 2) an increase in uncertainty leads to a short-term fall in investment, 3) an increase in uncertainty leads to a medium-term increase in investment, 4) these impacts vary over time and 5) these impacts are greater during periods of peak uncertainty.

To consider these hypotheses, a small-scale model of investment was variously augmented with one of three uncertainty measures: a forecaster dispersion index, an implied volatility VIX index and a rolling sales growth volatility measure. Estimation of time-varying parameter VAR models with stochastic volatility indicate uncertainty exhibits drop, rebound and overshoot impacts on Japanese private fixed investment that are consistent with real-options theory. The impact of such shocks appear linear in time and magnitude. These findings are consistent with assumptions used in the large-scale modelling analysis by Bloom (2009) and Bloom et al. (2014).

The finding that uncertainty has linear impacts on investment in Japan during the period 1990-2011 is novel to the literature, including Abel and Eberly (1999), Bloom (2009), Bachmann et al. (2013), and Caggiano et al. (2015). The TVP-VAR analysis

suggests that the apparently non-linear appearance of uncertainty shocks in much of the literature may be inability to allow for stochastic volatility.

Falls in private fixed investment are linked (Horioka 2006) with Japan's 'Lost Decade', but simulated uncertainty spikes during this period consistently indicate a rebound effect inconsistent with sustained declines. The data indicates long-term collapses in investment cannot be attributed to short-term uncertainty shocks.

Understanding the linear role uncertainty plays in deterring investment emphasises the importance of forward-guidance, crisis management and political stability.

Areas for future investigation include potential variations in sector-level responses and causal mechanisms behind the differing apparent impacts of domestic and international, real and financial uncertainty instruments. Further, the issue of how macroeconomic policy may have variously stabilised or exacerbated investment responses to uncertainty shocks remains unclear. Extending the findings of this chapter into these areas of research may assist policymakers in responding to macroeconomic crises in Japan and abroad.

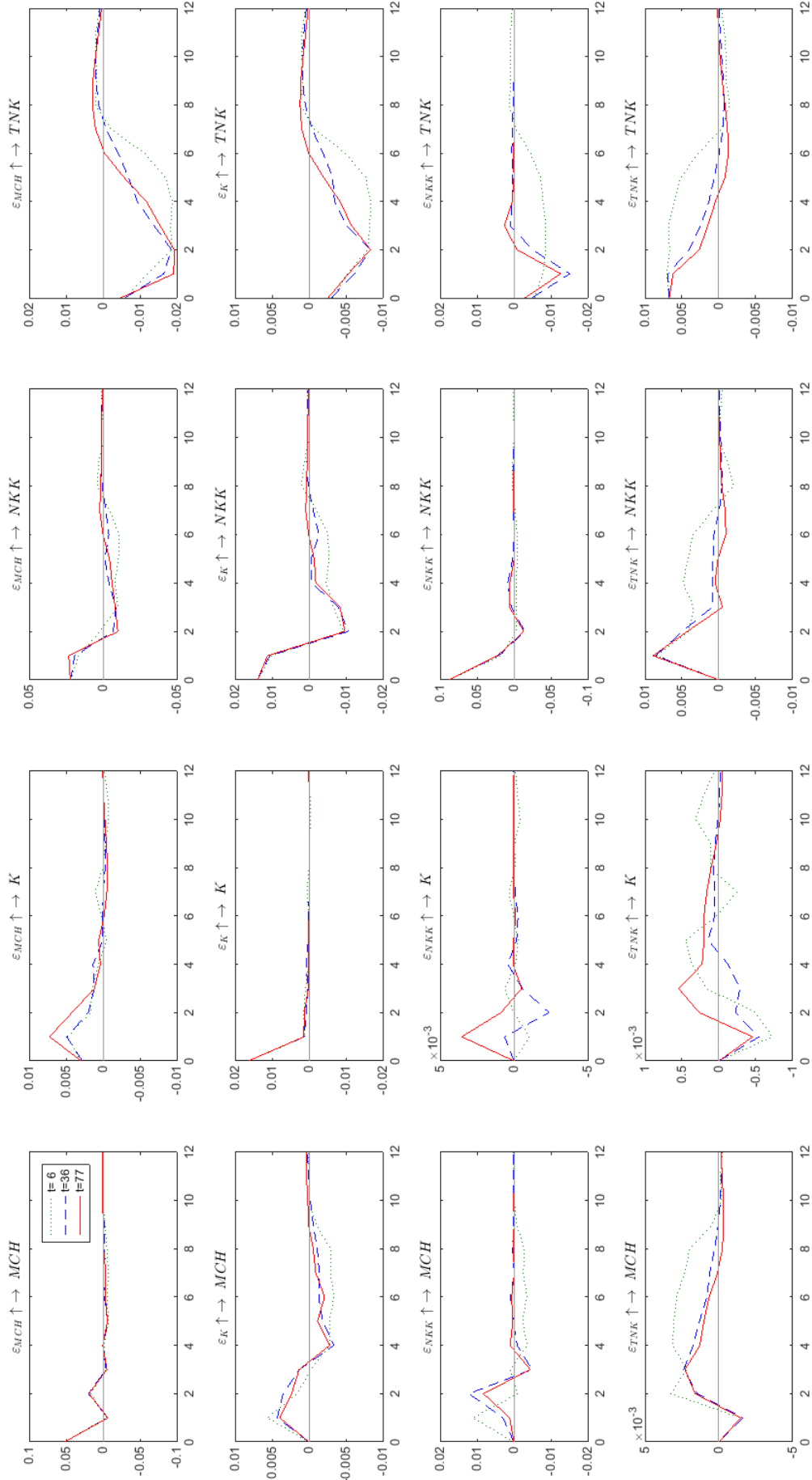


Figure 3.5: Impulse responses, Tankan dispersion specification. Impulse responses gathered at periods of unusually high equity market volatility {Q4:1990, Q3:1998, Q4:2008} respectively corresponding to the lines $t=6$, 36, 77.

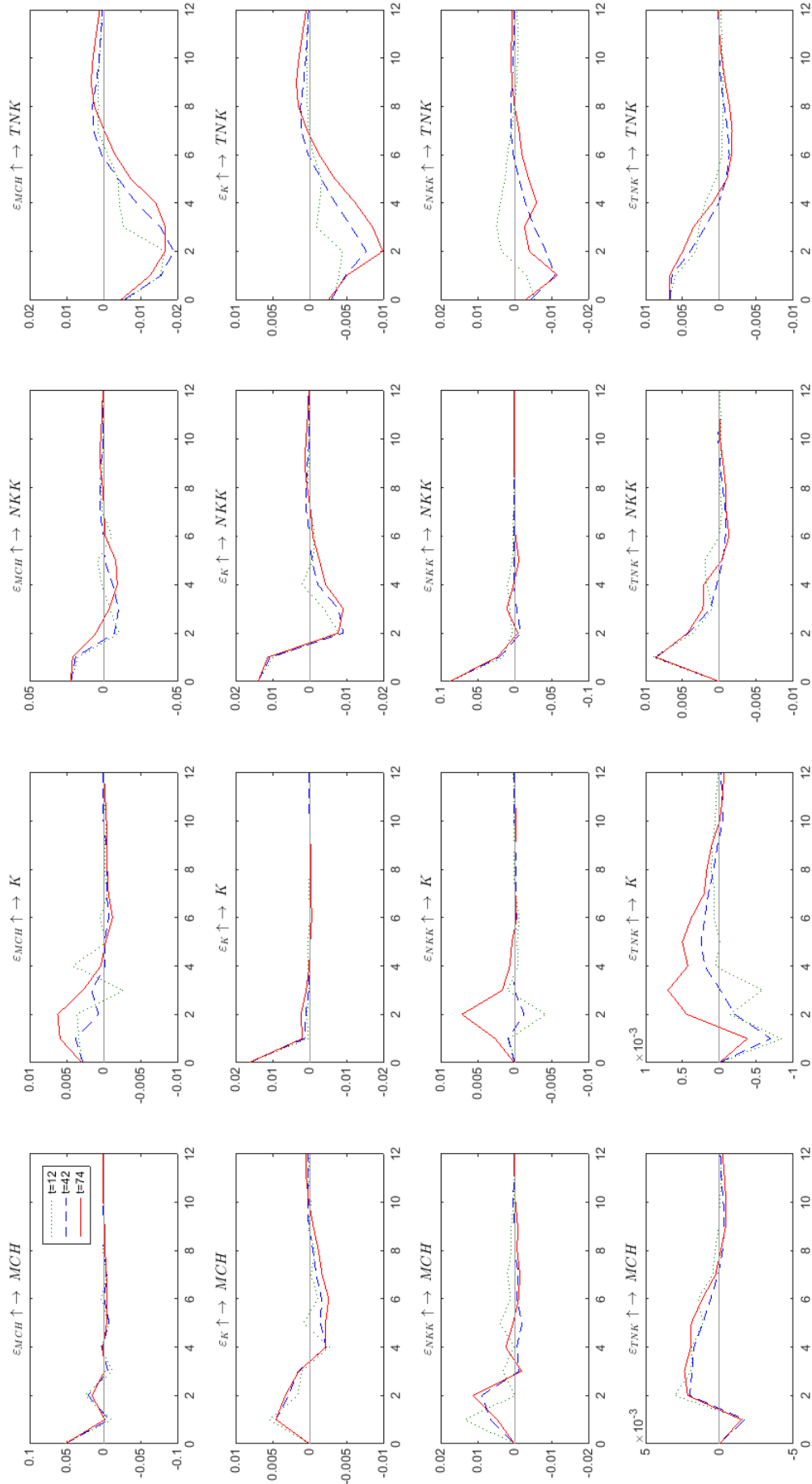


Figure 3.6: Impulse responses, Tankan dispersion specification. Impulse responses gathered at periods of unusually low equity market volatility {Q2:1992, Q1:2000, Q4:2007} respectively corresponding to the lines t=12, 42, 74.

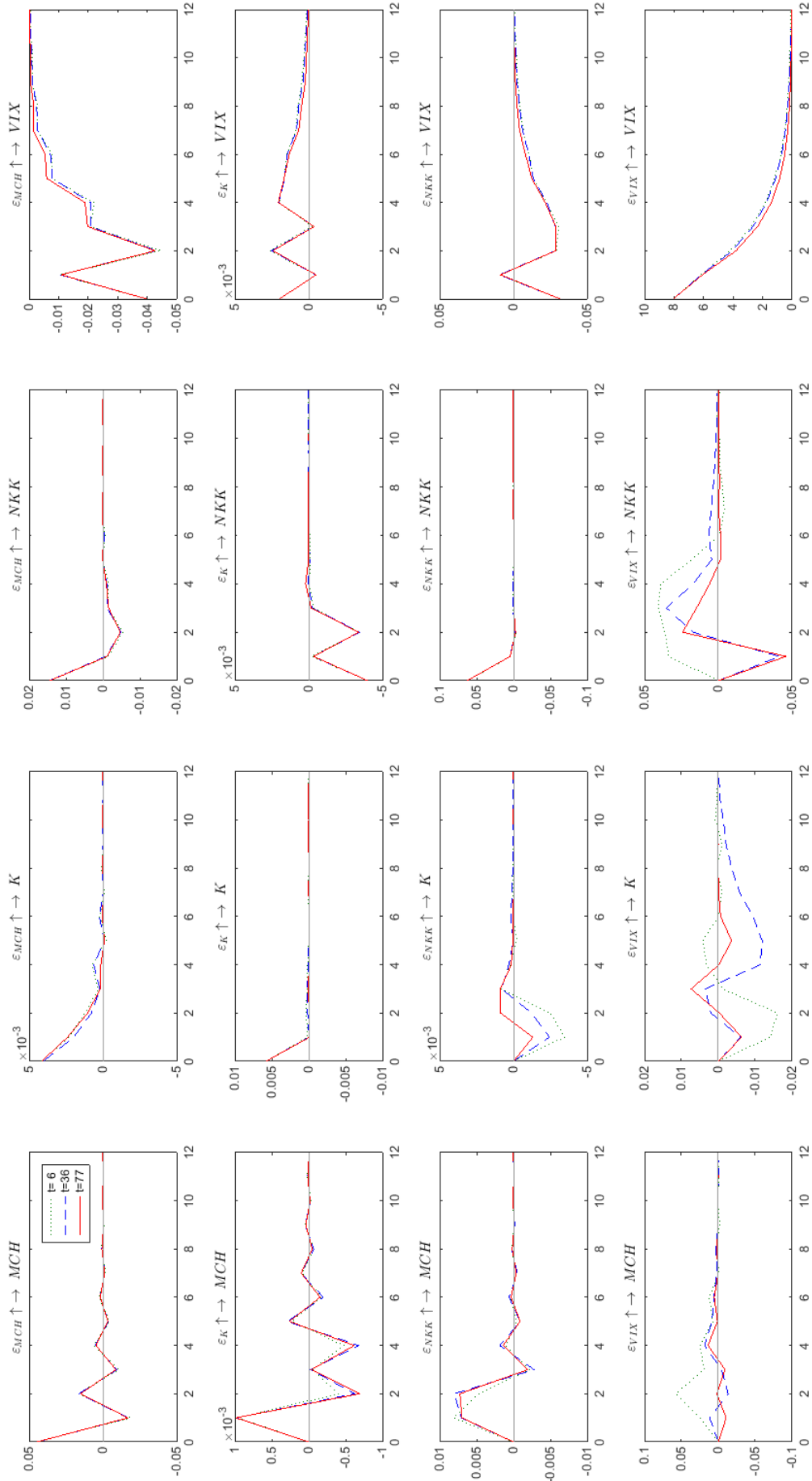


Figure 3.7: Impulse responses, VIX specification. Impulse responses gathered at periods of unusually high equity market volatility (Q4:1990, Q3:1998, Q4:2008) respectively corresponding to the lines t=6, 36, 77.

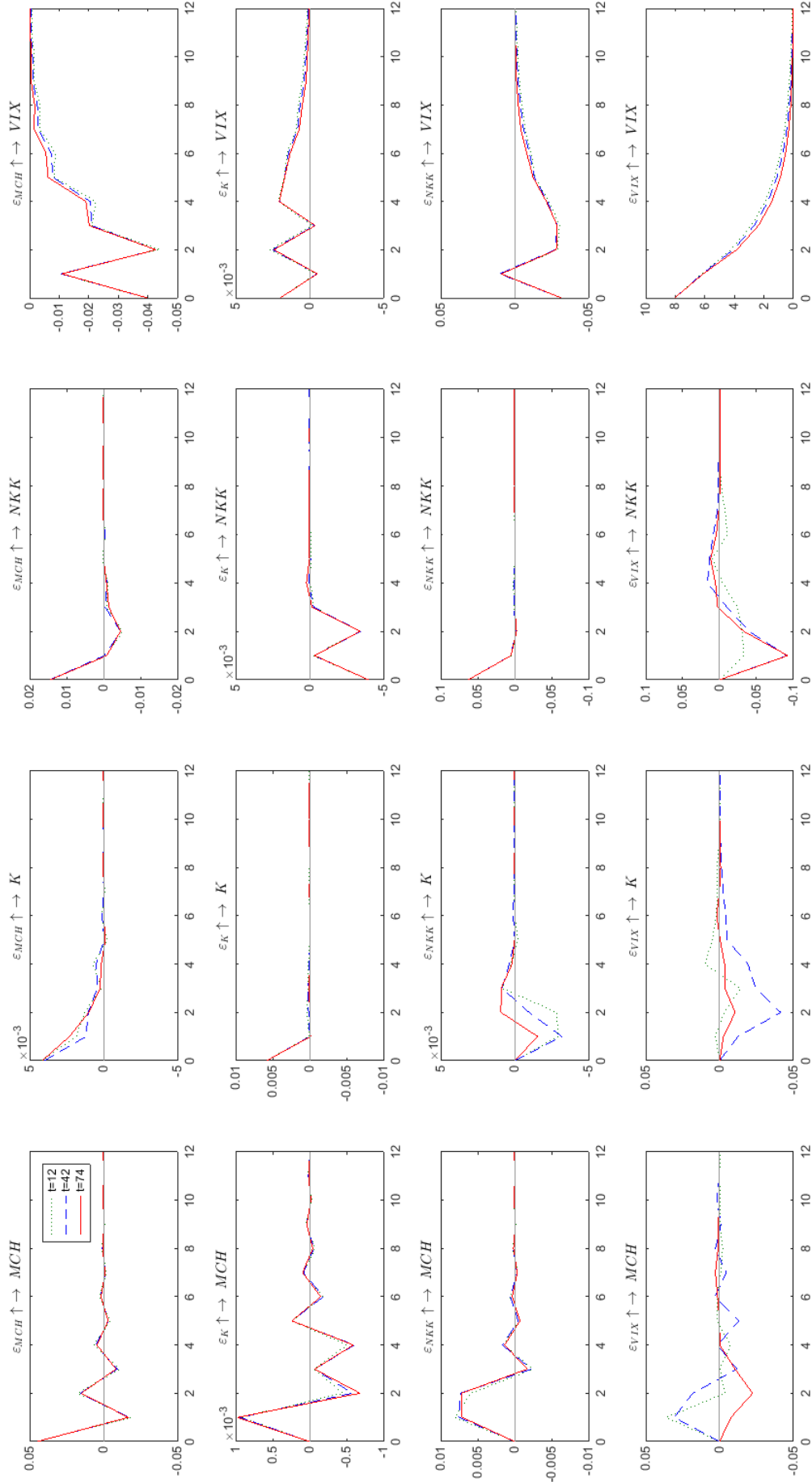


Figure 3.8: Impulse responses, VIX specification. Impulse responses gathered at periods of unusually low equity market volatility [Q2:1992, Q1:2000, Q4:2007] respectively corresponding to the lines t=12, 42, 74.

