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The views expressed in this study are those of the author and do not necessarily reflect the views of the Bank of Finland.

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Abstract

This thesis consists of an introductory chapter and three essays, all of which aim to study the functioning of a small open economy. The thesis starts with an investigation of export and import price determination and moves to a small open economy DSGE model framework in order to study the role of financial factors in economic fluctuations. In all three essays, theoretical small open economy models are used for quantitative analysis of the small open economy of Finland.

The first essay develops a model for aggregate trade price inflation that takes into account two price setting conventions: local currency pricing (LCP) and producer currency pricing (PCP). In our empirical work, we confront our model with Finnish data and estimate the relative shares of LCP and PCP firms in the economy. In the estimation period 1980–1998, the share of local currency pricing was 40 percent in the export sector and 60 percent in the import sector, implying a limited pass-through from exchange rate to destination-country prices in both sectors.

The second essay builds a small open economy DSGE model with the BGG financial accelerator and financial market shocks. In our empirical work covering the period 1995–2008, we provide evidence of an operative financial accelerator in Finland. The financial accelerator acts as an amplifying mechanism for many disturbances hitting the Finnish economy. Our main result is that financial market disturbances have contributed significantly to Finnish cyclical fluctuations between 1995 and 2008. Even allowing for several shocks stemming from both domestic sources and the international economy, domestic financial market shocks emerge as key drivers of recent business cycle fluctuations in Finland.

The third essay studies the boom-bust period in Finland in the late 1980s and early 1990s, focusing on the role of financial factors and investment behaviour. We construct a small open economy DSGE model with the BGG financial accelerator and an unconventional shock structure that captures the key events of the episode. In this model framework, we study the role of financial market deregulation in the boom, the negative impact of the collapse of Soviet-Finnish trade in 1991, and the effect of the collapse of the fixed exchange rate regime in 1992. We argue that the financial accelerator mechanism is a key amplifying mechanism that helps the model to match, in particular, the large and persistent swings of investment first above

and later below its trend. This essay demonstrates that the shocks Finland encountered combined with financial frictions are able to produce a boom and a severe depression, matching key salient features of the actual boom-bust cycle experienced in Finland in the late 1980s and early 1990s.

Key words: small open economy, DSGE models, economic fluctuations, boom-bust cycles, foreign trade price determination, BGG financial accelerator, financial market shocks

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Tiivistelmä

Väitöskirja koostuu johdannosta ja kolmesta tutkimusluvusta, joiden tutkimuskohteena on pienen avoimen talouden toiminta. Väitöskirjassa tutkitaan ensin vienti- ja tuontihintojen määräytymistä, minkä jälkeen tarkastellaan rahoitustekijöiden merkitystä talouden vaihteluissa koko pientä avotaloutta kuvaavan modernin dynaamisen makromallikehikon avulla. Kaikissa kolmessa tutkimusluvussa teoreettisia pientä avotaloutta kuvaavia malleja käytetään Suomen talouskehityksen kvantitatiiviseen analyysiin.

Ensimmäisessä tutkimusluvussa kehitetään kansainvälisesti kaupattavien hyödykkeiden inflaatiokehitystä kuvaava malli, jossa hintajäykkyys otetaan huomioon niin, että ulkomaankaupan hinnat voivat olla jäykkiä joko ostajan valuutassa (hinnoittelu paikallisen valuutan määräisenä) tai myyjän valuutassa (hinnoittelu tuottajan valuutan määräisenä). Empiirisessä työssä estimoidaan Suomen tilastotietoja käyttäen ostajan ja myyjän valuutassa hinnoittelevien yritysten suhteellinen osuus taloudessa. Estimointiajanjaksona 1980–1998 ostajan valuutassa hinnoittelevien yritysten estimoitu osuus oli 40 % vientisektorilla ja 60 % tuontisektorilla. Näin ollen valuuttakurssin läpimeno kohdemaan tuontihintoihin oli estimointiajanjaksolla epätäydellinen sekä vienti- että tuontisektorilla.

Toisessa tutkimusluvussa rakennetaan pienen avotalouden makromalli, jossa on BGG-rahoitusakseleraattori sekä rahoitusmarkkinoilta peräisin olevia sokkeja. Työn empiirisessä osassa, joka koskee ajanjaksoa 1995–2008, osoitetaan rahoitusakseleraattorin toimineen Suomen taloudessa. Rahoitusakseleraattori voimistaa monien Suomen talouteen kohdistuvien sokkien vaikutuksia. Työn keskeinen tulos on, että rahoitusmarkkinasokeilla on ollut suuri vaikutus Suomen talouden suhdannevaihteluihin vuosina 1995–2008. Kotimaiset rahoitusmarkkinasokit näyttäisivät olevan keskeisiä suhdannevaihteluita aiheuttavia sokkeja silloinkin, kun lukuisat muut kotimaasta ja kansainvälisestä taloudesta peräisin olevat sokit on otettu huomioon.