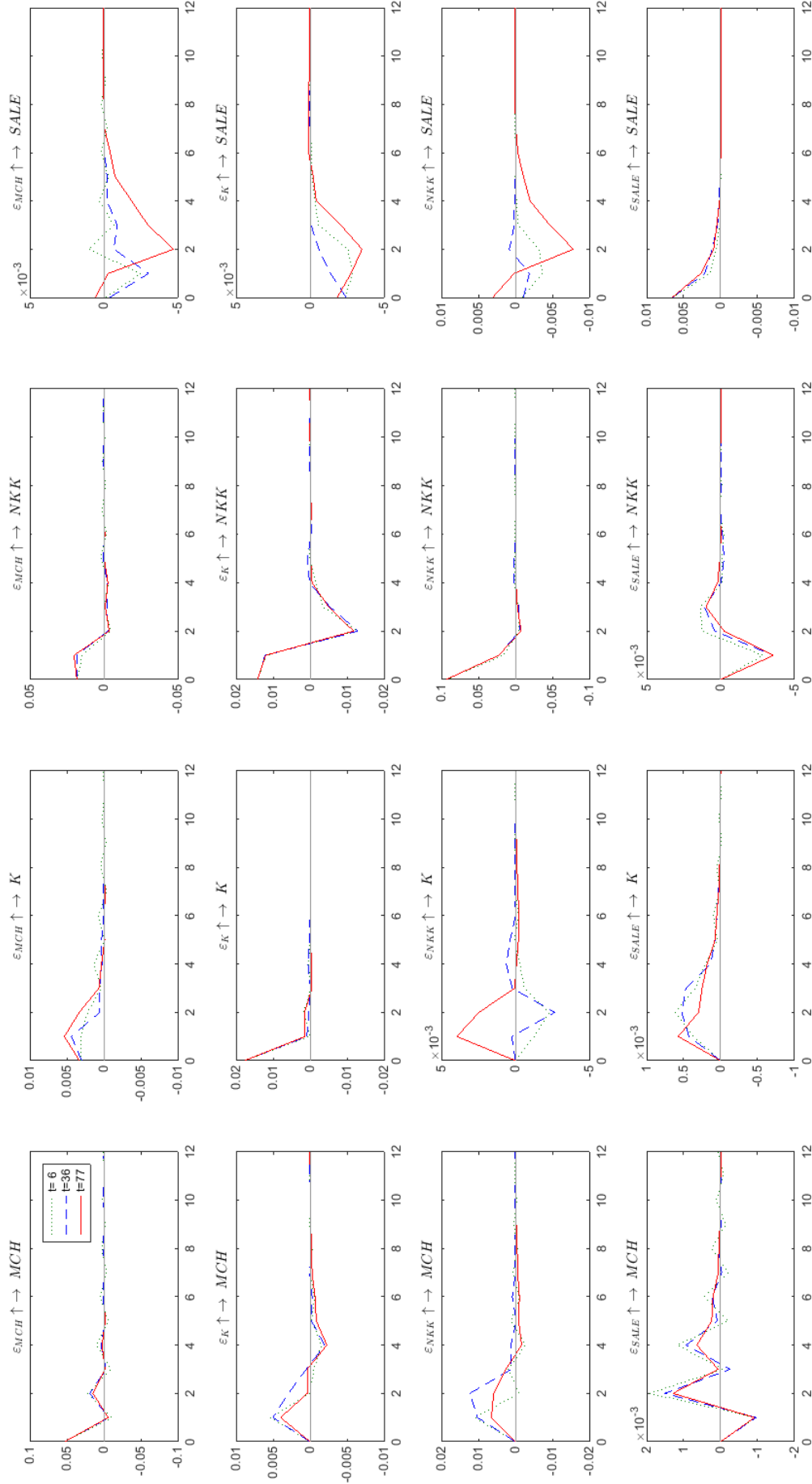


Figure 3.9: Impulse responses, Sales volatility specification. Impulse responses gathered at periods of unusually high equity market volatility {Q4:1990, Q3:1998, Q4:2008} respectively corresponding to the lines t=6, 36, 77.

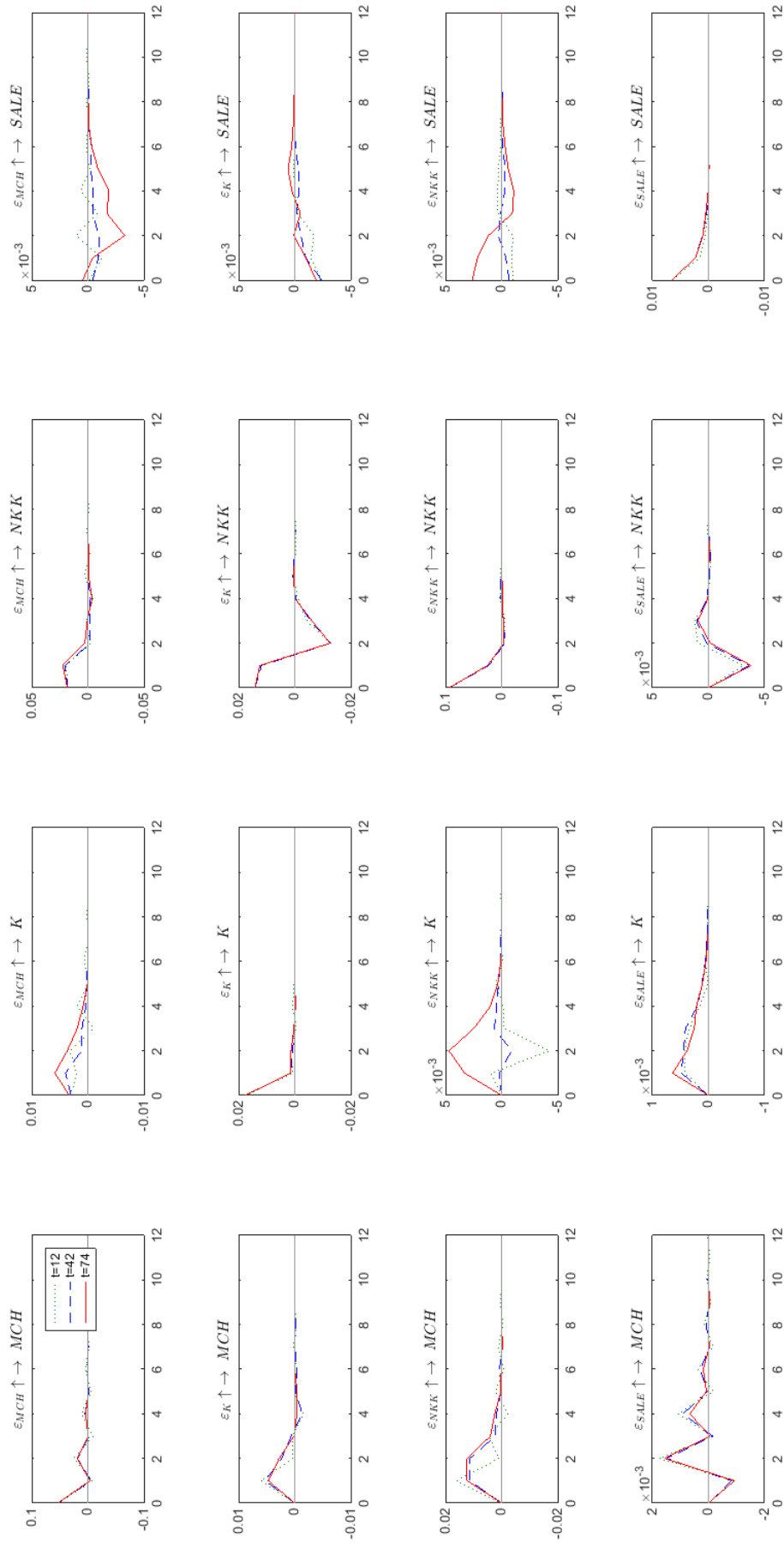


Figure 3.10: Impulse responses, Sales volatility specification. Impulse responses gathered at periods of unusually low equity market volatility {Q2:1992, Q1:2000, Q4:2007} respectively corresponding to the lines t=12, 42, 74.

Chapter 4

Investment, output and the yen

4.1 Introduction

Results from the DMA exercise in Chapter 2 indicate that there is substantial time-variation in the optimal forecasting model for investment. Input and output components of private investment variously enter and exit the optimal forecasting model, seemingly in correspondence with external shocks and domestic business cycles. The apparent time-variation in the forecasting utility of the real exchange rate is of particular interest due to the domestic and international policy relevance of real exchange rates as a potential policy tool and indicator. The open-economy macroeconomic literature suggests pricing-to-market shifts during this period may explain variations in real exchange rate impacts on private fixed investment. This chapter follows these suggestions and evaluates changes in sector-level investment sensitivities to real exchange rate variations in Japan.

Private fixed investment is viewed as a key component of growth in Japan, and is correspondingly an important policy indicator, and as discussed in Chapter 1, even a policy target. The role of the level of the real exchange rate has been actively discussed¹, particularly as it relates to output and investment; a high yen/USD exchange rate is frequently identified as a constraint of investment and growth in policy circles.² This chapter asks three questions. What is the relationship between the yen, invest-

¹Obstfeld (2011): “two periods of *endaka fukyo*, or recession induced by a strong yen, occurred in the late 1980s and the early 1990s... Japan’s real economic growth rate is rather strongly negatively correlated with the level of the yen’s real effective exchange rate ... [at] -0.38”.

²Governor Kuroda of the Bank of Japan: “the correction of excessive yen strength has had a positive effect on Japan’s economy. Corporate earnings have risen and sentiment has improved” (Kuroda, 2013).

ment and output in Japan? Did this relationship change through the 'Lost Decade' period? If so, what economic models may aid understanding of these shifts?

I discuss several open-economy macroeconomic models that may provide useful insight into the yen-investment-output relationships. Time-varying empirical analysis indicates a substantial structural change during the period, the nature and direction of which is partially at odds with standard model predictions. The evaluation of a model of multi-national firm investment in tradeable and non-tradeable sectors indicates increasing investment 'off-shore' may be driving change. Sectoral time-varying analysis supports this suggestion and indicates an important divergence in the drivers and impacts of secondary and tertiary industry investment in Japan.

This chapter contributes to the literature by providing evidence that investment doesn't always respond as expected to variations in the exchange rate, and therefore that the impact of exchange rate variations on output is not always as expected. In particular, innovations of gross private investment result in very different GDP responses depending on when the impulse is simulated: impulses in the 1980s are associated with strong increases to GDP, but impulses in the 2000's deliver near-zero impact in the short-term, and negative responses in the medium-term. A further counter-intuitive result is that investment innovations appear to drive short-term real exchange rate appreciation, but the medium-term response falls from a relatively strong depreciation of the real exchange rate in the 1980s, to an appreciation by the mid-2000s. This is evidence that broad private fixed investment innovations are no longer associated with increased gross output over the three-year medium-term in Japan.

This evidence supports the need for a more nuanced theoretical model of structural change in industrial structure of the economy over time.

4.2 Open-economy models of trade and growth

Multiple theoretical models are used across a large literature to examine similar questions to those that motivate this chapter, falling as they do in the intersection of trade, growth and macroeconomic research. Such multiplicity of models, together with evidence of significant structural change before, during and after the 'Lost Decade' period, makes policy analysis complex. The purpose of the modelling exercise in this

chapter is to examine the empirical evidence for competing theoretical explanations for major macroeconomic features of the Japanese economy. This is an exceptionally broad topic, but can be usefully narrowed by specifically considering the task at hand - contributing to the policy discussion concerning the importance of investment and exchange rate variation to Japanese output.

One standard model for examining trading economies at the macro scale is the open economy IS-LM model, generally discussed as Mundell-Fleming (here MF). Fully developed in Mundell (1968, chpt.18), merging Keynesian pricing assumptions and international market segmentation within a simple framework, the contributions of Mundell and Fleming provided the basic template for much subsequent research in both theory and policy. The continued relevance of this extended IS-LM approach is forcefully argued by Lane (2001), who notes the model's utility to policymakers in many countries and Krugman (2014) who argues examinations of the shifting IS, LM and BP curves usefully proxy findings from more complex modern macroeconomic models.

MF makes a series of assumptions: there is a single level of prices (P) which are fixed; aggregate demand is positively related to exogenous overseas output (Y^F) and the nominal exchange rate (e) and negatively to the domestic interest rate (r) which is separately determined to the global rate (r^*). Investment $I(r, Y_{t-1})$ is increasing in lagged income and decreasing in current interest rates. Money demand (M^D) is positively related to domestic income (Y) and negatively to r . Money supply (M^S) is set by the central bank. The capital account (KA) is affected by the domestic-foreign interest rate differential and expected exchange rate variation $E[\Delta e/e]$; the current account (CA) is determined by the relationship between Y and Y^F and the real exchange rate $X = eP^F/P$. The current-capital account balance of payments (BP) is set to zero to represent immediate exchange rate variation. Net exports are determined by local and foreign output, moderated by the real exchange rate.

Consider the IS-LM-BP curves, respectively:

$$Y = C(Y) + I(r, Y_{t-1}) + G + NX(Y^F, Y, \frac{eP^F}{P}) \quad (4.1)$$

$$M^D(Y, r) = M^S \quad (4.2)$$

$$BP = CA(Y^F, Y, \frac{eP^F}{P}) + KA(\eta(r - r_F), E[\Delta e/e]) = 0 \quad (4.3)$$

Under imperfect capital mobility the balance of payments curve BP is upwards-sloping as in Figure 4.1: a rise in output leads to an increase in imports in turn creating a deficit in the current account, forcing an increase in r to attract more capital. Assuming imperfect capital mobility is appropriate in the case of Japan (see the high-frequency evidence of segmented capital and consumption markets provided by Bengui et al. (2013)). Figure 4.1 below represents a diagrammatic analysis of a currency depreciation, noting that a devaluation increases NX only if, firstly, relative prices do not change (or are slow to change), so that a decrease in nominal exchange rate will also mean a decrease in the real exchange rate (exports become cheaper in foreign currency and more expensive in domestic currency) and secondly, the value of exports increases more than the value of imports. This in turn depends on the price elasticities of demand for exports and imports - the Marshall-Lerner condition where the sum of price elasticities of demand for exports and imports exceeds 1. If we assume the Marshall-Lerner condition holds and relative prices are fixed or sticky, then a fall (devaluation) in e_N shifts both IS and BP curves to the right:

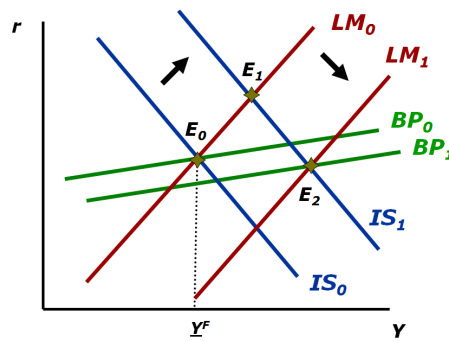


Figure 4.1: IS-LM-BP analysis of nominal depreciation

E0 to E1 : Devaluation shifts the equilibrium balance of payments from BP0 to BP1. Net exports shift IS0 to IS1. Output expands and in consequence interest rates rise, leading to a capital inflow, in turn resulting in a balance of payments surplus (point E1), and excess demand for domestic currency. E1 to E2 : under short-term

sticky exchange rates (a necessary assumption to model devaluation in an IS-LM-BP setting) if money supply expands to accommodate the excess demand of domestic currency, this will give a further impulse to aggregate demand and the final short-term equilibrium will be at a higher level of output. The impact on investment given $I(r, Y_{t-1})$ is unclear, but depends on the relative investment elasticity of interest rates and demand, although is likely positive given plausible empirical coefficients of cash-flow and interest rates (see the cost-of-capital and cash-flow discussions in Meehan (2015a) and long-term empirical analysis by Kothari et al. (2014)).

In summary, a Mundell-Fleming analysis of the short-term impact of devaluation on output and investment indicates a lower yen may be associated with increased output and investment. Even in this model the medium- and long-term impacts of devaluation are negligible, given competitiveness ($\frac{eP^F}{P}$) is determined by real factors, and a home currency devaluation will likely see import prices of raw materials rise and domestic firms potentially facing higher wage claims over time.

Although the Mundell-Fleming model has remained highly influential in academic and policy circles, developments in macroeconomics beginning in the late 1970s questioned the use of models in which the underlying preferences and technology were not fully specified and long-run budget constraints were not satisfied. Notably, Dornbusch (1976) presented a dynamic version of MF to consider exchange rate volatility in a deterministic perfect foresight setting. Dornbusch's extension discussed an 'overshooting' possibility in response to an unanticipated monetary expansion, in which instantaneous real exchange rate depreciation exceeds long-run depreciation - a result of expected future real exchange rate appreciation as the local interest rate is set below the world rate. This result enabled the model to predict a more volatile exchange rate than the underlying fundamentals posited in MF would otherwise indicate.

But the Mundell-Fleming-Dornbusch model lacked explicit choice-theoretic foundations which would enable it to demonstrate how gaps in aggregate demand and output close when prices are non-market clearing. Similarly, the lack of private and public intertemporal optimisation under budget constraints meant current account dynamics were difficult to analyse. This lack of microfoundations made welfare and behavioural analysis challenging. Furthermore, the simplistic modelling of investment in MF makes determining the direction of response in output and investment to

devaluation difficult.