Kolmannessa tutkimusluvussa tutkitaan Suomen talouden ylikuumenemista 1980-luvun lopulla sekä 1990-luvun alun lamaa keskittymällä erityisesti rahoitustekijöiden ja investointien merkitykseen. Työssä rakennetaan pienen avotalouden makromalli, jossa on BGG-rahoitusakseleraattori sekä epätavanomainen sokkirakenne, joka formalisoi aikakauden keskeiset tapahtumat. Tässä mallikehikossa arvioidaan rahoitusmarkkinoiden vapauttamisen merkitystä

1980-luvun talouden ylikuumenemisessa, vuoden 1991 Suomen Neuvostoliiton-kaupan romahduksen epäsuotuisia vaikutuksia sekä vuoden 1992 kiinteästä valuuttakurssijärjestelmästä luopumisen vaikutuksia. Keskeinen tutkimustulos on, että rahoitusakseleraattorilla on tärkeä sokkien seurauksia voimistava vaikutus, mikä auttaa mallia toistamaan erityisesti investointien suuret ja pitkäaikaiset vaihtelut trendinsä ylä- ja alapuolelle. Tässä tutkimusluvussa osoitetaan, että Suomeen kohdistuneet sokit yhdistettynä rahoituskitkatekijöihin pystyvät aikaansaamaan talouden ylikuumenemisen ja syvän laman ja toistamaan Suomen 1980-luvun lopun ja 1990-luvun alun toteutuneen talouskehityksen keskeiset piirteet.

Avainsanat: pieni avotalous, DSGE-mallit, suhdannevaihtelut, talouden ylikuumeneminen ja lama, ulkomaankaupan hintojen määräytyminen, rahoitusakseleraattori, rahoitusmarkkinasokit

JEL luokitus: E32, E44, F41

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Contents

Chapter 1

Introduction

Contents

[1] An extended version of the first essay has been published as a licentiate thesis (Hanna Freystätter: Price setting behavior in an open economy and the determination of Finnish foreign trade prices. Bank of Finland E:25/2003).

1 Background

A small open economy is influenced by both domestic and foreign factors. An economy with a high output share of foreign trade can only be analyzed in a model framework that takes the openness into account. In an open economy, the exact form of price setting in the foreign trade sector affects the way the economy responds to shocks. Despite the importance of foreign factors and trade, a small open economy is also affected by domestic factors and disturbances. Recently, the 2007–2008 global financial crisis has spotlighted the role of financial markets in times of crisis as well as in the propagation of the business cycle (see, for example, Gertler et al, 2007; and Christiano et al, 2003, 2010). Importantly, domestic financial factors and financial disturbances should be analyzed in an appropriate open economy framework in order to capture all the crucial mechanisms affecting the propagation of shocks in a small open economy.

This thesis aims at analyzing the functioning of a small open economy. The thesis starts with an investigation of price setting in the foreign trade sector and moves to a modern macroeconomic model – a DSGE model – incoporating foreign trade but also other features important for studying a small open economy. In particular, in the DSGE model analysis we focus on the role of financial conditions in macroeconomic dynamics.

The traditional idea of trade price determination in a small open economy is relatively simplified. It is based on the assumption that all exporters act as price-takers. This implies that all internationally traded goods have exogenously given world market prices. In this case, both import and export prices simply follow foreign trade prices, including changes in the nominal exchange rate. In Finland, as in many other countries, this does not appear to have always been the case. For example, exchange rate fluctuations in the 1990s are not fully reflected in Finnish foreign trade prices, ie the pass-through of the exchange rate has been limited.

Before the onset of the 2007–2008 global financial crisis, financial factors typically played no role in DSGE models. These models were built assuming the Modigliani-Miller (1958) theorem, according to which the financial structure is both indeterminate and irrelevant to real economic outcomes. The global financial market crisis has demonstrated that financial markets matter. Financial markets are a source of shocks affecting the real economy as well as the financial sector. Moreover, financial factors can amplify fluctuations, even if

the initial shock comes from outside the financial markets. Financial market activities and developments in the real economy are tightly linked, which should be taken into account when the focus is on normal business cycle fluctuations or on the times of crisis.