Obstfeld and Rogoff (1995) developed a 'Redux' model which aimed to match the empirical utility and close connection to policy of MF in a choice-theoretic general equilibrium setting. This launched a literature stream known as 'New Open Economy Macroeconomics' (NOEM), developments in which did much to "bridge the traditional gaps between open macro and trade theory" (Corsetti, 2008). NOEM models typically feature imperfect competition in factor and/or product markets to allow the explicit analysis of pricing decisions by firms. This is an attractive feature when studying how firms may respond to real exchange rate shifts, although the lack of an explicit factor, capital, and corresponding investment terms hampers this. The fact that these models deal with firms with monopoly power, means that equilibrium production can fall below the social optimum (see the survey by Lane, (2001)), and create incentives for activist monetary policy intervention, which may be further analogous to the Japanese case.

'Redux' introduces money into the consumer utility function, together with a disutility of labour concept. Consumers hold CES preferences over a large variety of goods and can only hold assets in the form of a real (consumer price denominated) bond. Concerning international financial structure, 'Redux' contrasts with MF in that it only allowed international trade in the risk-free real bond, a modelling choice defended by Obstfeld and Rogoff (1996, P.679) who note both the depth of empirical evidence against perfect capital mobility, and that price and wage rigidities are difficult to reconcile with perfect international risk sharing. Consistent with the Mundell-Fleming reasoning, in the 'Redux' NOEM, exchange rate movements play the stabilising role of adjusting international relative prices in response to shocks via expenditure switching effects. More precisely, they model export prices as sticky in the currency of the producer, forcing nominal import prices to move in line with the exchange rate - Producer Currency Pricing.

Comparative statics analysis of the 'Redux' model (see the demonstration in Obstfeld and Rogoff 1996, P.682) in the case of an exchange rate depreciation forced by unanticipated expansion in the home money supply, where output prices are 1-period fixed, indicates current account changes will alter the distribution of world wealth, which in turn has real steady-state effects. The real exchange rate jumps to a new

(lower) steady state value, without overshooting (the model doesn't allow real interest rates to differ between countries). This induces expansion in domestic production and consumption; conceivably a mechanism by which a depreciation in the yen could increase both investment and output.

There are many ways in which this NOEM setup can be deepened with relevance to the Japanese situation here under analysis. One useful area of expansion considers loosening the Producer Currency Pricing restriction, and the associated Law of One Price, in the form of pricing-to-market, a widely-observed empirical phenomenon (Krugman, 1987). Another extension would allow for capital in the production function, thus giving an explicit role to investment. A third would engage with the empirical evidence that exchange rate changes not only alter domestic behaviour, but redirect spending (including investment).

Obstfeld (2001) discusses a range of models that work on loosening the Law of One Price assumption made by 'Redux'³. These models are able to demonstrate behaviour consistent with the low pass-through of exchange rate variations to domestic retail prices, but generate further issues by introducing a reverse inflexibility. Such a set-up effectively implies that exchange rate depreciation *improves* the home country's terms of trade, due to import prices remaining denominated in the domestic currency - which is difficult to reconcile with intuition or historical data. Obstfeld (2001) demonstrates the key issue with inflexible pricing setups (either in Producer or Local currency terms) is that they prevent exchange rate variations from redirecting expenditure internationally. This is a key point when it comes to modelling investment (and consequently output) responses to exchange rate variations, as cash-flow variations are important empirical determinants of firm behaviour (as demonstrated by the DMA analysis in Chapter 2). In the same paper, Obstfeld presents a relatively simple NOEM with some attractive features for evaluating Japan's international linkages. The model combines Producer and Local currency pricing setups and allows intermediate goods to be produced variously at foreign subsidiaries or domestic firms, which is particularly relevant when considering Japanese firms working in a regionally-integrated trade network⁴. The final-goods distributor uses a mix of local and foreign-produced

³Including Devereux and Engel (2003), and Chari et al. (2000) who adapt NOEM to allow Local Currency Pricing by exporters.

⁴See the production integration discussion in WTO and IDE-JETRO (2011), the financial integration

intermediate goods, each with separate production cost functions in labour, money and productivity: a sourcing setup. This setup enables a firm-level expenditure-switching impact from exchange rate variations. In equilibrium, a currency depreciation caused by a monetary expansion induces a domestic increase in both employment and production in this (capital-free) model, without impacting foreign output.

A further demonstration of the importance of correctly modelling international pricing is given by Betts and Devereaux (2001) who develop a NOEM in which the degree of Local or Producer currency pricing may vary, as can the degree of capital account integration. Further, they allow a role for capital as a factor of production, making this a particularly useful model in examining how exchange rates, investment and output may interrelate in the Japanese setting. They find that the degree of completeness of asset markets has minimal impact on the international transmission of monetary policy impacts. This is in stark contrast with the importance of pricing-to-market variations, as the modelled impact of monetary expansion on output, consumption, investment and the terms of trade are reversed when switching from local (positive) to producer (negative) currency pricing.

In the book chapter in which Betts and Devereaux (2001) present a capital-augmented NOEM, the reaction of the real exchange rate to investment variations is not explicitly plotted. But the requirement that output equal aggregate demand means we can gain a sense of likely drivers of investment variations and the reactions of related variables. In the market-clearing equation for their model, total demand is a function of consumption, government and investment goods. The investment goods can be supplied by local or foreign firms that either do or do not price to market. Partial equilibrium analysis would suggest that the reaction of the real exchange rate to investment variations depends on both the location of investment goods purchased (from foreign or local producers) and the state of pricing-to-market. In the model these are summed separately and it is conceivable that the change in proportional magnitudes of these sub-types of investment good providers may account for variations in the real exchange rate response. From a partial-equilibrium, static analysis, it is difficult to identify the magnitudes of pricing-to-market variations necessary to induce a change

discussion by Miankhel et al. (2011) and the demonstration that global production sharing strengthens trade and investment relations between home and host countries by Nishitateno (2013) in a case study of the Japanese automobile industry.

in the sign of exchange rate response to investment variations.

A more manageable task would be to consider what structural changes within markets could induce pricing-to-market variations. The implications from both the Betts and Devereaux (2001) and Obstfeld (2001) NOEM assumptions are that such changes are necessarily representative of variations in intermediate good (producer-priced) and final consumption goods (local-priced) consumption patterns. Evidence of such changes may therefore imply changes in industrial sector consumption patterns. Any evidence of a re-weighting of secondary industry demand (in terms of traded goods) and tertiary industry demand (in terms of final consumption goods) may be consistent with the pricing-to-market variations implied.

The analysis from Obstfeld (2001) and Betts and Devereaux (2001) is suggestive in light of dynamic model averaging findings in Chapter 2. In that paper the degree of usefulness of the real exchange rate in predicting private fixed investment varied considerably across the 1980-2014 estimation period. The modelled NOEM logic suggests variations in pricing-to-market behaviour during this period may explain variations in real exchange rate impacts on private fixed investment. The possibility of different pricing-to-market sensitivities in different industrial sectors may supply the drivers and means of testing for these pricing variations.

But any such variation would be at odds with the strong cross-country empirical findings by Bems (2008) who demonstrated the aggregate investment expenditure shares on tradeable and non-tradeable goods are very similar across countries and substantially stable over time. The modelling literature has evaluated the theoretical impact of this finding, with recent International Real Business Cycle modelling by Oviedo and Singh (2013) allowing multisectoral capital inputs of stable proportions. Their research indicated models augmented in this way could demonstrate improved matching of macroeconomic data patterns in terms-of-trade, sectoral production quantities and consumption.

There is also substantial empirical literature demonstrating investment sensitivity to real exchange rate variations, in partial contrast to Bems (2008). Campa and Goldberg (1999) demonstrated the varying impact of real exchange rate appreciation on manufacturing sectors with varying export exposure - a 'revenue channel' finding. The Nucci and Pozzolo (2001) findings regarding Italian data support the theory that

a depreciation of the real exchange rate has a positive effect on investment through the revenue channel, and a negative effect through the cost channel, a finding made by comparing sectoral sensitivities to exchange rate variations with estimated sectoral cost and revenue external exposures. Cavallo et al. (2013) empirically test the impact of relative price volatility on sector-level investment in the manufacturing sectors of 65 countries. They find that changes in real exchange rate volatility alter observed level of manufacturing investment away from the level predicted by sector-level TFP. In the Japanese case, Matsubayashi (2011) demonstrated that yen depreciation stimulates corporate investment in correspondence with a sector's external exposure.

To complement the above discussion of the exchange rate - investment relationship, and to provide context for further examinations of the associated policy implications, it is important to consider the relationship between investment and output. Any policy discussion of the exchange rate - investment relationship is going to crucially depend on the link between investment and growth. It is therefore worth noting that the positive impact of investment on output $\{(\delta I / \delta Y) > 0\}$ is a standard part of economic modelling in which capital is held as a factor of production and increases thereof consequently increase output. The empirical literature finds some variation in evidence for this assumption; Podrecca and Carmeci (2001) find Granger causality of investment shares to growth rates to be negative, which supports recent work by Cheung, Dooley and Susko (2012) whose simple regression estimates of lagged investment on rolling 3-year real GDP growth rates found a possible negative relationship between investment and growth for several developed countries, including Japan. Vanhoudt (1998) argues any negative relationship may be consistent with neo-classical growth models: where an economy is on its balanced growth path under some level of investment, an exogenous increase in foregone consumption suddenly raises investment which instantly raises the growth rate. This growth rate then gradually decreases as the economy returns to the long-run growth rate of exogenous technological change.

This section surveyed the open economy modelling literature with particular focus on two key questions: what determines the exchange rate, and what is the impact of change on the exchange rate on investment and output. The more recent literature examined indicates the anticipated directions of movements in the real exchange rate are

dependent upon capital account and pricing-to-market assumptions, and the empirical literature emphasises the importance of sectoral variations. These more nuanced models are in sharp contrast with the earlier and simpler models which still tend to inform policy debate, leading to the apparent inconsistency between statements that yen appreciation will always be harmful to investment and growth (and depreciation beneficial) and the empirical evidence. This has important consequences for policy advice and response.

4.3 Counter-intuitive responses: TVP-VAR estimation

This section presents evidence on the output-investment-real exchange rate relationship in Japan using a time-varying VAR method with stochastic volatility to allow for structural shifts in the relationships between variables. The purpose is to examine whether *prima facie* there is a need to reconsider the more nuanced models discussed in Section 2 in the case of Japan. The resulting TVP-VAR impulse response diagrams are challenging to fully integrate with simple Mundell-Fleming or the more nuanced New Open-Economy Macroeconomics model, as there are periods in which the response directions are not as anticipated.

Econometric estimations of open-economy macroeconomic models have featured widely in the literature. Selections from a large literature include Cushman and Zha (1997), who empirically identify the impact of monetary policy in a VAR motivated by Obstfeld and Rogoff's (1995) 'Redux' model and Betts and Devereaux (2001) who motivate their NOEM model by estimating monetary policy shocks on output, investment, exchange and interest rates in the G7. In a different stream of open-economy modelling, the influential papers of Smets and Wouters (2003, 2007) compare DSGE model impulse response systems for the EU and US respectively with impulse responses from VAR analyses. Bergin (2006) tests the NOEM implications using VAR models fitted to US and G7 data, finding general support for local currency pricing models and is able to generate a good general fit to the exchange rate and current account. A summary of the international transmission of interest rates via the exchange rate is provided by Engel (2015).

But these estimation techniques typically evaluate the average impact of coef-

ficients over the estimation period, and as such are poorly suited to questions of structural change over time. The Japanese economy experienced substantial macro-economic variable variations in both level and volatility since the 1970s - particularly in consideration of the 'bubble' years of the late 1980s as compared with the 'Lost Decade' of the 1990s.

Figure 4.2 depicts the breakpoint analysis results from Zivot-Andrews (1992)⁵ unit-root tests for Gross Domestic Product (GDP), private fixed investment and the real exchange rate in Japan, Q1:1980 to Q1:2010. Domestic Japanese private investment (I) data are sourced from Japan's Cabinet Office 'The private sector capital stock bulletin' SNA release, sub-section 'Gross new investment by industry, excluding construction in progress'. This data is collected by the Ministry of Finance directly from corporations, (174,944 manufacturing corporations and 848,777 non-manufacturing corporations in Q2:2014). Companies supply information taken from 'Statement of Financial Position' equivalents, which do not separate investment location (i.e. foreign- or domestic-based investment, a point discussed in greater detail in Section 5). The real exchange rate of the Japanese yen ($\frac{e^{\text{PF}}}{P} = X$) are the 'Real Effective Exchange Rates Based on Manufacturing Consumer Price Index for Japan' data release from the OECD's 'Main Economic Indicators'. The same source provides Japanese income data (Y) 'Gross Domestic Product for Japan'.

The results are consistent in identifying a structural shift in the early 1990s for all of GDP, private fixed investment and the real exchange rate. Results in Table 4.1 indicate the null hypothesis of a unit root is rejected at the 5% level for GDP and private investment, with a borderline non-rejection for the real exchange rate. Given that permanent structural shifts in the real exchange rate may be unlikely under an inflation-targeting central bank, this chapter treats all variables as $I(0)$.

⁵Zivot and Andrews (ZA, 1992) proposed a unit-root test in which the existence and timing of a single structural break would be determined endogeneously from the data. The ZA approach is to perform a sequential test using the full data sample in which a different dummy variable is allocated to each possible structural break date. The final break date is selected by choosing the smallest t-statistic from Augmented Dickey-Fuller tests of unit root. This is equivalent to ensuring that the break date will be chosen when the evidence for a unit-root process is weakest. If the analyst wishes to extended this test to allow for the possibility of multiple break points, they will inevitably face a the trade-off between unit-root test power and the amount of information included to evaluate the structural breaks. This chapter uses the single-break unit root test proposed by Zivot and Andrews (1992) under the assumption that accounting for the structural break of the 'bubble' era to 'Lost Decade' transition can allow an efficient unit root test - an assumption supported by the output trend in Figure 4.6.

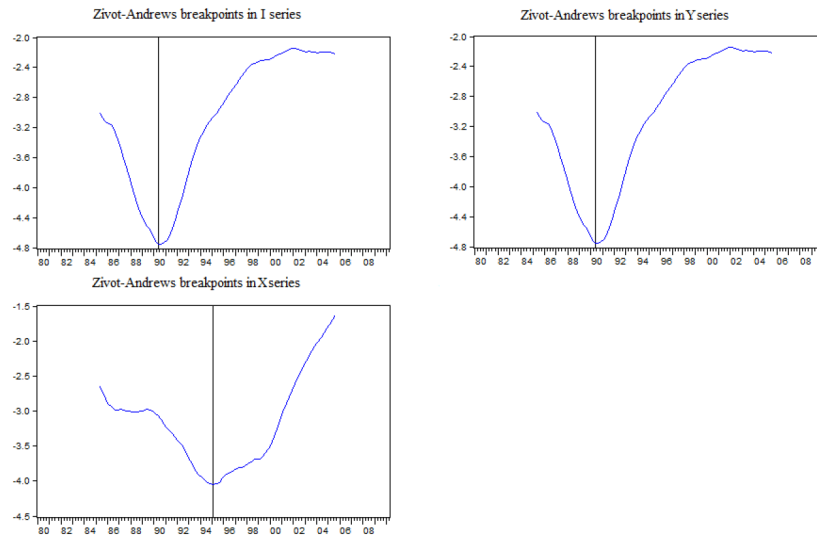


Figure 4.2: GDP (Y), private fixed investment (I) and the real exchange rate (X) for Japan: Zivot-Andrews unit root test results of the point in time of the estimated breakpoints in trend. The y-axis depicts the critical values at each point in time as per Zivot and Andrews (1992).

	Y	I	X
ZA test statistic	-4.63	-4.76	-4.05
1% critical value	-4.80		
5% critical value	-4.42		
10% critical value	-4.11		

Table 4.1: $\{Y, I, X\}$ unit root test results on log-levels data against the null of a unit root process with drift, where the alternative is a trend stationary process allowing for a one-time structural break in trend as per Zivot and Andrews (1992).

This unit-root evidence suggests any useful estimation technique must be sufficiently flexible as to allow the level and volatility of both variable coefficients and the exogenous ‘structural shock’ error term to vary stochastically over time. These requirements are satisfied by the use of a time-varying parameter vector autoregression which allows for stochastic volatility (TVP-VAR). A fully-worked outline of the TVP-VAR methodology is given in Chapter 3 of this thesis: ‘Uncertainty and investment in Japan’.

In the following TVP-VAR estimation of the GDP, investment and the real exchange rate with 2 lags (as indicated by AIC, with AIC selected as per reasoning in Chapter 2), all data are in quarterly, seasonally-adjusted, log-levels forms covering the period Q1:1980 to Q1:2010 inclusive.

In considering the determinants of output change in the IS curve in the MF system, the question of specification in this chapter’s posited output-investment-exchange rate

relationship immediately occurs. Consumption is implemented as playing a substantial role in the MF model as both a determinant of and determined by output. But the documented low correlations between consumption and the real exchange rate (Backus and Smith, 1993) may support the setting-aside of consumption when evaluating the impact of real exchange rate variations on growth.

Both the lower-triangular covariance matrix used in the TVP-VAR estimation and the Cholesky decomposition used in the VAR analysis are highly sensitive to changes in variable ordering. The ordering here (GDP; Private Fixed Investment; Real Exchange Rate ; {Y, I, X}) reflects the anticipated speed of reaction of variables; that the real exchange rate shifts more rapidly in response to shocks than does aggregate private fixed investment, which in turn responds more quickly to shocks than does GDP. As with many studies of this kind, changing the order gives different results.

4.3.1 Results

Figure 4.3 displays the parameter estimation evaluation tests from the TVP-VAR analysis of the GDP, investment and the real exchange rate. These results show the Markov Chain Monte Carlo (MCMC) algorithm is functioning efficiently, covering parameter distributions with minimal residual autocorrelation. This chapter draws TVP-VAR impulse response charts with lines at 4, 8 and 12 quarters-ahead for each time period. Figure 4.4 displays the impulse response diagram. As discussed in Chapter 3, reading TVP-VAR impulse response diagrams differs from standard VAR impulse response diagrams due to the number of coefficients estimated and the concomitant myriad of response vectors to be drawn. The standard method is to draw the n-period response lines across time, as follows below. This is opposed to drawing the system response line across n-periods, as displayed in Chapter 3. A useful metaphor to bear in mind in reading these charts is the leaves of a book: a normal impulse response diagram is a single page, a TVP-VAR impulse response is drawn across the edge of all the leaves.

In this specification, positive shocks to output result in increases in gross private investment that are relatively consistent across the estimation period, i.e. the impulse-response plot is roughly flat from 1980 to 2010. Similarly, positive GDP impulses result in relatively consistent short-term negative impacts on the real exchange rate.⁶ This

⁶At this point it is worth noting that a fall in the real exchange rate is broadly analogous to currency

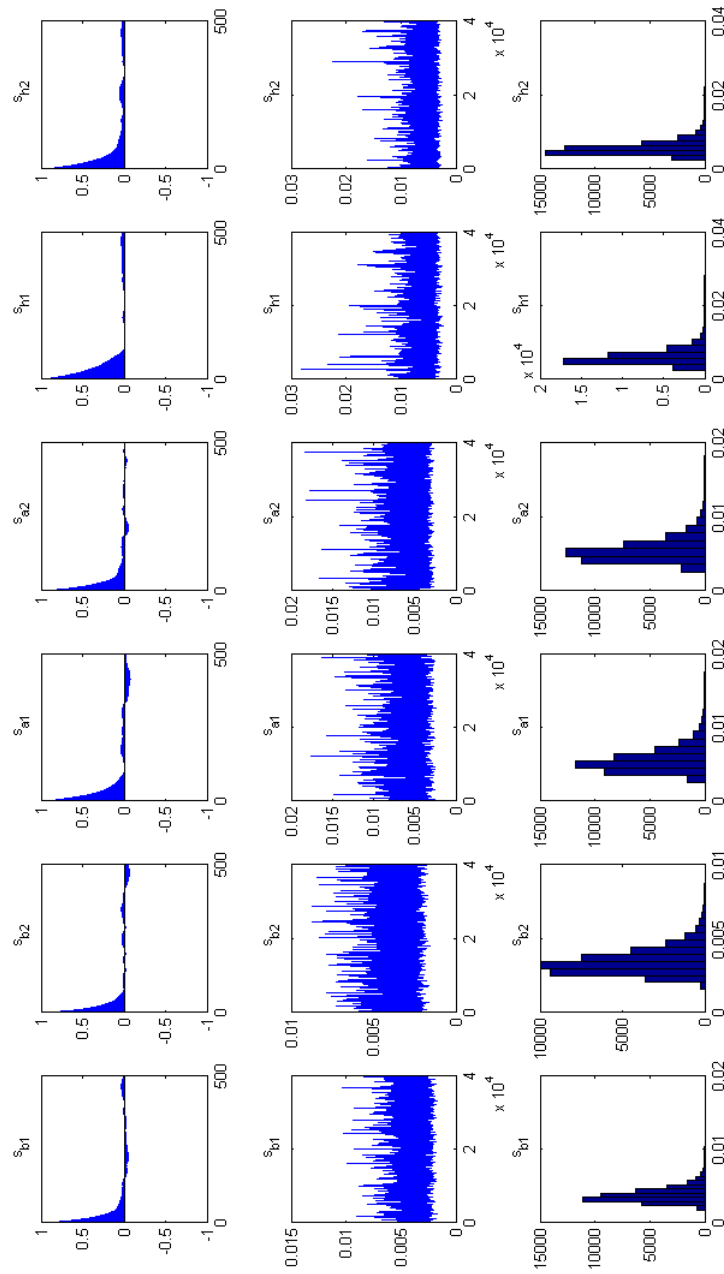


Figure 4.3: GDP, Investment, Real exchange rate TVP-VAR estimator diagnostic charts.

makes intuitive sense in that an economic expansion may well be associated with increased inflation or more imported goods; it is explained in the MF framework by an increase in output raising the real interest rates and attracting capital inflow.

Innovations of gross private investment result in very different GDP responses depending on when the impulse is simulated. Impulses in the 1980s appear to deliver strong increases to GDP. But impulses in the 2000's deliver near-zero impact in the 4-quarter response, and negative responses in the 12-quarter. This is evidence that broad private fixed investment innovations are no longer associated with increased gross output over the three-year medium-term in Japan. The crossover point is broadly in the 1999-2001 period, but the negative trend of decreasing GDP returns to investment shocks is quite consistent throughout the estimation period. This is difficult to explain given the anticipated positive sign of $(\delta I/\delta Y)$ in macroeconomic models discussed earlier.

Investment innovations to appear to drive short-term real exchange rate appreciation. But the 12-quarter response falls from a relatively strong depreciation of the real exchange rate in the 1980s, to an appreciation by the mid-2000s. This variation is difficult to interpret the MF framework, as an increase investment would shift the IS curve to the right, raising domestic interest rates and causing the LM to shift outwards to restore BP equilibrium; such a framework is unable to generate both positive and negative real exchange rate responses to investment innovations. In Obstfeld's (2001) NOEM with local-currency pricing for consumption goods and producer-currency pricing for intermediate goods, examining the monetary equilibrium conditions indicates a shift in the real exchange rate that does not influence output (as per the impulse response constraints in a VAR model) must be counter-balanced by shifts in local and foreign employment. In this modelling setup, local employment (or investment) falling following a real exchange rate appreciation implies a far larger increase in foreign employment must occur. This may indicate an important role for direct investment overseas (and possibly be analogous to the 'hollowing-out' suggestion,⁷) and, in light of the negative response of output to investment innovations in the TVP-

appreciation, and this chapter will continue to refer to 'appreciation' and 'depreciation' to avoid confusion.

⁷Saito (2013) frames the issue clearly in the introduction to The Brookings Institution's (2013) panel debate 'The hollowing-out of Japan's economy: myths, facts and countermeasures'. Referred to as 'kudoka' in Japan, hollowing-out is the concept of a local productive base declining as a result of firms preferring investment in foreign productive capacity.

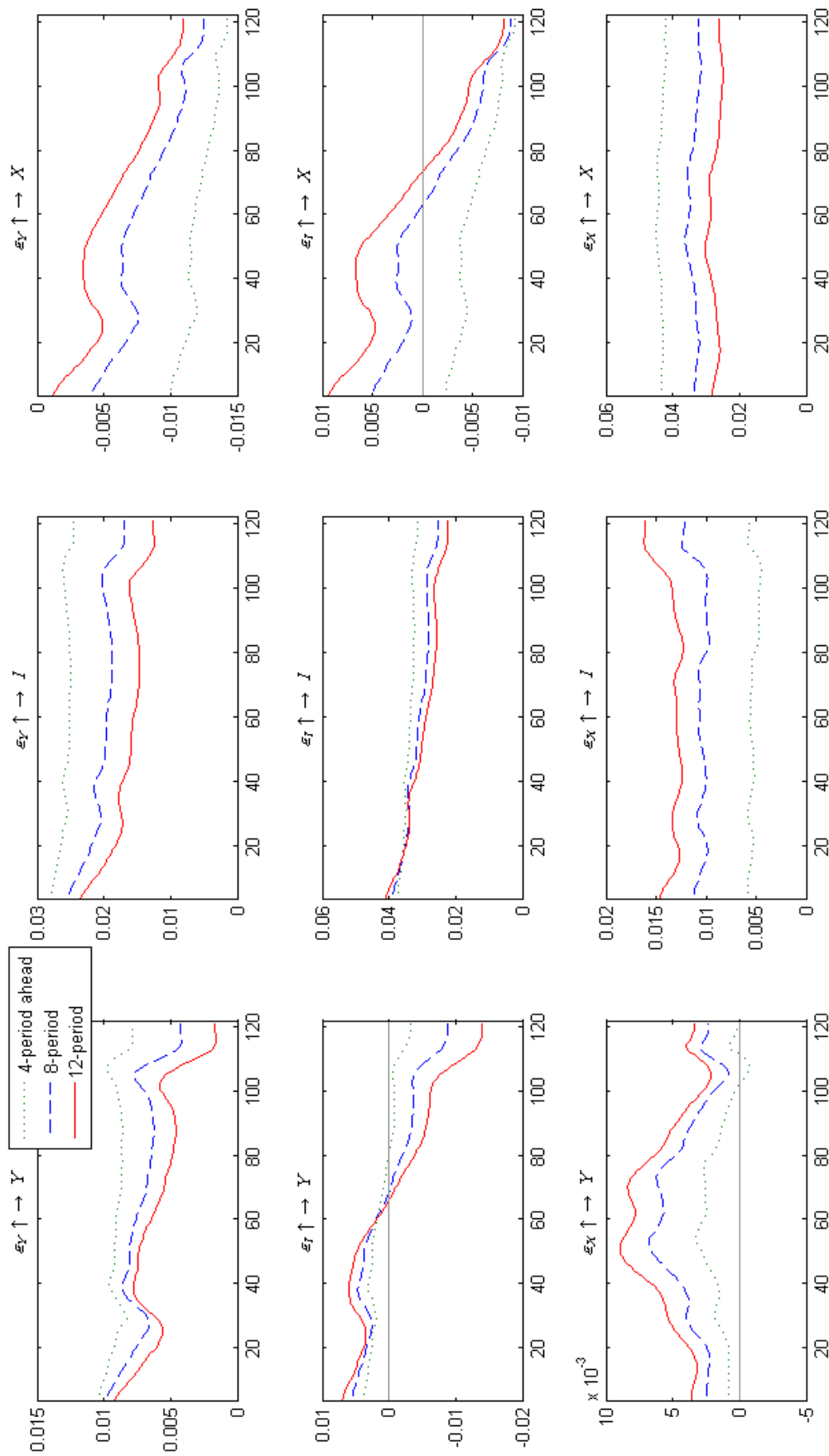


Figure 4.4: Impulse response from the TVP-VAR analysis of $\{Y, I, X\}$ -ordering, Q11980:Q42010, 2 lags. Impulses plotted at $Q=4, 8, 12$ periods ahead for each period.

VAR system by 2010, may merit further investigation.

Real exchange rate depreciation impulses on output have generally positive impacts across 4, 8 and 12 quarters: a real exchange rate depreciation appears associated with increased levels of output across the 1980-2010 period. This result is consistent with prior expectations from open-economy macro models discussed earlier, and may suggest the model is properly specified.

The results indicate real exchange rate depreciation shocks are associated with consistently positive investment responses across the estimated period. This may indicate Japanese firms' investment activities respond more positively to a fall in the cost of imported capital (as implied in the exchange rate) than to a fall in the cost of domestic capital (i.e. a fall in the interest rate). An alternative view is that an increase in the real Yen/USD ratio may imply an increase in the Yen-value of overseas earnings (if USD-denominated). These are two quite separate suggestions, but as with the Investment-Real exchange rate impulse response discussion above, both suggestions are consistent with the concept that international exposure of industrial production is key to understanding the Japanese macro-economy's international linkages.

The results from the TVP-VAR analysis of the $\{Y, I, X\}$ -ordered group for the period 1980-2010 in Japan require further analysis. In particular, that innovations of gross private investment result in very different GDP responses depending on when the impulse is simulated is suggestive of structural change. This suggestion is supported by the result that investment innovations appear to drive short-term real exchange rate appreciation, but medium-term responses appear time-inconsistent.

To understand the results of impulses to and from the real exchange rate, the relative balance of externally- and internally-exposed investment should be carefully modelled and evaluated, and is presented in Section 4.3. The counter-intuitive results from the investment-output shocks require discussion of FDI, together with analysis of data composition, and is discussed in Section 4.4.

4.4 Modelling open-economy investment

TVP-VAR impulse responses of a $\{Y, I, X\}$ -ordered system for Japan suggested private fixed investment would respond positively to depreciation of the real exchange rate.

Further, responses of the real exchange rate to investment innovations were suggestive of pricing-to-market variations, when viewed from a NOEM perspective. This section discusses and estimates a model for investment that allows for domestic firms' local investment in tradeable and non-tradeable sectors, as well as FDI in tradeable sectors. The model provides one possible theoretical explanation for the counter-intuitive patterns observed in the simulations, in that it provides a framework for looking for evidence of change in the economic structure of Japan. Least squares analyses of three models of firm investment are conducted using Japanese data from 1980 to 2010.

Working from the income identity $Y = C + I + G + (X - M)$ Campa and Goldberg (1999), Nucci and Pozzolo (2001, 2011) and Landon and Smith (2009) empirically evaluate models in which allows firms are able to import inputs or source them domestically, and export outputs or sell them domestically. This structure includes both investment (capital goods) and intermediate goods. The following model is an extension of Landon and Smith (2009, here referred to as a model of Type 1 firms) extended to enable consideration of *three* firm types. Type 1 produces in the local country using imported and local inputs and sells output in both foreign and local markets. Type 2 produces in the local country using imported and local inputs which it sells only in the local market. Type 3 produces in the foreign country using foreign and local goods, which are then sold in local and foreign markets.

These three firms types are modelled with specific features that can be observed in the Japanese economy, and motivated by the results in Section 2. Type 1 firms produce tradeable goods in Japan, using local (labour) and tradeable (capital) inputs. Type 2 produces non-tradeables in Japan, using traded capital and local labour. The modelled Type 3 firms correspond to foreign-based subsidiaries of Japanese-owned tradeable goods firms.

Type 1: a representative firm in sector j produces output using domestic and imported inputs. The firm sells output Q_j in domestic and foreign markets: Q_j^D and Q_j^F respectively. The firm uses tradeable capital inputs K_j with non-tradeable inputs L_j to produce output according to the production function:

$$Q_j^D + Q_j^F = f(K_j, L_j) \quad (4.4)$$

The firm chooses its input and output quantities via maximising the present discounted value of current and future real net cash flow:

$$\max_{Q_j^P: Q_j^F: K_j: I_j: L_j} \sum_{t=0}^{\infty} (1+r_t)^{-t} \frac{1}{P_t} \{P_{jt}Q_{jt} + eP_{jt}^F Q_{jt}^F - W_{jt}L_{jt} - P_{Kjt}I_{jt}\} \quad (4.5)$$

subject to Equation 4.3.1 and the capital accumulation dynamic:

$$K_{jt} = (1 - \delta)K_{j,t-1} + I_{jt} \quad (4.6)$$

where in time t , P_t is the domestic general price level, P_{jt} is the domestic price of the firms production, P_{jt}^F is the foreign price of production, e is the domestic currency price of one unit of foreign currency, W_t is the price of domestic non-tradeable inputs, P_{Kjt} is the price of new investment I_t in sector j , $(1+r_t)^{-t}$ is the constant discount factor and δ is the constant rate of depreciation.

Demand for the firm's output depends on relative prices and income, and from Marston (1990), imply inverse demand functions:

$$P_j = \rho_j(Q_j, y)P, \quad \frac{\delta \rho_j(Q_j, y)}{\delta Q_j} < 0, \quad \frac{\delta \rho_j(Q_j, y)}{\delta y} > 0 \quad (4.7)$$

$$P_j^F = \rho_j^F(Q_j^F, y^F)P^F, \quad \frac{\delta \rho_j^F(Q_j^F, y^F)}{\delta Q_j^F} < 0, \quad \frac{\delta \rho_j^F(Q_j^F, y^F)}{\delta y^F} > 0 \quad (4.8)$$

where P^F is the foreign general price level; y and y^F are domestic and foreign real income respectively. The cost of increasing capital by investment is a function of the prices of the inputs required to produce the capital. I assume these are non-tradeable labour and tradeable capital. The real per unit cost of investment goods purchased by the representative firm in sector j will depend on the real price of non-tradeable domestic inputs ($\frac{W}{P}$) and the real domestic price of tradeable capital, ($\frac{eP_K^F}{P}$):

$$\frac{P_{Kj}}{P} = p_{Kj}(\frac{W}{P}, \frac{eP_K^F}{P}) \quad \frac{\delta(P_{Kj}/P)}{\delta(W/P)} > 0, \quad \frac{\delta(P_{Kj}/P)}{\delta(eP_K^F/P)} > 0 \quad (4.9)$$

where P_K^F is the foreign currency price of tradeable capital.