In this thesis, we reconsider many of the earlier simplifying assumptions of the functioning of a small open economy. Firstly, we extend the analysis of how firms set prices of internationally traded goods along the lines of new open economy macroecomics (initiated by Obstfeld and Rogoff, 1995) and the inflation dynamics literature (for example, Galí and Gertler, 1999; and Galí, Gertler and López-Salido, 2001). In this literature, as well as in this thesis, imperfect competition and sticky prices play a crucial role. Instead of price-taking, there is monopolistic competition in the goods market and firms face a downward-sloping demand curve that allows them to set their prices above marginal cost. In the first essay, we build a model that allows for different price setting regimes in the foreign trade sector. We then abandon the Modigliani-Miller theorem in the second and the third essay and incorporate a genuine role for financial market frictions and imperfections into our business cycle model. Our aim is to conduct research on the interaction of financial factors and economic fluctuations in a small open economy framework. To this end, the second essay incorporates financial frictions and financial shocks into a small open economy DSGE model in order to study business cycle fluctuations. In the third essay, we build a DSGE model suitable for analyzing the role of financial factors in the boom-bust cycle experienced in the small open economy of Finland in the late 1980s and early 1990s. In all three essays, the theoretical small open economy models are used for quantitative analysis of the small open economy of Finland.

2 Modelling of a small open economy: shocks and propagation

2.1 Sticky prices in an open economy context

This thesis builds on the assumption of price stickiness. New-Keynesian DSGE models start from the assumption that prices are sticky. Incorporating price frictions into a DSGE model gives a role to monetary policy and improves the empirical fit of the model. Incorporating price stickiness into a theoretical model takes as given either the cost of adjusting price or the fixed or random interval for setting the price. Subject to this constraint, an optimal price for maximizing profits can be found. Because it will be costly or difficult to change prices in the future, the future affects the current pricing decision. In this thesis, the first essay uses the cost-of-changing prices approach of Rotemberg (1982). The second and the third essay incorporate Calvo (1983) price setting, in which firms are not allowed to change prices unless they receive a random price-change signal. However, it has been demonstrated in Rotemberg (1987) that dynamic adjustment costs, although simple to specify and work with, generate price dynamics identical to those of Calvo random price staggering.

The first essay focuses on foreign trade prices, which may indeed exhibit different properties from consumer prices. The exact form of pricing behaviour of internationally traded goods is important since it affects competitiveness (relative prices), terms of trade, exchange rate pass-through (correlation between exchange rate changes and inflation), inflation, development of profits and output (via the expenditure-switching effect).

In an open economy, nominal price rigidities can take a variety of forms since monopolistic producers can choose to preset product prices in domestic or foreign currency. The Obstfeld-Rogoff (1995) model is based on the conventional price setting assumption of producer-currency pricing (PCP). In this case, prices are set in the seller's currency and the law of one price holds. Under producer currency pricing, because the producer sets prices in home currency but does not change them frequently (prices are sticky), prices faced in the export market fluctuate with changes in the nominal exchange rate, reflecting a complete pass-through of exchange

rates to destination-country prices. In this case, nominal currency depreciation leads to a shift towards domestically produced tradables, a phenomenon referred to as the expenditure-switching effect. Under producer-currency pricing, shocks that cause the exchange rate to depreciate can put substantial upward pressure on consumer prices via the imported price component as well as through stimulating real activity by encouraging higher real net exports.

The alternative convention of local currency pricing (LCP) means that prices are set in the buyer's currency and are sticky.[2] Local currency pricing has been offered as an explanation for the well-documented empirical failure of the law of one price (see, for example, Betts and Devereux, 1996, 2000): prices are sticky but not in the seller's currency. In this case, changes in nominal exchange rates do not affect goods prices in the local market of sale, ie there is zero pass-through of exchange rates to import prices (in the short run).[3] Local currency pricing reduces the traditional expenditure-switching role of exchange rate changes. For example, in the case of currency depreciation, the shifts of domestic demand away from imports and global demand towards domestic tradables are moderated. This feature tends to markedly dampen the pass-through from exchange rates to destination-country prices in line with the empirical evidence, both directly, because import prices respond by less to the exchange rate, and indirectly, because exchange rates tend to have smaller effects on domestic production. This specification forces a substantial 'disconnect' between changes in exchange rates, inflation and real activity.

[2]Local-currency pricing refers simply to sticky prices in the currency of the buyer and does not assume differences in market conditions across countries. Pricing to market, introduced by Krugman (1987), on the other hand, refers to a monopolistic firm that intentionally chooses different prices for different markets because of different market conditions in different markets.

[3]In this thesis, local currency price stability of imports is attributed entirely to nominal frictions. In the literature, recent alternative explanations to the high degree of stability of import prices in local currency are, for example, the presence of costs incurred locally before the goods reach the consumers (such as distribution or assembling costs) and optimal markup adjustment by monopolistic firms, which maximize profits through price discrimination across national markets (pricing to market) (see, for example, Bacchetta and Van Wincoop, 2003; Burstein et al, 2004; Corsetti and Dedola, 2005). There is an ongoing debate on the extent to which the local currency stability of imports can be explained by nominal rigidities (see, for example, Corsetti et al, 2007).