Solving the maximisation problem of the firm given in Equation 4.3.1 yields an expression for the long run optimal level of capital:

$$K_j = \left(\frac{eP^F}{P}, \frac{eP_K^F}{P}, \frac{W}{P}, y, y^F, r, \delta \right) \quad (4.10)$$

In order to transform Equation 4.3.7 into a long-term investment format, I assume the growth rate of capital in sector j is constant and equal to domestic real income y :

$$I_j = (y + \delta)K_j \quad (4.11)$$

This transformation allows the analysis of investment without capital asset prices entering into the estimation. This is of particular use in the Japanese context, where corporate capital levels were influenced by land-price valuation peaks in the early 1990s, as well as ongoing loan valuation issues (i.e. the 'zombie' firms of Caballero, Hoshi and Kashyap, 2008). Given the identity in Equation 4.3.9, we can substitute Equation 4.3.8 into 4.3.7 and derive the long-run investment function of Equation 4.3.10:

$$\frac{eP_K^F}{P} = \left(\frac{eP^F}{P} \right) \cdot \left(\frac{P_K^F}{P} \right) \quad (4.12)$$

$$I_j = I_j \left(\frac{eP^F}{P}, \left(\frac{eP^F}{P} \right) \cdot \left(\frac{P_K^F}{P} \right), \frac{W}{P}, y, y^F, r, \delta \right). \quad (4.13)$$

Equation 4.3.10 indicates a depreciation of the real exchange rate affects the level of Type 1 firms' investment through three channels: export earnings, the price of imported capital and the price of intermediate goods. A rise in $\frac{eP^F}{P}$, in this instance equivalent to a depreciation of the yen, increases the domestic currency value of foreign exports and increases domestic investment. In the opposite direction, a rise in $\frac{eP_K^F}{P}$ increases the domestic currency cost of foreign capital and could be expected to decrease investment. As both positive and negative effects are evident in this model the impact of a currency depreciation on investment is uncertain.

As the indeterminacy of impact direction is linked to the cost of imported capital, sectoral variation in investment response to currency depreciation may be evident; I

suggest a country that experiences shifts in the relative weighting of industrial sectors should exhibit different investment responsiveness to currency variations over time.

Type 2: a firm that uses imported capital to produce non-tradeable goods would face a different optimisation problem. Sectors featuring such firms may include construction, transport, healthcare and finance. With only a single inverse demand function, Equation 4.3.4, the long run investment function would be:

$$I_j = I_j\left(\frac{1}{p}, \left(\frac{eP^F}{p}\right), \left(\frac{P_K^F}{P^F}\right), \frac{W}{p}, y, r, \delta\right) \quad (4.14)$$

A firm described by this function would respond to the increased foreign-denominated cost of capital goods arising from a depreciation of the yen by choosing a lower long-term level of investment.

Type 3: to understand the role FDI options play, it may be informative to consider the case of a firm that accrues earnings domestically from both foreign and domestically-sold goods that are produced overseas:

$$Q_j^D + Q_j^F = f(K_j^F, L_j^F,) \quad (4.15)$$

$$\max_{Q_j^D: Q_j^F: K_j^F: I_j^F: L_j^F} \sum_{t=0}^{\infty} (1+r_t)^{-t} \frac{1}{P_t} \{P_{jt} Q_{jt} + eP_{jt}^F Q_{jt}^F - eP_{jt}^F W_{jt}^F L_{jt}^F - P_{Kjt} I_{jt}^F\} \quad (4.16)$$

$$K_{jt}^F = (1-\delta)K_{j,t-1}^F + I_{jt}^F \quad (4.17)$$

where K^F, L^F, I^F, W^F indicate the foreign equivalents of capital, non-tradeable inputs, investment and non-tradeable input costs respectively. The FDI-option firm faces unchanged inverse demand functions (Equations 4.3.4 and 4.3.5). The real per unit cost of investment goods purchased by the representative firm in sector j will depend on the real domestic price of non-tradeable foreign inputs $(eP_{jt}^F \cdot \frac{W^F}{P})$ and the real domestic price of tradeable capital, $(\frac{eP_K^F}{P})$:

$$\frac{P_{Kj}}{P} = p_{Kj}\left(\left(\frac{eP_{jt}^F}{P}\right), \left(\frac{W^F}{P}\right), \frac{eP_K^F}{P}\right) \quad (4.18)$$

$$\frac{\delta(P_{Kj}/P)}{\delta((eP_{jt}^F).(W^F/P))} > 0, \frac{\delta(P_{Kj}/P)}{\delta(eP_K^F/P)} > 0$$

Solving the maximisation problem of the firm yields an expression for the long run optimal level of capital:

$$K_j = \left(\frac{eP^F}{P}, \frac{eP_K^F}{P}, \frac{W^F}{P}, y, y^F, r, \delta \right) \quad (4.19)$$

Using structures from Equations 4.3.12 and 4.3.14, the long-run investment function becomes:

$$I_j = I_j \left(\frac{eP^F}{P}, \left(\frac{eP^F}{P} \right) \cdot \left(\frac{P_K^F}{P^F} \right), (eP_{jt}^F) \cdot \left(\frac{W^F}{P} \right), y, y^F, r, \delta \right). \quad (4.20)$$

A Type 3 firm with the above maximisation function would experience a depreciation of the yen, or rise in $\frac{eP^F}{P}$, as a rise in domestic earnings, an increase in the cost of foreign capital and an increase in non-tradeable input costs. In the scenario where all returns from sales had to be repatriated, an FDI-only firm would experience increases in the ability to invest along with the cost of investment. The model assumes the firm can only invest overseas using expatriated domestic capital. Accordingly, the increase in external investment costs (W^F and eP_K^F) would be unable to be offset by the increase in domestic and repatriated foreign earnings ($P_{jt}Q_{ft} + eP_{jt}^F Q_{jt}^F$), as all income would need to be adjusted by the depreciated exchange rate in order to be applied to capital. In consequence, this model suggests the effect of a rise in $\frac{eP^F}{P}$ would have a uniformly negative impact on FDI. If zero currency transaction costs are assumed, then the repatriation constraint no longer binds.

Modelling of Type 3 firms suggests that Japanese corporations having both domestic and foreign productive bases may be more likely to invest domestically. This likelihood is dependent on the comparison of real foreign vs. domestic non-tradeable costs ($\frac{W^F}{P}$ and $\frac{W}{P}$). This model suggests the global impact on corporate investment of a real yen depreciation is uncertain, but probably negative. The local impact is uncertain, and depends on the magnitude of real domestic currency earnings increases, the degree to which foreign earnings are repatriated (in turn the expected trend of future currency movements), the relative sectoral weightings of Type 1&3 firms to Type 2, as well as the substitutability of tradeable for non-tradeable investment inputs. Full

analysis of sectoral trends - their weightings, exchange-rates sensitivity and impact on net output - is therefore necessary to evaluate the impact of yen depreciation on gross private fixed investment and output.

4.4.1 Open economy investment estimation

This sub-section discusses the estimation of least squares time-series estimates of firm Types 1, 2 and 3 (Type 1: produce locally and trade globally, Type 2: produce locally and trade locally, Type 3: produce overseas and sell globally) corresponding to the below equations indexed by 1, 2 and 3 respectively:

$$I_1 = I_1\left(\frac{eP^F}{P}, \left(\frac{eP^F}{P}\right) \cdot \left(\frac{P_K^F}{P^F}\right), \frac{W}{P}, y, y^F, r, \delta\right). \quad (4.21)$$

$$I_2 = I_2\left(\frac{1}{P}, \left(\frac{eP^F}{P}\right) \cdot \left(\frac{P_K^F}{P^F}\right), \frac{W}{P}, y, r, \delta\right) \quad (4.22)$$

$$I_3 = I_3\left(\frac{eP^F}{P}, \left(\frac{eP^F}{P}\right) \cdot \left(\frac{P_K^F}{P^F}\right), (eP_{jt}^F) \cdot \left(\frac{W^F}{P}\right), y, y^F, r, \delta\right). \quad (4.23)$$

where private domestic investment is a function of private domestic investment I , the domestic price level P , the foreign price level P^F , the real exchange rate $\frac{eP^F}{P}$, the global price of capital inputs P_K^F , domestic wages W , foreign wages W^F , domestic income y , foreign income y^F , and the constant rates r and δ . Consistent with the earlier TVP-VAR analysis, all data are in quarterly, seasonally-adjusted, log-levels covering the period Q1:1980 to Q1:2010 inclusive.

A simple analytical separation of Firm Types 1&3 and 2 would be manufacturing industries as Type 1&3, and services industries as Type 2. Figure 4.5 illustrates the divergent evolution of these two series, particularly in the post-bubble era following the early 1990s. Such separation makes the relatively strong assumption that services are non-tradeable. I construct investment in services industries as the sum of 'Wholesale and retail trade', 'Real estate', 'Business services', 'Hospitality', 'Entertainment' and 'Other services'. Excluded are 'Utilities' and 'Finance'. Data and definitions are as provided in Japan's Cabinet Office SNA release, and these sub-categories span the 'Services' sectors (i.e. there are no sub-categories overlooked). Of these sub-sectors,

business services, transport, entertainment and hospitality may be conceived a priori to develop substantial international earnings.

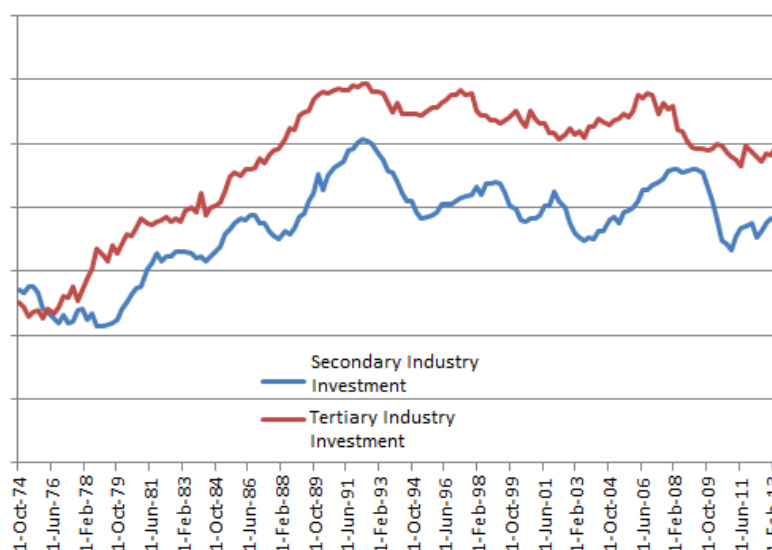


Figure 4.5: Time series of ‘Manufacturing’ and ‘Services’ private sector investment log-levels, data sources as per Section 3.

To examine this issue, consider the Balance of Payments (Services) data in Table 4.2, taken from the March 2015 release from the Japanese trade organisation JETRO. Service sector sales are between two and three times the volume of manufacturing sales during this period, but there is an order of magnitude of difference in the Sales/Export ratio between the two sectors. This is persuasive evidence that Types 1&3 and 2 of firms as modelled above can be reasonably mapped onto the manufacturing and services sectors respectively.

	Services			Manufacturing		
Year	Export earnings	Gross sales	SE	Export earnings	Gross sales	SE
2006	110,251	10,480,359	95	570,644	4,491,897	8
2007	117,219	10,396,427	89	616,194	4,793,839	8
2008	129,104	9,708,814	75	677,009	4,201,868	6
2009	148,668	9,178,669	62	740,613	3,757,426	5
2010	128,261	9,713,219	76	545,328	4,178,937	8
2011	141,826	9,362,640	66	727,457	4,023,504	6
2012	145,222	8,904,293	61	785,496	3,869,003	5
2013	145,558	9,152,614	63	772,313	3,936,202	5
2014	147,821	9,369,996	63	690,482	3,907,164	6

Table 4.2: Services and manufacturing export earnings and gross sales, 2006-2014. Export earnings sourced from Balance of Payments release JETRO, gross sales from Financial Statements Statistics from Japan’s Ministry of Finance. Figures in hundreds of millions of yen. ‘S/E’ refers to the Gross sales to Export earnings ratio.

The real exchange rate of the Japanese yen, $\frac{eP^F}{P}$, are the 'Real Effective Exchange Rates Based on Manufacturing Consumer Price Index for Japan' data release from the OECD's 'Main Economic Indicators'. The same source provides Japanese income data y 'Gross Domestic Product for Japan', and price index data P 'Consumer Price Index for all Items in Japan'.

The real global prices of capital inputs, $\frac{P_K^F}{P^F}$, are not directly observable and require instrumentation. Appropriate instruments would reflect the actual cost of physical or financial capital goods encountered by a Japanese firm trading in global markets. Global oil prices ('Crude Oil Prices: West Texas Intermediate' quarterly average spot prices from U.S. Department of Energy: Energy Information Administration) weighted by US inflation ('Consumer Price Index for All Urban Consumers: All Prices' from the US Department of Labor, Bureau of Labor Statistics), as an instrumental estimate of physical capital input costs.

Domestic Japanese wages are sourced from Japan's Ministry of Finance 'Financial statistics of corporations by industry' release, Line 4. Line description 'Personnel expenses'. Domestic income and the domestic price level are from the OECD's 'Main Economic Indicators'. Foreign wages are instrumented by 'Benchmarked Unit Labour Costs - Industry for the Republic of Korea', adjusted into real terms by 'Consumer Price Index: All Items for Korea', with both series sourced from FRED Economic Data. Due to a long history of FDI, comparable living standards and large inter-linked productive base, South Korean wages may be appropriate instrument for the wages faced by externally-producing Japanese firms.

Foreign income y^F is instrumented by US GDP, chosen due to the US's role as a major consumer of exported goods. 'The Basic Discount Rate and Basic Loan Rate', sourced from Bank of Japan Statistics, provides data for the discount rate r . The depreciation rate δ is represented in the constant term c in the state-space model presented in Section 4.3.2.

Investment equations from Section 4.2 suggest estimation of a model featuring cost and revenue channels variously altered by real exchange rate terms. But for Japan, agglomerated quarterly sectoral investment data is only consistently available (i.e., without changes to the collations strategy) for the period 1980-2010, or around 120 observations. Non-linear least squares estimates of equations for firm Types 1-3 are

given in Table 4.4. As quarterly FDI data for Japanese manufacturing firms are unavailable, the investment dependent variable for Type 3 firms is the reported investment in manufacturing, and identical to the dependent variable for Type 1 firms. As mentioned in Section 4.2, the investment data held by Japan's Ministry of Finance is not explicitly localised, and contains information from all Japanese corporate activity. In consequence, the specifications only differ in the treatment of non-traded labour input, being the real manufacturing wage (Japan) for Type 1 firms, and the localised, real South Korean manufacturing wage for Type 3.

	Mean	Maximum	Minimum	Std.Dev	Obs
SEC	15.55	16.00	15.10	0.23	121
TER	15.92	16.26	15.24	0.31	121
Y	-0.2	0.03	15.24	0.20	121
YUS	-0.71	0.00	-1.67	0.49	121
REX	0.10	0.52	-0.28	0.19	121
JPNCPI	95.65	104.30	74.73	7.61	121
RMW	0.12	0.15	0.12	0.01	121
RNM	0.13	0.15	0.12	0.01	121
I	11.51	11.94	10.57	0.29	121
OIL	3.34	4.78	2.42	0.51	121

Table 4.3: Summary statistics of key variables SEC=Secondary industry firm investment, TER=Tertiary industry firm investment, Y=Japan GDP, REX=Japanese real exchange rate, JPNCPI=Japanese CPI, YUS=US GDP, RWM=Real wages in manufacturing industries in Japan, RNM=Real wages in non-manufacturing industries in Japan, OIL=West Texas Intermediate price and I=Aggregate Japanese private fixed investment, quarterly Q1:1980-Q1:2010.

This section presents estimates of the investment equations from Section 4.2, as described below in Table 4.4:

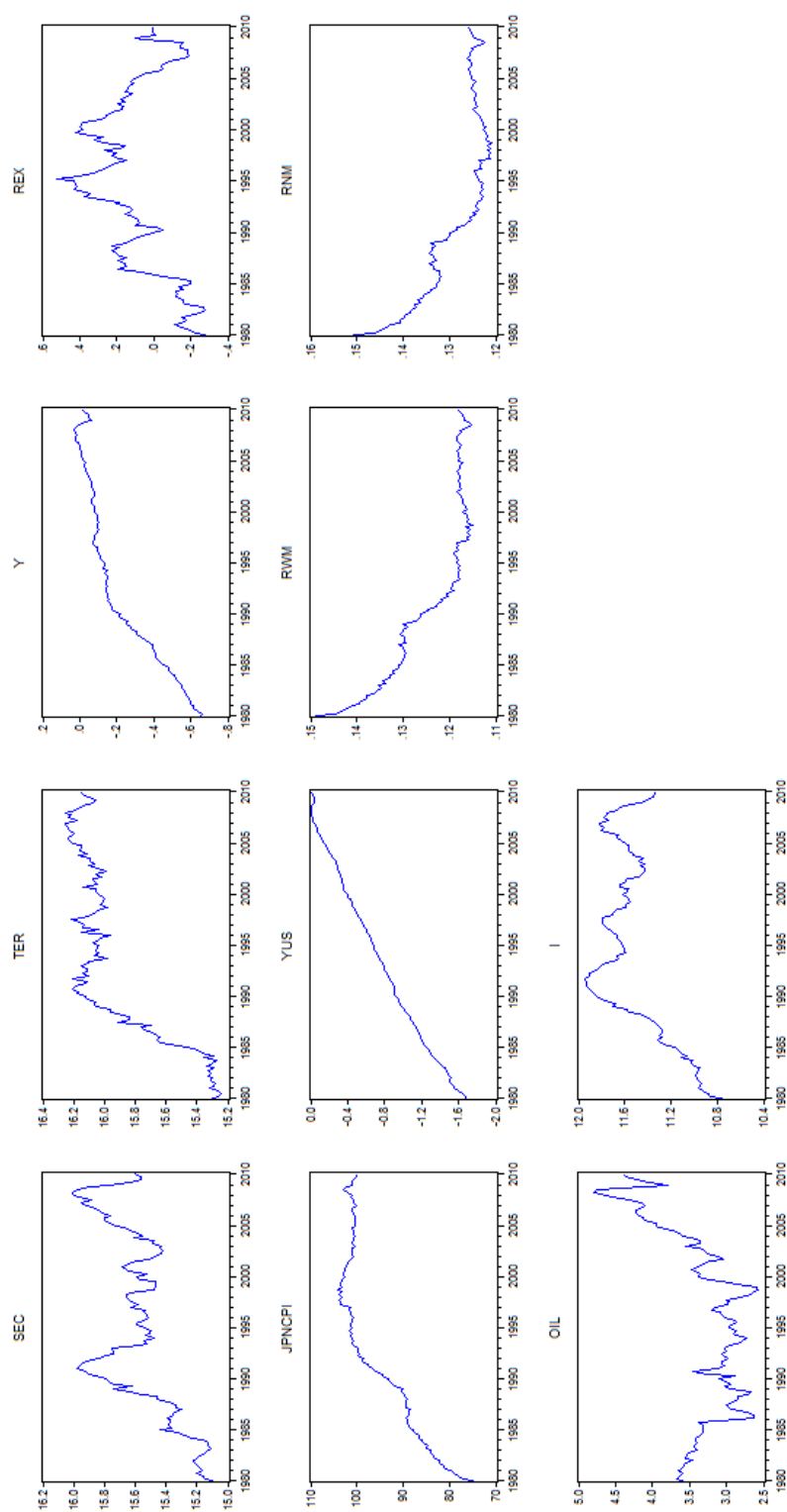


Figure 4.6: Time series of key variables. SEC=Secondary industry firm investment, TER=Tertiary industry firm investment, Y=Japan GDP, REX=Japanese real exchange rate, JPN CPI=Japanese CPI, YUS=US GDP, RWM=Real wages in manufacturing industries in Japan, RNM=Real wages in non-manufacturing industries in Japan, OIL=West Texas Intermediate price and I=Aggregate Japanese private fixed investment, quarterly Q1:1980-Q1:2010.