In the first essay our contribution is the building of a model that combines producer and local currency price setting in the foreign trade sector. As a result, we get a model that allows for less-than-perfect exchange rate pass-through to import prices at the aggregate level. We argue that this is important since it is unlikely that the pass-through is either full or non-existent in the short run. In the second and the third essay, there is limited pass-through from exchange rate changes to domestic consumer prices. However, export prices are set in the producer's currency.

2.2 Financial frictions and aggregate fluctuations: the financial accelerator

In the second and the third essays, we extend the standard business cycle model of the New Keynesian variety by allowing for financial frictions. The implication of financial frictions is that there is a link between the financial markets and the real economy in the model. In a model with financial frictions, financial conditions affect the short-term economic dynamics. In this thesis, we study the role of financial conditions in amplifying domestic and foreign influences in a small open economy.

There is more than one way to incorporate financial frictions into a standard business cycle model. The DSGE models constructed in this thesis incorporate the theory of the financial accelerator described in Carlstrom and Fuerst (1997) and Bernanke, Gertler and Gilchrist (1999) (BGG). The BGG financial accelerator mechanism introduces a balance sheet constraint on entrepreneurs' ability to obtain finance: entrepreneurs pay an external finance premium that depends inversely on their net worth.[4]

A key concept in the financial accelerator mechanism is the external finance premium, defined as the difference between the cost to a borrower of raising funds externally and the opportunity cost

[4]The idea in the models that build on Bernanke, Gertler and Gilchrist (1999) is that borrowers' financial positions affect their external finance premiums and thus their overall cost of credit. This strand of theoretical literature does not limit the level of debt but instead generates a cost of funds that exceeds the riskless rate. Some alternative theoretical literature introduces a collateral constraint that generates quantitative rationing, leaving the cost of funds at the riskless rate level (for example, Kiyotaki and Moore, 1997; and Iacoviello 2005).

of internal funds. As opposed to a standard model in which it is implicitly assumed that a borrower pays the riskless interest rate and there are no limits to borrowing, the presence of financial frictions means that the borrower has to pay a risk premium for obtaining external finance. Moreover, the external finance premium that the borrower pays depends inversely on the strength of the borrower's financial position, measured in Bernanke, Gertler and Gilchrist (1999) by net worth. Borrowers in good financial condition pay a lower premium for external finance since they have a significant stake in the enterprise and therefore have a greater incentive to make well-informed investment choices and take actions to ensure good financial outcomes.[5]

The economic impact of the financial accelerator is seen in that during an economic upswing risk premia decline, while during a downswing risk premia increase. In this way the financial accelerator reinforces the cycle. For example, during a downswing, corporate and household balance sheets become weaker, meaning both businesses and households have to pay higher risk premia on loans. The risk premia grow because lenders want to be compensated for borrowers' weakened ability to pay back their loans and the consequent heightened risk of default. During an upswing, in contrast, balance sheets strengthen and risk premia decline, because the ability of borrowers to pay back their loans improves.

A rise in the cost of finance will lead to weaker aggregate demand and slower growth. Expanding risk premia have a particularly constricting effect on investment, as investment projects typically require external finance.[6] Declining demand leads to a drop in asset prices, which erodes corporate and household balance sheets and further pushes up the cost of finance. The spiral of a contracting economy and tightening financial conditions can lead to a severe decline in economic activity. During an upswing, the same mechanisms operate in the opposite direction, to fuel economic activity.

[5]Bernanke, Gertler and Gilchrist (1999) model financial frictions as a costly state verification problem. Due to asymmetric information between the borrower and lender, the lender charges the borrower a premium to cover the expected bankruptcy cost. The financial contract implies an external finance premium that depends on the borrower's leverage ratio.

[6]Consumption demand could also be constrained if households' access to finance is squeezed. In addition, the cost and availability of finance has implications for exporters. In this thesis, the focus is solely on investment.

As debt contracts generally state the nominal value of a loan, changes in inflation will affect the real value of the loan. As a result, the financial accelerator impact on cyclical fluctuations is not automatically procyclical. The effect on the economy of some shocks is to move output and inflation in opposite directions. If output rises but inflation simultaneously declines – as, for example, when there is a positive shock to productivity – the deceleration in inflation will increase the real value of loans. This is called the Fisher effect (Fisher, 1933). With this type of shock, the rise in asset prices related to improved output increases borrowers' net wealth, while the increased real value of nominal loan agreements operates in the opposite direction, reducing net wealth. The impacts are thus offsetting at least in part, whereupon the economy may behave almost as if there were no financial accelerator.[7]

However, the theory of the financial accelerator needs empirical studies to quantify its strength. In this thesis, we assess the role of financial frictions in Finland by incorporating credit frictions in a quantitative DSGE framework. The second essay studies the role of financial frictions in normal business cycle fluctuations, while the third essay considers the importance of financial frictions during a boom-bust period.[8] Based on our results, the financial accelerator has operated in the Finnish economy over the years 1995–2008. Moreover, we can plausibly demonstrate the crucial role of financial factors in the boom-bust period in Finland in the late 1980s and early 1990s. We argue that the shocks that hit Finland in the late 1980s and early 1990s were greatly amplified by the financial accelerator mechanism. In the third essay, the financial accelerator is the key amplifying mechanism allowing the model to match the large and persistent swings in investment, first above and later below its trend.

The presence of the financial accelerator shapes our view of how the economy operates and what the effects of economic policy are. The financial accelerator reinforces many of the shocks affecting the economy. It renders the economy vulnerable to changes in borrowers' net wealth. If the net wealth of borrowers declines due to a shock,

[7] In the original paper by Bernanke, Gertler and Gilchrist (1999), the debt contract is specified in terms of the real interest rate. In this thesis, in order to capture the debt-deflation effect, we follow Christiano, Motto and Rostagno (2003) and assume that a borrower signs a nominal debt contract.

[8] Christiano, Motto and Rostagno (2003, 2010) used the BGG approach to study the financial factors driving recent business cycles as well as in the US Great Depression.

this will have an immediate negative impact, via the cost of finance, on both investment and output.

Central bank policy rates or market rates alone do not give a complete picture of financial conditions, as the overall costs of investment projects also depend on the strength of borrowers' balance sheets. At a time of generally low interest rates, weak balance sheets and heavy indebtedness can push up the costs of finance, thereby restricting investment.

Because of the financial accelerator, changes in asset prices have a direct impact on output. For example, movements in share prices and housing prices affect borrowers' balance sheets by raising or lowering the value of their assets. Changes in the value of net wealth are followed by changes in risk premia. Thus, via their effect on borrowers' balance sheets, asset price changes influence cyclical fluctuations in the real economy.

2.3 Extending the shock structure of a small open economy DSGE model

Incorporating the BGG financial accelerator in a small open economy model implies that financial markets propagate the shocks to the economy. In this model framework, financial factors contribute to economic fluctuations by either boosting or depressing economic activity. Furthermore, the effects of a shock on financial conditions could lead to persistent fluctuations in the economy, even if the initiating shock had little or no intrinsic persistence.

However, the focus of interest in business cycle analysis is not only on the propagation of shocks, but also on the shocks themselves. In the second essay, we explore the types of shocks that drive business cycle fluctuations. In the third essay, we use our DSGE model framework to investigate what kinds of shocks are able to produce a boom and bust. A key contribution in this thesis is to extend the shock structure of a small open economy DSGE model in order to study the relevance and impacts of some new, less conventional, shocks.

An economy may be hit by different kinds of shocks. Some of the standard shocks typically included in business cycle models are disturbances to technology, government consumption, household preferences and monetary policy. In a small open economy, shocks

that originate in the international economy also play an important part. In the second and the third essay, we extend the shock structure of a small open economy DSGE model to financial market shocks. Thus, in addition to the possibility that financial markets play an important part in the propagation of non-financial market shocks, we allow for the possibility that financial markets are a source of shocks.

A financial market shock is at issue when the risk premia on corporate and household loans increase (decrease) in size unexpectedly and more (less) than would be expected under the prevailing cyclical conditions. Thus, enlargement of risk premia due to a financial market shock differs from that due to the financial accelerator, which derives from weakening balance sheets caused by a downturn in the business cycle. A negative financial market shock will thus be reflected in an unexpected increase in risk premia, but the possible causes of such a shock are numerous and diverse. Some financial market shocks relate to problems of financial intermediation. Such shocks in our model are labeled credit supply shocks, following Gilchrist, Ortiz and Zakrajsek (2009). For example, a decline in interbank confidence can boost banks' own funding costs. This is then reflected in higher costs for borrowers, even if the borrower's own balance sheet is unchanged. Financial market shocks are also at issue in the case of exogenous movements in asset prices. Such changes could be triggered eg by the fading of unrealistically positive expectations as to stock or housing markets. In our DSGE model framework, we follow Christiano, Motto and Rostagno (2003) and introduce a financial wealth shock into the creation of firms' net worth. The financial wealth shock exogenously destroys or adds to the aggregate net worth of the entrepreneurial sector, leading to changes in risk premia. A decline in asset prices due to a financial market shock (or to a cyclical downturn) depresses net corporate and household wealth (assets minus debts), which in turn leads to enlarged risk premia. The risk premia will remain high and thus hamper the economy's recovery from the downturn until borrowers' net wealth grows, ie until the level of indebtedness declines.