	Type 1		Type 2		Type	
		<i>std.err</i>		<i>std.err</i>		<i>std.err</i>
Japan GDP	1.89***	0.41	1.69***	0.35	2.19***	0.52
RealExchange rate	-0.01	0.44	-0.22	0.37	-0.62	0.60
Japan CPI			-0.01	0.02		
US GDP	-0.13	0.19			-0.35	0.21
Real manufacturing wage	16.52**	6.45				
Real non-manufacturing wage			-5.86	16.20		
RealExch*(Oil/US.CPI)	0.27	0.63	0.55	0.51	1.33*	0.73
(Oil/US.CPI)	-0.12	0.195	0.23	0.13	-0.17	0.17
RealExch*(For.wage/JPN.CPI)					41.32	27.25
(Foreign.wage/JPN.CPI)					-28.00	33.43
Constant	13.91***	0.76	17.00***	4.10	15.84***	0.79
AR(1)	1.21***	0.20	1.346***	0.21	1.23***	0.24
AR(2)	-0.33**	0.19	-0.40**	0.21	-0.31	0.23
MA(1)	-0.22	0.20	-1.01***	0.20	-0.27	0.24
MA(2)	0.10***	0.10	0.51***	0.12	0.34***	0.10
Post.1991 indicator	-0.04	0.05	-0.08**	0.04	-0.05	0.05
Adj. R-squared	0.96		0.98		0.96	
D-W h statistic	1.95		2.01		1.97	

Table 4.4: ARMA(2,2) estimates of models of log-level firm investment with robust standard errors, separated by firm types as per Equations [N] respectively. Q1:1980 - Q1:2010, N=120 2 decimal places. *, **, *** correspond to statistical significance levels of 0.1, 0.05 and 0.01 percent respectively. 2 autoregressive lags are used as indicated by AIC. 2 moving average terms are used to eliminate residual autocorrelation. Independent (Oil/US.CPI) and (Foreign wage / JPN.CPI) terms are added to the estimation as is appropriate for interaction terms, despite not being specified in Equations [N]. A dummy variable for post Q1:1991 is included following the Zivot-Andrews breakpoint indication in Section 2.

The substantial degree of autocorrelation in private investment is discussed in the literature, recently by Eberly et al. (2012), and is important in this instance in that it may justify the use of investment as a policy target (as any change to investment may have lasting impacts on the level) and in that strong autocorrelation and moving average factors may dominate other specified variables. Also of note is the consistently high degree of statistical significance in Japanese GDP, included as a demand instrument. This is of particular interest when compared with the smaller and insignificant coefficient on the real exchange rate, or the real foreign price of oil, both of which are included as indicators of cost instruments. The small coefficients on the real exchange rate are in stark contrast to the very large coefficients (with varying statistical significance) on the real wages terms, some of which are an order of magnitude large than that of GDP. It is perhaps interesting that both the size and degree of significance on wages terms varies substantially between manufacturing and services (i.e. Type 1&3

and Type 2). In the non-manufacturing setup the wages coefficient is far smaller than in Type 1 or 3 specifications, and with a substantially smaller p-value. Wages terms in Type 1 and Type 3 specifications have positive coefficients, consistent with of labour / capital substitution opportunities in manufacturing that are unavailable in service industries.

Whilst the ARMA(2,2) estimation of Types 1, 2 and 3 is not completely instructive as to the domestic vs. external drivers of Japanese private fixed investment, some useful information may be gleaned. Returning to the estimation results in Table 4.4, we see the real exchange rate only enters significantly and positively in its interaction with the real foreign price of oil, used as a tradeable capital indicator in the Type 3 specification. Considering the Type 1 and 3 dependent variables are identical, the very large coefficients on the (borderline significant) real foreign wage terms in the Type 3 specification may be indicative of the external sensitivity of Japanese investment.

The motivation for the exercise was the unanticipated impulse-response results from Section 4.2, which indicated a positive investment response to real exchange rate innovations, and a depreciation-to-appreciation change of sign in the response of the real exchange rate to investment innovations. The indications of Japanese manufacturing investment sensitivity to price variations in external factors of production may aid understanding of these results, and suggests that internationalisation of production may play an important role in driving the observed investment dynamics.

4.5 The investment-output anomaly

Private fixed investment is a key policy measure in Japan due to its anticipated strong, positive link with economic output and consequently social welfare. Section 4.2 discussed evidence that broad private fixed investment innovations are no longer associated with increased gross output over the medium-term in Japan. Impulse response diagrams from time-varying parameter VAR estimations indicate the positive-to-negative crossover point is broadly in the 1999-2001 period, but the negative trend of decreasing GDP returns to investment shocks is quite consistent throughout the estimation period.

The open-economy models discussed in Section 4.1 uniformly hold as positive the

sign of $(\delta I/\delta Y)$, as increasing factors of production may reasonably be expected to increase production. This section identifies, discusses, and evaluates 3 theories that may partially explain the observed sign change in $(\delta I/\delta Y)$.

Firstly, that proposed by Vanhoudt (1998), who argued an observed negative impact on growth rates was the expected result of investment shocks in neoclassical growth models. This finding is empirically supported by Granger causality work by Podrecca and Carmeci (2001) and the rolling least squares estimates of Cheung, Doolley and Susko (2012). Vanhoudt's (1998) argument follows the neoclassical growth model in evaluating the impact of an exogenous positive shock to investment share on the long-term growth rate. By definition, the long-term growth rate is a function of the rate of exogenous technological change, and in consequence time-series estimations of accumulation rates of physical capital on long-run growth rates should be unable to identify a causal relationship. This definition effectively excludes any short- or medium-term positive impact of investment on growth by assumption; in any system with forced mean-reversion, any disruption to the mean will be forced to revert, i.e. after a positive shock, the medium-term growth sign of investment must be negative as in an error-correction model. More modelling that places different constraints on the dynamics of growth may lead to a different interpretation, for example in the Obstfeld and Rogoff (1995) 'Redux' 2-country model, where permanent monetary expansions may have permanent output effects. The reasoning in Vanhoudt (1998) does have several testable implications: the observed medium-term coefficient of investment on growth should be negative, the long-term impact of investment on growth should be negligible, and any observations should be capital-type agnostic.

In order to analyse an observed negative investment impact on GDP, it is necessary to consider the assumptions inherent in the assumed positive relationship. In standard models, investment ought to raise growth by raising capital, which in turn raises gross domestic product: there are two relationships which could be further examined. The second theory concerns the break-down of the first relationship, and questions when investment could not lead to the accumulation of capital. Examples of non-productive investment of this type may conceivably include investing in non-productive capital for speculative purposes or inadvertently due to obsolescence. The period 1980-2010 in Japan was associated with substantial speculative investing in

land and equities, notably during the late 1980s 'bubble era'. The 1980-2010 period is also associated with (amongst other factors) the introduction of advanced business information systems, affordable computing power, increased East Asian (especially Chinese) productivity, and increased robotisation. Presumably, if Japanese firms invested in productive methods that were out-competed by more technologically advanced or most cost-competitive neighbours, then increases in *a priori* productive capital would be rendered otherwise. It is at least theoretically conceivable that 'mal-investment' in either of these fashions could be associated with the accumulation of non-productive capital. Whilst a full investigation of this concept is beyond the scope of this chapter, a brief examination of Figure 4.7 may be informative. Macroeconomically-substantial degrees of mal-investment by Japanese firms during this period may be expected to deliver decreased cash from operating activities, as firms are out-competed by more efficient investors. The strong increasing trend in cash earned from operating activities from 1994 suggests that, if there was substantial mal-investment, then Japanese firms were able to generate increasing profits with stable or declining levels of productive capital; this is less likely than the alternative theory that macroeconomically-substantial mal-investment was not a continual fact throughout the period. This is particularly likely given the divergence of the two trends in the late 1980s and early 1990s, peak 'bubble era', which saw rapidly rising investment and falling operating returns - consistent with investment in non-productive capital. As such we can assign a low probability to large-scale private-sector mal-investment driving negative trends in the investment-output relationship.

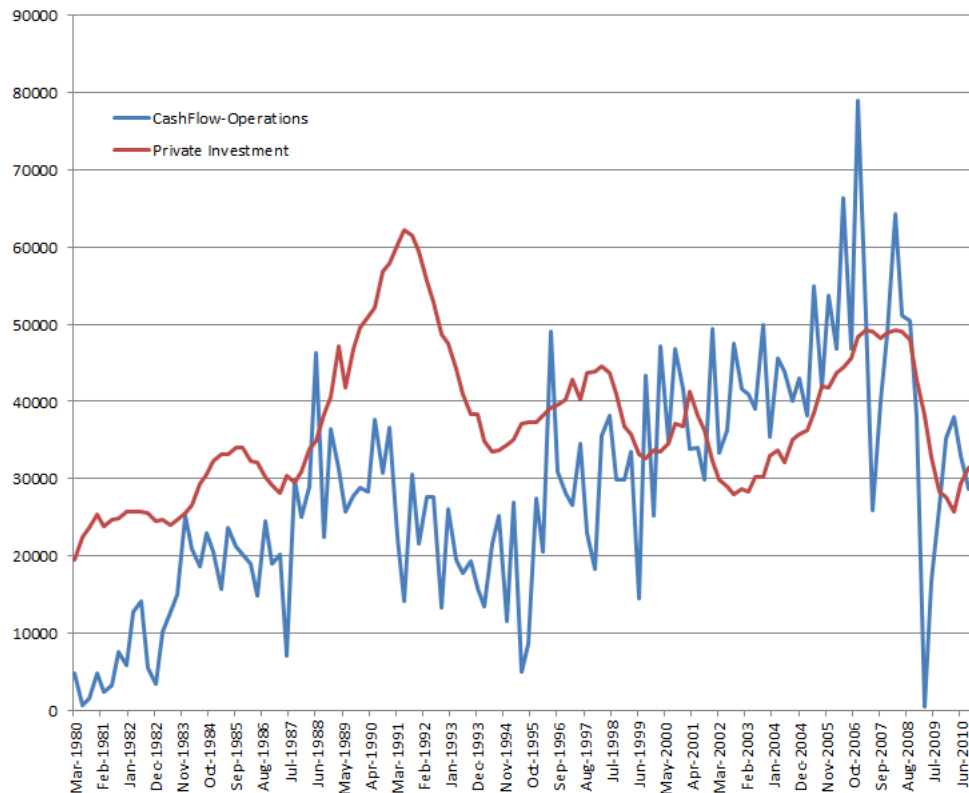


Figure 4.7: Cash Flow from Operating Activities and Private Fixed Investment, Japanese firms with <100,000 yen in operating capital, Q1:1980-Q1:2010, Ministry of Finance, Japan. LHS units are 100 millions of 2005 JPY, seasonally adjusted with additive X12 ARIMA.

The third theory considers the possibility that accumulated capital may not contribute to national output. That it may not contribute due to its inherently non-productive nature (as in any purely speculative activity) was discussed and discarded above. For productive capital to not contribute to gross domestic product suggests that the 'domestic' adjective should be examined. Should the investment be occurring internationally, the applicable open-economy models would be mis-informed, and empirical analyses of such may deliver non-typical results.

Anticipated macro-scale analytic results from large-scale substitution of overseas for domestic investment include changes in the anticipated relationship between the real exchange rate and investment. Domestic investment involves the accumulation of local capital, which may be both expected to compete for potentially scarce local capital (in turn raising the associated rental interest rate) and to import raw and intermediate factors from overseas (in turn raising the nominal exchange rate). The net impact on the real exchange rate would depend on the relative shifts in these two fac-

tors, and nature of investment. If a substantial proportion of the costs of investment are faced either before or during the early stages of productive activity then the local interest rate changes and the nominal exchange rate changes may not be contemporaneous. The literature discusses this possibility in depth - typically using the example of building a factory which would operate for many years - see the 'lumpy' investment discussion in the second chapter of this thesis. The anticipated time-variation would involve the real exchange rate initially depreciating as imported factors were paid for, then appreciating as higher local rates of return attracted international capital. The testable implication of substantial overseas investment would be that the real exchange rate would fall as the overseas investment was paid for, but that increased production would not compete for local capital, thereby not raising rates and appreciating the real exchange rate. This would be consistent with the time-varying parameter VAR results from Section 4.2, but further testing across differing import-sensitive sectors would be an improved demonstration.

This third theory's plausibility further depends on the data collated for the Statement of National Accounts release by the Cabinet Office of Japan. The degree of incidental capture of foreign-located investment along with domestic-located investment within the National Accounts is challenging to determine, as it concerns a complex accounting identities, including subsidiary cost recognition, software installation location and recognition, currency choice variations, tax-offsetting decisions and cross-national accounting complexities. This may be an important area of investigation for statistical agencies, but due to the breadth of challenge it represents, this chapter's scope is limited to considering whether the results from macro-scale analysis are consistent with some degree of un-accounted international investment.

The rejection of long-term mal-investment leaves two theories of the post-1990s, medium-term negative investment/growth relationship to be examined: that such is the anticipated result of post-shock convergence to a long-term trend (hereafter 'Trend'), as per Vanhoudt (1998), and that Japan's Statement of National Accounts may be inadvertently capturing non-domestic investment data (hereafter 'FDI').

There are several testable implications for both theories. Whilst it may be difficult to completely assign causality to a single factor, empirical examination of anticipated vs. evaluated implications can deliver useful guidance for future research. As

discussed above, the implications associated with the 'Trend' reasoning include: the observed medium-term coefficient of investment on growth should be negative, the long-term impact of investment on growth should be negligible, and any observations should be capital-type agnostic. The implications associated with the 'FDI' logic suggest the presence of observable variations in real exchange rate responses to investment, particularly a shift from the posited depreciated-to-appreciate shock response to a depreciate-only situation. Further, as manufacturing investment may be more easily undertaken overseas than investment in services industries, separate analysis of industrial sectors may be productive.

Sector-level time-varying analysis of the output, investment, real exchange rate relationship is an appropriate empirical method for considering the 'Trend' and 'FDI' theories. This section uses the TVP-VAR method with ordering consistent with that used in Section 4.2, and the investigated data as discussed with Sections 4.2 and 4.3. Impulse response diagrams from (Output, Manufacturing investment, Real Exchange Rate $-(Y, M, X)$) and (Output, Services investment, Real Exchange Rate $-(Y, S, X)$) analyses follow below:

'Trend' reasoning implied that the observed medium-term coefficient of investment on economic activity should be negative. Comparing the impulse response results in Figures 4.8 and 4.9, we see the impact of service sector investment on GDP is consistently positive, and becoming increasingly so towards 2010. In comparison, the impact of manufacturing sector investment on GDP shifts from positive to increasingly negative over the same time period. These differing descriptions of sector-level investment are not consistent with the simple neoclassical model discussed by Vanhoudt (1998), suggesting there may be limits to the 'Trend' theory's utility in explaining investment-output variations.

In comparison, increasing investment overseas as per the 'FDI' theory would potentially involve the presence of observable variations in real exchange rate responses to investment. Notably, the posited depreciated-to-appreciate shock response to a depreciate-only situation is not only visible over the broad system, as in Section 4.2, but occurs differently in services and manufacturing investment.