In the second essay, we show that both credit supply shocks and financial wealth shocks turn out to be important sources of business cycle fluctuations in Finland. Based on our results we argue that assessments of the causes of business cycle fluctuations in Finland that do not take into account the role of financial factors and shocks could lead to their significance being underestimated and other factors' significance being overestimated. It would appear that favourable

and unfavourable shocks in technological development are typically given a key role in explaining cyclical fluctuations when financial market shocks are omitted entirely from the analysis. Including the financial markets in the analysis also makes it easier to explain certain phenomena: for example, it is more credible to explain the fading of investment following the escalation of the global financial market crisis at the end of 2008 with reference to financial market shocks than by appeal to an unexpected disruption in technological development leading to lower productivity.

In the third essay, we focus our analysis on the shocks that could plausibly account for the large swings in output and investment that Finland experienced in the late 1980s and early 1990s. We refer to this period as a boom-bust cycle, since an economic boom was followed by a depression that was much more severe and elongated than an ordinary business cycle. During the boom-bust cycle Finland experienced events that are formalized in the third essay as economic shocks. The two financial market shocks discussed earlier – the credit supply shock and the financial wealth shock – are used in the third essay to capture the effects of financial market deregulation often claimed to have produced the boom in the late 1980s. A key addition to the model is a disturbance to the quality of capital, following Gertler and Karadi (2010). In our model, a capital obsolescence shock affects the balance sheets of non-financial firms, as opposed to those of the financial intermediary sector, as in Gertler and Karadi (2010). The role of the capital obsolescence shock in our model is to formalize the collapse of Soviet-Finnish trade in 1991 and the consequent sudden redundancy of Soviet-oriented manufacturing that wiped out part of the economically valuable capital from the economy and resulted in a dramatic weakening of firms' balance sheets. We argue that the shocks that hit Finland were powerful sources of sizable economic fluctuations since they impacted the balance sheets of leveraged and credit-constrained firms. We show that we are able to produce a boom-bust period matching the Finnish data in a DSGE model framework that combines the appropriate shocks with the BGG financial accelerator that greatly amplifies the effects of the shocks.

3 Summary of the essays

In this section, we summarize the contents of the three essays. In all the essays, the aim is to investigate the functioning of a small open economy. The first essay focuses on price setting of internationally traded goods, which is key to understanding how foreign variables affect a small open economy. The second essay builds a DSGE model incorporating internationally traded goods but focusing this time on the linkages between financial factors and the real economy in a small open economy. In the second essay, price setting frictions are thus complemented by financial frictions that also affect the propagation of shocks in a small open economy. The second essay also allows for shocks that originate in the financial market. In the first essay we find empirical evidence of price setting frictions in the Finnish economy, and, in the second essay we find also evidence of financial frictions. Furthermore, the second essay points out that even if a small open economy is affected by shocks from the international economy, shocks stemming from the financial market are important sources of business cycle fluctuations affecting, in particular, the behaviour of private investment.

The third essay incorporates the key ingredients studied in the first two essays and develops the small open economy DSGE model further into a model framework suitable for studying the boom-bust episode in Finland in the late 1980s and early 1990s. Financial factors play a key role in the third essay, in either boosting or reducing economic activity throughout the boom-bust cycle. The third essay builds a DSGE model with shocks and propagation mechanisms that allow us to tell a story of the Finnish boom-bust cycle that matches the Finnish data.

The empirical methods applied in the thesis are the following: The first essay uses the Generalized Method of Moments (GMM) to estimate key parameters of the trade price equations. In the second essay, the estimation of the DSGE model is carried out using the Bayesian Maximum Likelihood approach. The quantitative analysis in the third essay is based on calibrating the DSGE model to match the Finnish data and comparing the model outcome with key salient features of an actual boom-bust cycle experienced in Finland in the late 1980s and early 1990s. The first and the third essays consider the time period before the introduction of the euro in 1999. The second

essay, on the other hand, studies Finland as part of the euro area.[9] We argue that Finland offers interesting and rich data for studying the functioning of a small open economy.

3.1 Price setting behaviour in an open economy and the determination of Finnish foreign trade prices[10]

The first essay investigates the price setting of internationally traded goods. The main contribution of the first essay is to develop a theoretical framework in which pricing behaviour in an open economy can be analyzed and to examine aggregate Finnish foreign trade price data within this framework.