This empirical and theoretical consistency is suggestive of an important role for overseas investment by Japanese manufacturing firms in driving changes to the investment-

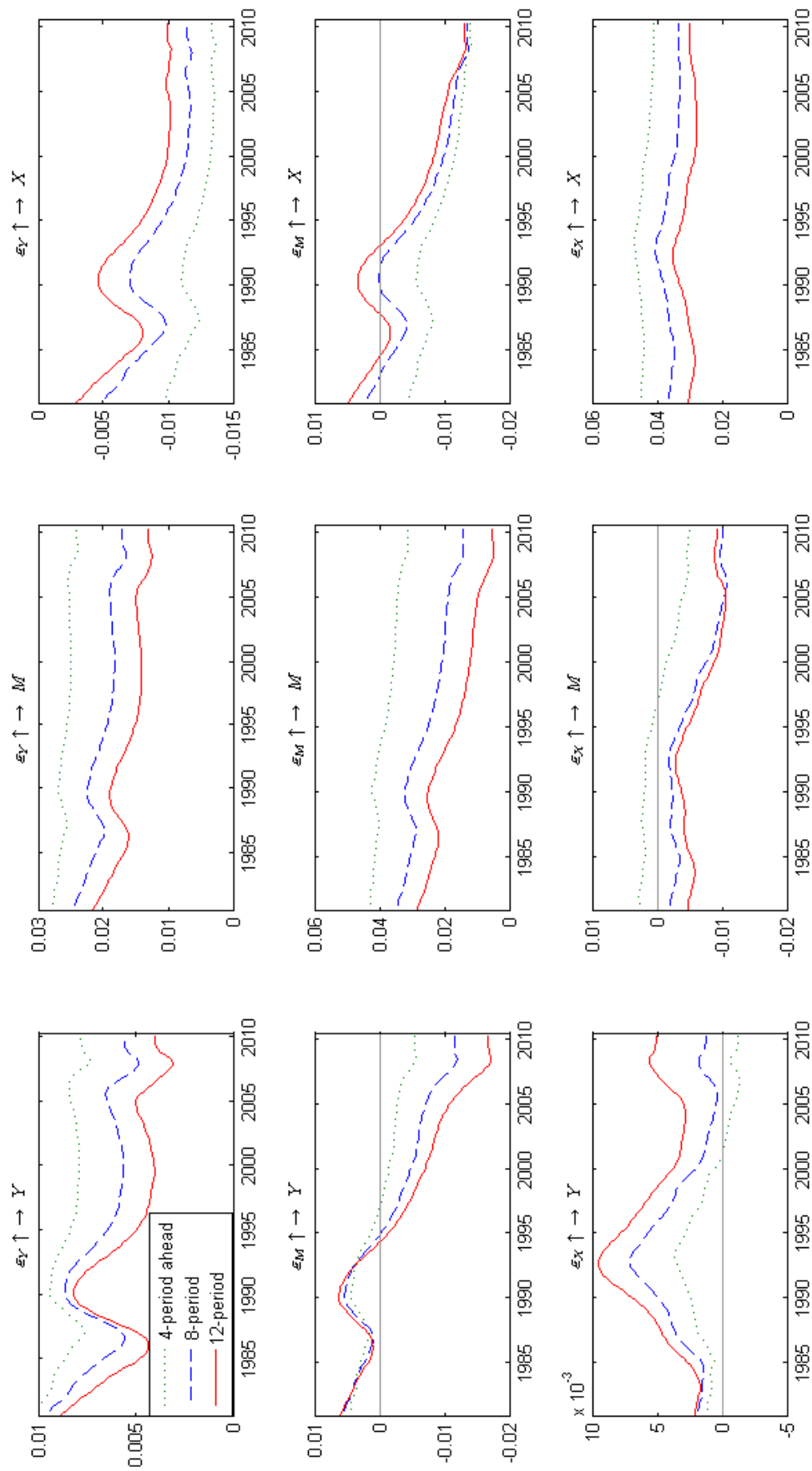


Figure 4.8: Impulse response from the TVP-VAR analysis of $\{Y, M, X\}$ -ordering, Q1:1980:Q4:2010, 2 lags. Impulses plotted at $Q=4, 8, 12$ periods ahead for each period.

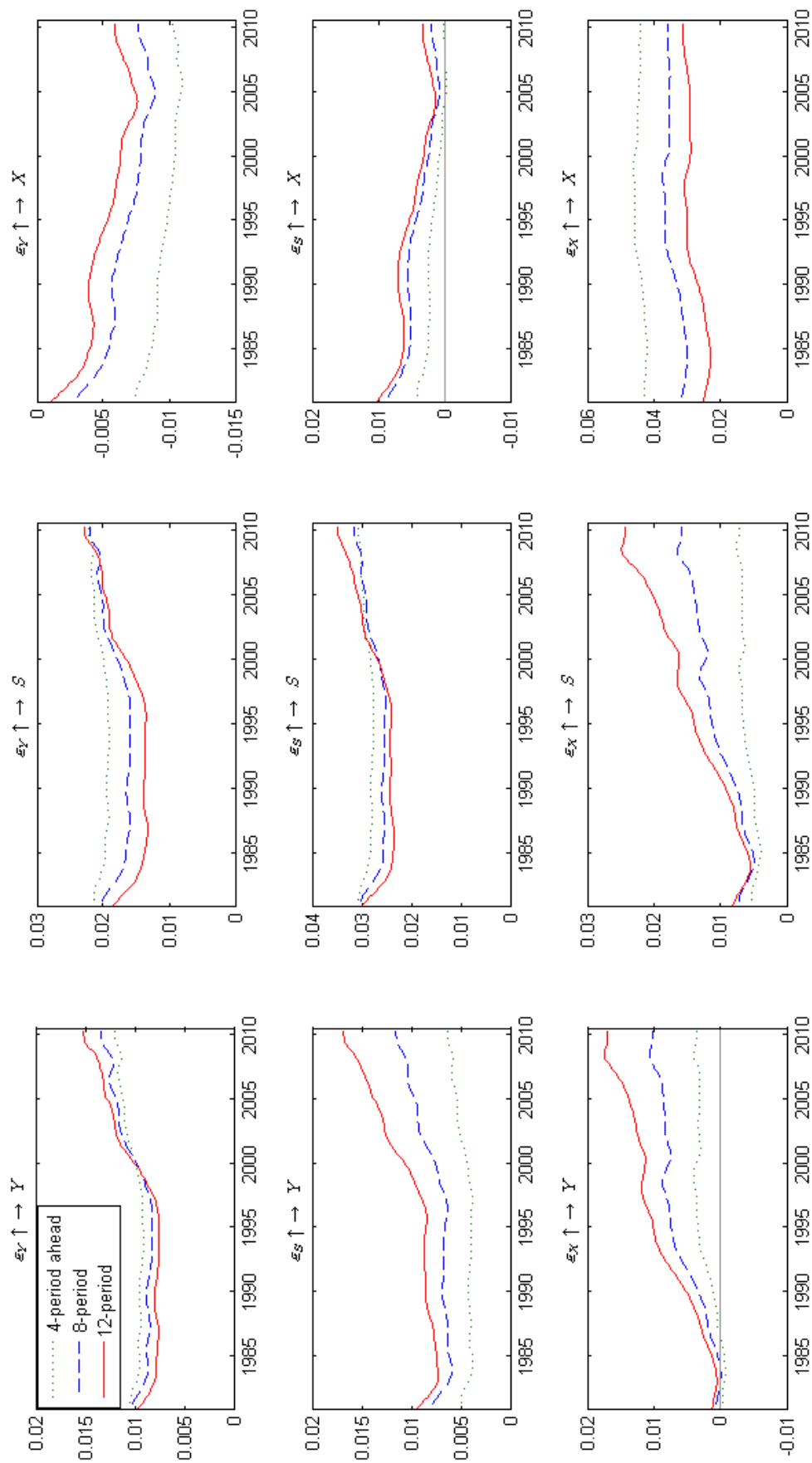


Figure 4.9: Impulse response from the TVP-VAR analysis of (Y, S, X) -ordered system, Q11980:Q42010, 2 lags. Impulses plotted at $Q=4, 8, 12$ periods ahead for each period.

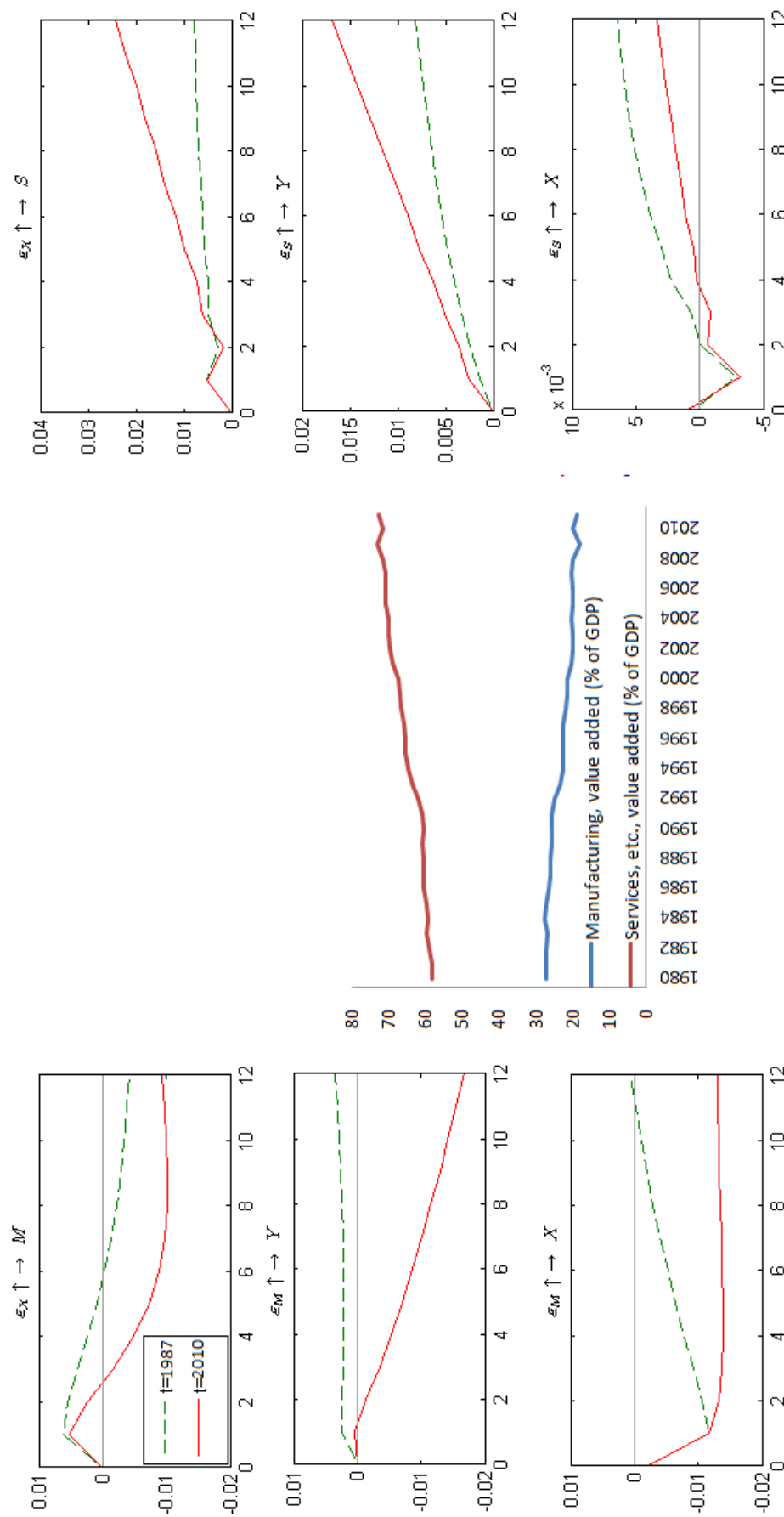


Figure 4.10: Impulse response from the TVP-VAR analysis of $\{Y, S, X\}$ and $\{Y, M, X\}$ -ordered systems, Q11980:Q42010, 2 lags. Impulses plotted at $T=1987, 2010$ for 12 quarters.

output relationship. This is particularly evident in Figure 4.10, which depicts the same systems as analysed in Figures 4.7 and 4.8, but with a decreased number of impulse responses diagrams drawn which are drawn at specified points in time. Reading of these impulse responses provides strong support for the 'FDI' theory, which suggests the exporting of investment is an important factor in the 2010s negative relationship between investment and output. Notably, the changed response of the real exchange rate to manufacturing investment impulses suggests that capital exported in the investment process remains overseas for the medium-term in 2010, unlike in 1987. Similarly, investment in industries that are challenging to export, such as those collated as services, has output and real exchange rate impacts fully consistent with *a priori* model-based expectations.

4.6 Summary

A TVP-VAR estimation of Japanese output, investment and real exchange rates provided counter-intuitive impulse-response signs and variations. Motivated by these results, and informed by discussions of the international sensitivities of private fixed investment and the role of an 'over-valued' yen, this chapter examined the history and state of open- economy macroeconomic modelling of investment in the Japanese context. The results of impulses to and from the real exchange rate indicated the relative balance of externally- and internally-exposed investment ought be carefully modelled and evaluated. Counter-intuitive indications from examining the impact of investment shocks on GDP suggested the value of discussion of FDI, data composition and growth dynamics.

Optimisation modelling and time-series analysis of domestic and international investment decisions delivered indications of Japanese manufacturing investment sensitivity to price variations in external factors of production, and further suggested the internationalisation of production may play an important role in driving observed investment dynamics. This suggestion was supported by non-linear time-varying analysis of manufacturing and service sector investment, which was consistent with an increasing degree of exporting of manufacturing investment. An incidental finding was that Japanese economic expansion to 2010 responds strongly to service-sector in-

vestment.

These results are preliminary, in terms of the limitation to medium-term dynamics, the inability to confirm or deny the necessary incidental capture of foreign investment activity in the domestic accounts, and the lack of long time-series foreign direct investment data. Considering the policy importance of private fixed investment, and the substantial international discussions regarding yen valuation, further research on overcoming these limitations should be encouraged.

Chapter 5

Conclusion

This thesis sought evidence for whether different models for investment may apply at different points in time.

The thesis primarily contributes three linked, empirical chapters, which take three perspectives in considering a single question: Are the drivers of Japanese private fixed investment dynamic, and what might this imply?

Chapter 2 compared optimal forecasting models for investment across time, and described the variation in model constituents observed. Motivated by the important role measures of uncertainty played in investment forecasts, Chapter 3 considered the relationships between post-1990 Japanese private fixed investment trends and three indicators of macro-uncertainty. Chapter 4 examined evidence indicating changes in the relationships between Japanese investment and external factors of production, and asked whether a sectoral-level analysis may explain these changing sensitivities.

In essence, the answers Chapters 2, 3 and 4 provide to the question of dynamics are: there is reason to believe some of the driving components of investment in Japan change over time; understanding some of these dynamics can shed light on important structural economic changes, such as the varying macro-economic importance of manufacturing investment; and conversely, understanding the consistency of the uncertainty-investment relationship provides emphasis for consistent forward-guidance and policy stability.

In economic models, capital is a factor of production and investment is its adjustment. This setup leads quite inevitably to aggregate investment being a topic of substantial interest to policy makers and research economists. This is particularly the

case for aggregate private fixed investment, as public investment is often assumed to follow rules more political than profitable.

But whilst there is rich literature in modelling private fixed investment, both in the individual and in the aggregate: “The empirical investment literature is full of disappointments... there are, and perhaps insurmountable, data problems.” (Caballero, Engel and Haltiwanger, 1995).

The increasing availability of integrated, computerised, large-scale, time-series databases of firm activities has reduced the problems Caballero et al. grappled with in 1995, but the “myriad incentive problems these investors face” are unlikely to be captured in corporate reports. The difficulty in capturing, for instance, firm-idiosyncratic uncertainties suggests both aggregate analysis and the utility of Bayesian econometrics that allow for the modelling of prior beliefs.

Japan represents an important focus for empirical economic investigation. One of the world’s largest economies for the last 50 years, Japan is a systematically-important member of the global economy. With reliable economic data over many years of economic policy decisions, the Japanese economy is attractive to the econometrician and macro-economist alike. Moreover, some of the major events in modern economics were first intensively observed in Japan, from an era of investment and export-led growth, through joint land-equity price bubbles, towards a ‘Lost Decade’ of zero growth, policy and theory issues with the zero lower bound on interest rates, the complex dynamics of an ageing population and the large-scale foreign direct investment in a rising neighbouring economy in China. Private fixed investment plays a key role in many of these phenomena and, given the existence of both complete mid-frequency data and modern computational econometrics, a better understanding of Japanese investment dynamics is both possible and of potential value to Japanese and international policymakers who are grappling with the management and consequences of variations to aggregate investment.

The methodological approach of this thesis was largely motivated by the suggestion that models for some particular economic concept may be differently constituted at different points in time. The evaluation of such time-varying suggestions are not novel to either the economic literature, nor to specifically to the investment literature. Many researchers have estimated models with structural-change parameters, time-

dummies or conducted event studies.

But recent computational econometric advances allow researchers to evaluate a time-series model at every point in time at which it is constituted. These techniques potentially allow for a different form of model comparison, one in which the movement of variable coefficient to and from zero over time may indicate the true, underlying, model specification is also changing.

Essentially, this thesis uses time-varying econometrics to analyse models for Japanese private fixed investment, and compares model implications with analytical outputs in their proper theoretical and historical context.

Chapter 2 was motivated by the degree of divergence in the private fixed investment literature. The chapter's approach was motivated by the emergence of sophisticated time-varying econometric models, and the question of whether such techniques could shed light on the literature. This chapter suggested that a novel empirical method from the forecasting literature could be re-purposed as a model comparison tool. Dynamic model averaging is a technique that aims to select some combination of current and lagged models that have maximised forecasting value at any point in time.