In an open economy, the firm has to make a choice whether to set the price in home or foreign currency. The first essay contributes by building a model of export and import price determination that takes into account two price setting conventions: local-currency pricing (LCP) and producer-currency pricing (PCP). We develop a model for aggregate trade price inflation that incorporates sticky prices in the currencies of the buyer (LCP) and seller (PCP). The nature of price setting is thus forward looking, and the exchange rate effect depends on the relative shares of local-currency and producer-currency pricing firms in the economy. In the export sector, the larger the share of local currency pricing firms, the greater the impact from exchange rate fluctuation to export prices measured in domestic currency. The same applies to the import sector, except that the firms that set prices in foreign currency are exercising producer-currency pricing. Under local currency pricing, all producers who hold their foreign-currency prices

[9] The exchange rate was fixed in the 1980s up to the third quarter of 1992 when the markka was allowed to float. However, the fixed exchange rate period includes some exchange rate realignments such as devaluations in 1982:4 and in 1991:4. The decision to switch to a floating exchange rate in 1992:3 preceded a crises leading to an excessive depreciation of the Finnish currency followed by a recovery. In 1996:4 the markka became part of the exchange rate mechanism of the European Union. As part of the euro area since 1999, Finland lacks an independent monetary policy, and nominal exchange rate fluctuations reflect developments in the euro area.

[10] An extended version of the first essay has been published as a licentiate thesis (Hanna Freystätter: Price setting behavior in an open economy and the determination of Finnish foreign trade prices. Bank of Finland E:25/2003).

constant allow their profit margins (measured in home currency) to adjust in proportion to unexpected exchange rate movements.

In our empirical work, we confront our model with Finnish data and estimate the relative shares of LCP and PCP firms in the economy. The model is estimated with quarterly Finnish foreign trade price data for the period 1980–1998. We apply the generalized method of moments (GMM) to study the determination of Finnish trade prices. The estimation results seem to support the model. In the estimation period, the share of local-currency pricing is 40 percent in the export sector and 60 percent in the import sector, implying that there is limited pass-through from exchange rate to destination-country prices in both sectors. Furthermore, the results suggest that the expenditure-shifting effect of the exchange rate is weaker than in the pure producer-currency case often assumed in theoretical models. Exchange rate volatility is not clearly reflected in Finnish trade prices, since during the estimation period roughly 60 percent of both exports and imports were priced in home currency.[11]

3.2 Financial market disturbances as sources of business cycle fluctuations in Finland

The 2007–2008 financial crisis has highlighted the relevance of changes in financial conditions for real activity. Moreover, the recent financial crisis has shown that macroeconomic analysis should focus on new sources of shocks stemming from the financial market itself. The second essay aims at investigating both the qualitative and quantitative importance of financial markets and financial market disturbances in understanding macroeconomic dynamics. The empirical work covers the period 1995–2008 in Finland. This is an interesting period because around the turn of the century the Finnish

[11] Adoption of the euro at the start of 1999 has likely affected the development of aggregate trade prices: Firstly, the euro suddenly became the euro area countries' home currency, which led to an increase in trade conducted in the home currency of all these countries. Secondly, the importance of the euro in world trade has increased, as its role as an important world currency has become better established. Therefore, as a result of the adoption of the euro the foreign trade prices of euro area countries have probably become (or are becoming) more insulated from exchange rate fluctuations.

economy, along with many others, experienced a stock market boom and bust. The period also covers the start of the financial market turmoil of 2007–2008.

The second essay constructs a small open economy DSGE model that incorporates the financial accelerator of Bernanke, Gertler and Gilchrist (1999). A key contribution is to include two domestic financial market shocks – a credit supply shock and a financial wealth shock – in a small open economy model. The credit supply shock changes exogenously the risk premia firms pay for external finance, while the financial wealth shock destroys or creates aggegate entrepreneurial net worth. In the empirical DSGE literature, investment-specific shocks often turn out to be the most important driving force of economic fluctuations. However, as it may actually hide unmodeled frictions in the capital accumulation process, we omit the investment-specific technology shock from the analysis and concentrate on the explanatory power of financial disturbances. Despite this omission and in contrast to much of the existing literature, our model has a rich shock structure, allowing us to study the relative importance of domestic and international shocks in the aggregate fluctuations of a small open economy. Furthermore, we take into account an important feature of the small open economy of Finland: as part of the euro area, the Finnish economy cannot rely on the two important channels that help a standard small open economy adjust to economic shocks, namely the nominal exchange rate and the policy rate set independently by the central bank.