The chapter argues that there is a need to use such a-theoretical comparison tools due to the extant investment literature, consisting of a large range of theories, evidence bases and perspectives – the analysis of which resulted in a large range of models and empirics. Chapter 2 reviews in detail these disparate investigations, drawing them into a series of general streams of investment research: Tobins q , financing, uncertainty, factors, and surveys.

Considering model sets of variables drawn from four strands of economic and financial literature, this chapter used DMA as a data-mining tool to evaluate whether the optimal forecasting models changed over time. The time-variation of these models was then linked back to known events in modern Japanese economic history, in an attempt to understand how and why models for investment may change over time.

The evaluation presented evidence of substantial evidence of model variation over time. This variation appeared driven by expenditure on input factors and by the availability of external finance. There appeared little time-variation in uncertainty, GDP and average q . These results are consistent with their anticipated priors from their

relevant literatures, and indicate the usefulness of DMA as a model comparison tool.

Chapter 3 was motivated by a potential conflict between the findings of Chapter 2 with regard to uncertainty and the broader policy, news and economic discussions of the macro-economic impacts of uncertainty. The DMA exercise in Chapter 2 indicated that uncertainty was a consistently useful forecaster of Japanese private fixed investment, albeit one that was equally useful during periods of *a priori* high uncertainty (such as the collapse of the stock market bubble in early 90s Japan, or the advent of the Global Financial Crisis in 2007/8), and during periods of anticipated low uncertainty (such as the period of low-volatility Japanese GDP growth in the early 2000s). These findings contrasted with prior expectations of a non-linear relationship between uncertainty and investment, in which high levels of uncertainty may have very large impact of activity, whilst low levels may have a proportionally far smaller. As a result, the chapter sought to answer three questions: Does uncertainty matter for Japanese investment? Does this impact vary over time, particularly in periods of crisis? Could uncertainty shocks have contributed to the 'Lost Decade'?

To consider these questions the Chapter conducted TVP-VAR analyses of small-scale models of investment, variously augmented with one of three uncertainty measures: a forecaster dispersion index, an implied volatility VIX index and a rolling sales growth volatility measure. Estimation indicated uncertainty exhibits drop, rebound and overshoot impacts on Japanese private fixed investment that are consistent with real-options theory. The impact of such shocks appear linear in time and magnitude, consistent with the findings from Chapter 2.

The finding that uncertainty has linear impacts on investment in Japan during the period 1990-2011 is novel to the literature, including Abel and Eberly (1999), Bloom (2009), Bachmann et al. (2013), and Caggiano et al. (2015). Falls in private fixed investment are linked (Horioka 2006) with Japan's 'Lost Decade', but simulated uncertainty spikes during this period consistently indicate a rebound effect inconsistent with sustained declines. The data indicates long-term collapses in investment cannot be attributed to short-term uncertainty shocks.

Understanding the linear role uncertainty plays in deterring investment emphasises the importance of forward-guidance, crisis management and political stability.

Chapter 4 was broadly motivated by discussions of the international aspects of pri-

vate fixed investment and the role of an 'over-valued' yen to examine the history and state of open-economy macroeconomic modelling of investment in the Japanese context. As a first-pass examination, TVP-VAR estimations of key model components was undertaken using Japanese data in order to confirm the implications of such models. Such estimations indicated relationship signs and changes that were potentially difficult to reconcile with the anticipations from the literature. In particular, the impulse-response diagrams involving the real exchange rate provoked questions about the relative balance of externally- and internally-exposed investment.

The chapter undertook to update a factor-focused model of international investment, which allowed time-series analysis of domestic and international investment decisions. Results from this analysis indicated Japanese manufacturing investment sensitivity to price variations in external factors of production, and further suggested the 'off-shoring' of production may play an important role in driving observed investment dynamics.

The implications of these results were then drawn out by conducting a second set of TVP-VAR analyses. The resulting impulse response diagrams provided Chapter 4 with strong support for the suggestion that the exporting of investment is an important factor in the negative relationship between investment and output in the Japan of 2010. Notably, the changed response of the real exchange rate to manufacturing investment impulses suggests that capital exported in the investment process remains overseas for the medium-term in 2010, unlike in 1987. A final support for the theory is the TVP-VAR evidence that investment in service industries, has output and real exchange rate impacts fully consistent with a priori model-based expectations. The Chapter closes in noting the preliminary nature of the investigation, as well as the risks in over-interpreting aggregate information.

This thesis sought evidence that models for investment in Japan may change over time.

Chapter 2 discussed the theory and evidence from decades of research into private fixed investment, and noted some conflicts and inconsistencies between strands of investigation. A novel use for the novel 'DMA' forecasting tool delivered evidence of changes to the drivers of investment activity in the Japanese economy from 1965 to 2015, in particular noting evidence of change in financing variables that related to

periods of finance crisis.

Chapter 3 noted that uncertainty appeared constant over time, and sought to test the existence and stability of this appearance in 1990 to 2011 Japan. It conducted a time-varying parameter analysis of investment and three different uncertainty indicators. Chapter 3 found that not all uncertainty variables are associated with similar impacts, but that there is evidence in favour of real options-related investment responsiveness.

Chapter 4 noted the variability in the forecasting utility of investment factors in Chapter 2, and contrasted those with ongoing discussions of the exchange rate-investment relationship. Various time-varying analyses of a model of international investment indicated that the drivers and impacts of investment in the Japan of 2010 may be very different to that of 1980s Japan, and that these differences were consistent with the implications of the increasing importance of out-bound FDI.

The contribution to the economic literature of this thesis is that models for Japanese investment may be differently constituted at different points in time, and that these different constitutions should inform the decisions of policy makers and the research direction of investigators.

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Data Dictionary

The information in this section is presented in three parts: transformation, range and source. All parts are organised first by the chapter in which the variable appears, and second by the name of the variable. Information is provided for all variables on: data adjustment (i.e. differencing), seasonal adjustment, period of coverage units of measure, source name and identifying hyperlink - active as of April 2017.

Variable name	Adjustment	SA	Code	Details	Period	Units	Source	Link
Chapter 2: 1965Q1- 2013Q4								
Investment	1st Diff	X12	I	Investment by manufacturing firms in plant and equipment, excluding software	Full	100mn JPY	MOF, Financial Statements Statistics of Corporations by Industry, Quarterly	http://www.mof.go.jp/english/pri/reference/ssc/historical.htm
Invesment - large	1st Diff	X12	IL	Investment by large manufacturing firms in plant and equipment, excluding software	Full	100mn JPY	As I, but for firms >1bn JPY assets	http://www.mof.go.jp/english/pri/reference/ssc/historical.htm
Investment - SMEs	1st Diff	X12	IS	Investment by SME manufacturing firms in plant and equipment, excluding software	Full	100mn JPY	As I, but for firms <1bn JPY assets	http://www.mof.go.jp/english/pri/reference/ssc/historical.htm
Real GDP	1st Diff of ln	Source	Y	GDP expenditure approach, volume estimates, fixed PPPS, seasonally adjusted	Full	Mn USD OECD reference year	OECD Main economic indicators	http://www.oecd.org/std/oecdmaineconomicindicatorsmei.htm
Tobin's Q	1st Diff	No	Q	Estimate of Average Q: Q=NK/NA	Full	Ratio	Author's calculations from MOF, Financial Statements Statistics of Corporations by Industry, Quarterly	http://www.mof.go.jp/english/pri/reference/ssc/historical.htm

<i>Net Assets</i>	Lvls	X12	NA	Net assets of all manufacturing firms	Full	100mn JPY	MOF, Financial Statements Statistics of Corporations by Industry, Quarterly	http://www.mof.go.jp/english/pri/reference/ssc/historical.htm
<i>Nikkei225</i>	Lvls	No	NK	Nikkei 225 Index	Full	Index	FRED	https://fred.stlouisfed.org/series/NIKKEI225
Uncertainty	Lvls	No	U	Tankan diffusion, calculated	1974:Q3	$U = \sqrt{\text{FracPos} + \text{FracNeg} - (\text{FracPos} - \text{FracNeg})^2}$	BOJ Tankan Survey, Meehan	https://www.stat-search.boj.or.jp/ssi/mtshtml/co_q_1_en.html
Real Interest Rate	Lvls	No	RI	$RI = \text{BasicRate} - PPI$	Full	Rate	Author's calcs from BOJ	https://www.stat-search.boj.or.jp/ssi/mtshtml/ir01_m_1_en.html
<i>Inflation</i>	Lvls	Source	PR	PPI	Full	Rate	BOJ	https://www.stat-search.boj.or.jp/ssi/mtshtml/pr02_m_1_en.html
<i>Interest Rate</i>	Lvls	No	R	Basic Rate	Full	Rate	BOJ	https://www.stat-search.boj.or.jp/ssi/mtshtml/ir01_m_1_en.html
Wages	1st Diff	X12	W	Wages expense by manufacturing firms	Full	100mn JPY	MOF, Financial Statements Statistics of Corporations by Industry, Quarterly	http://www.mof.go.jp/english/pri/reference/ssc/historical.htm
Oil	1st Diff	No	O	WTI Spot to 2010, then WTI Cushing	Full	USD	FRED	https://fred.stlouisfed.org/series/DCOILWTICO
YEN/USD exchange rate	Lvls	No	X	360 until 1974:Q1	Full	JPY/USD	FRED	https://fred.stlouisfed.org/series/DEXJPUS

Cash Flow from Operations	1st Diff	TRAMO	CO	$CO = \text{Operating Profits} - \Delta(\text{AccRec}) - \Delta(\text{Inventories}) + \Delta(\text{AccPay}) + \text{NetInterest}$	Full	100mn JPY	Author's calculations from MOF, Financial Statements Statistics of Corporations by Industry, Quarterly	http://www.mof.go.jp/english/pri/reference/ssc/historical.htm
<i>Operating Profits</i>	Lvls	No	OP		Full	100mn JPY	MOF, Financial Statements Statistics of Corporations by Industry, Quarterly	http://www.mof.go.jp/english/pri/reference/ssc/historical.htm
<i>Accounts Receivable</i>	1st Diff	No	AR		Full	100mn JPY	MOF, Financial Statements Statistics of Corporations by Industry, Quarterly	http://www.mof.go.jp/english/pri/reference/ssc/historical.htm
<i>Inventories</i>	1st Diff	No	VN		Full	100mn JPY	MOF, Financial Statements Statistics of Corporations by Industry, Quarterly	http://www.mof.go.jp/english/pri/reference/ssc/historical.htm
<i>Net Interest</i>	Lvls	No	NI	$NI = \text{Interest Received} - \text{Interest Expenses}$	Full	100mn JPY	MOF, Financial Statements Statistics of Corporations by Industry, Quarterly	http://www.mof.go.jp/english/pri/reference/ssc/historical.htm
<i>Interest Received</i>	Lvls	No	NR		1983:Q2	100mn JPY	MOF, Financial Statements Statistics of Corporations by Industry, Quarterly	http://www.mof.go.jp/english/pri/reference/ssc/historical.htm
<i>Interest Expenses</i>	Lvls	No	NE		Full	100mn JPY	MOF, Financial Statements Statistics of Corporations by Industry, Quarterly	http://www.mof.go.jp/english/pri/reference/ssc/historical.htm
<i>Accounts Payable</i>	1st Diff	No	AP		Full	100mn JPY	MOF, Financial Statements Statistics of Corporations by Industry, Quarterly	http://www.mof.go.jp/english/pri/reference/ssc/historical.htm

Cash Flow from Financing	1st Diff	TRAMO	CF	$CF = \Delta(\text{ShortTermBorrowings} + \text{LongTermBorrowings} + \text{Bonds})$	Full	100mn JPY	Author's calculations from MOF, Financial Statements Statistics of Corporations by Industry, Quarterly	http://www.mof.go.jp/english/pri/reference/ssc/historical.htm
<i>Short Term Borrowings</i>	1st Diff	No	SB		Full	100mn JPY	MOF, Financial Statements Statistics of Corporations by Industry, Quarterly	http://www.mof.go.jp/english/pri/reference/ssc/historical.htm
<i>Long Term Borrowings</i>	1st Diff	No	LB		Full	100mn JPY	MOF, Financial Statements Statistics of Corporations by Industry, Quarterly	http://www.mof.go.jp/english/pri/reference/ssc/historical.htm
<i>Bond Issues</i>	1st Diff	No	BN		Full	100mn JPY	MOF, Financial Statements Statistics of Corporations by Industry, Quarterly	http://www.mof.go.jp/english/pri/reference/ssc/historical.htm
Chapter 3: 1990Q1-2011Q1								
Investment	1st Diff of ln	X12	MCH	Orders received for 'Boilers and power units', 'Heavy electrical machinery', 'Electronic and communication equipment', 'Industrial machinery', 'Metalcuttingmachines', 'Rollingmachines', 'Motorvehicles(over5000kg)' and 'Aircraft'.	Full	100mn JPY	ESRI, Cabinet Office, Machinery Orders	http://www.esri.cao.go.jp/en/stat/juchu/juchu-e.html

Capital	1st Diff of ln	X12	K	Capital stock, defined as the sum of 'Cash and deposits', 'Bills and accounts receivable', 'Inventories', 'Finished goods and merchandise', 'Works in process', 'Raw materials and goods supplies', 'Bonds and debentures', 'Other securities', 'Land', 'Intangible fixed assets' and 'Construction in process'. All firms with assets in excess of 10mn yen	Full	100mn JPY	MOF, Financial Statements Statistics of Corporations by Industry, Quarterly	http://www.mof.go.jp/english/pri/reference/ssc/historical.htm
Nikkei 225 Index	1st Diff of ln	No	NIKK		Full	Index	FRED	https://fred.stlouisfed.org/series/NIKKEI225
Sales volatility	Lvls	No	SALE	Rolling 1-year standard deviation of growth in sales	Full	Quarterly sales growth, 1 year standard deviation of, from units 100mn JPY	MOF, Financial Statements Statistics of Corporations by Industry, Quarterly	http://www.mof.go.jp/english/pri/reference/ssc/historical.htm
Uncertainty - Tankan diffusion	Lvls	No	TANK	Tankan diffusion, calculated	Full	$U = \sqrt{\text{FracPos} + \text{FracNeg} - (\text{FracPos} - \text{FracNeg})^2}$	BOJ Tankan Survey, Meehan	https://www.statsearch.boj.or.jp/ssi/mtshtml/co_q_1_en.html
VIX	Lvls	No	VIX	Quarterly maxima	Full	Index	FRED, CBOE	https://fred.stlouisfed.org/series/VIXCLS/

Chapter 4: 1980Q1- 2010Q1								
GDP	Ln Lvl	No	Y	Gross domestic product for Japan	Full	Bn yen	OECD Main economic indicators	http://www.oecd.org/std/oecdmaineconomicindicatorsmei.htm
Investment	Ln Lvl	X12	I	Gross new investment by industry, excluding construction in progress	Full	Bn yen	ESRI, Cabinet Office, Statement of National Accounts	http://www.esri.cao.go.jp/en/sna/menu.html
Real exchange rate	Ln Lvl	X12	X	Real Effective Exchange Rates Based on Manufacturing Consumer Price Index for Japan	Full	Index	OECD Main economic indicators	http://www.oecd.org/std/oecdmaineconomicindicatorsmei.htm
Price index, Japan	Ln Lvl	No	JPNC PI		Full	Index	OECD Main economic indicators	http://www.oecd.org/std/oecdmaineconomicindicatorsmei.htm
Secondary industry investment	Ln Lvl	X12	SEC	Manufacturing sector investment	Full		ESRI, Cabinet Office, Statement of National Accounts	http://www.esri.cao.go.jp/en/sna/menu.html
Tertiary industry investment	Ln Lvl	X12	TER	Summed investment from 'Wholesale and retail trade', 'Real estate', 'Business services', 'Hospitality', 'Entertainment' and 'Other services'. Excluded are 'Utilities' and 'Finance'	Full		ESRI, Cabinet Office, Statement of National Accounts	http://www.esri.cao.go.jp/en/sna/menu.html
US GDP	Ln Lvl	No	YUS		Full	BN USD	FRED	https://fred.stlouisfed.org/series/GDPC1
Real wage, manufacturing	Ln Lvl	X12	RM W	Wages expense by manufacturing firms, adjusted by Price Index, Japan	Full	100mn JPY / CPI	MOF, Financial Statements Statistics of Corporations by Industry, Quarterly	http://www.mof.go.jp/english/pri/reference/ssc/historical.htm

Real wage, non-manufacturing	Ln Lvl	X12	RNW	Wages expense by non-manufacturing firms, adjusted by Price Index, Japan	Full	100mn JPY / CPI	MOF, Financial Statements Statistics of Corporations by Industry, Quarterly	http://www.mof.go.jp/english/pri/reference/ssc/historical.htm
Oil	Lvl	No	OIL	WTI, quarterly average spot prices	Full	USD	U.S. Department of Energy: Energy Information Administration	http://www.eia.gov/petroleum/data.cfm#prices
Real foreign wage	Lvl	No	Foreign wage	Benchmarked Unit Labour Costs - Industry for the Republic of Korea, adjusted by 'Consumer Price Index: All Items for Korea'	Full	Index	FRED	https://fred.stlouisfed.org/series/ULQBBU01KRA657S
Discount rate	Lvl	No	R	The Basic Discount Rate	Full	Rate	BOJ	https://www.statsearch.boj.or.jp/ssi/msthtml/ir01_m_1_en.html
US CPI	Lvl	No	USCPI	Consumer Price Index for All Urban Consumers: All Prices	Full	Rate	US Department of Labor, Bureau of Labor Statistics	https://www.bls.gov/cpi/