The second essay contributes in evaluating empirically first the strength of the financial accelerator and secondly the role of financial market shocks in the small open economy of Finland. We estimate the model using a Bayesian Maximum likelihood approach and quarterly data on the Finnish economy over the period 1995–2008. In our empirical work, we provide evidence of an operative financial accelerator in Finland. The estimate of the parameter governing the strength of the financial accelerator is of the right sign and close to values obtained in the relevant international literature using estimated DSGE models to study the quantitative significance of the financial accelerator for the aggregate economy (see eg Christensen and Dib (2008)). We thus show that there is feedback between the financial and real sectors via

aggregate firm balance sheets. The financial accelerator acts as an ampliying mechanism for many disturbances to the Finnish economy.

Our main result is that disturbances stemming from the financial sector itself have contributed significantly to Finnish cyclical fluctuations between 1995 and 2008. Even allowing for several shocks stemming from both domestic sources and the international economy, domestic financial market shocks emerge as key drivers of recent business cycle fluctuations in Finland. We show that domestic financial market shocks to entrepreneurs and their demand for capital are key driving forces behind the fluctuations in investment and thus help explain particular business cycle episodes in Finland, such as the boom and bust of the stock market in the late 1990s and early 2000s, the subsequent early millennium slowdown and, more recently, the sudden reversal of investment activities in 2008 due to the global financial crisis.

3.3 Financial factors in the boom-bust episode in Finland in the late 1980s and early 1990s

The boom-bust cycle in Finland in the late 1980s and early 1990s manifested itself in a strong and persistent movement in investment first above and later below its trend. The severity of the depression gives Finland a place among the 'Big Five' postwar large scale financial crises in rich countries identified by Reinhart and Rogoff (2008). The third essay studies the Finnish boom-bust episode, focusing on the role of financial factors and investment behaviour.

The third essay contributes by proposing a DSGE framework for studying and explaining both the boom and the bust in Finland in the late 1980s and early 1990s. We develop a small open economy DSGE model with balance sheet-constrained firms a la BGG and an unconventional shock structure that captures the key events of the episode. The model is calibrated to the Finnish economy.

We use the model to simulate three events claimed to have played a key role in the Finnish boom-bust episode and compare the model outcome with actual Finnish data. Firstly, we assess in our DSGE framework the role of financial market deregulation in the 1980s, in the boom that preceded the crisis. Secondly, we use our model to evaluate the negative impact of the collapse of Soviet-Finnish trade in the beginning of 1991. Thirdly, we investigate the effect of the

collapse of the fixed exchange rate regime in September 1992. One of the contributions of the third essay is formalizing and calibrating these three events as shocks in the model, in order to assess their role in generating a boom-bust cycle that matches both qualitatively and quantitatively the one observed in Finland. We incorporate domestic financial market shocks into the model to capture the deregulation of the financial market, a capital obsolescence shock (instead of a conventional trade shock, see Gorodnichenko et al (2009)) to model the sudden redundancy of Soviet-oriented manufacturing, and a shock from the international financial market (a country borrowing premium shock) to capture the collapse of the fixed exchange rate regime.We argue that the shocks that hit Finland were powerful sources of pronounced economic fluctuations because they hit the balance sheets of leveraged and credit-constrained firms.

The third essay contributes by using a DSGE model for quantitative analysis of an actual boom-bust cycle experienced in Finland. The model is particularly successful in explaining the role of financial factors and in reproducing quantitatively the behaviour of investment activities and output during the boom-bust cycle. A key finding is the crucial role played by the financial accelerator in the ability of the model to mimic the response of the Finnish economy to the shocks that hit the economy. The procyclical variation in firms' balance sheets constitutes an important amplification mechanism in all three events studied in the essay. Absent credit market frictions, the initiating disturbances would have resulted only in a mild upturn or downturn. In our DSGE framework, we show how financial factors, either boosting or depressing economic activity, contributed first to the boom and later to the severity of the crisis and slow recovery of the Finnish economy. We argue that the financial accelerator is a key amplifying mechanism that helps the model to match, in particular, the large and persistent swings of investment first above and later below its trend.

In addition to the amplification mechanism, shocks are needed that directly impact entrepreneurs' balance sheets and cost of finance.This essay demonstrates that in our DSGE framework, the shocks to the Finnish economy combined with financial frictions are able to produce a boom and severe depression, matching key salient features of the actual boom-bust experienced in Finland in the late 1980s and early 1990s.

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Chapter 2

Price setting behaviour in an open economy and the determination of Finnish foreign trade prices

Abstract

This paper investigates price setting of internationally traded goods. We develop a theoretical model that incorporates sticky prices in the currency of both the buyer (local currency pricing) and seller (producer currency pricing). The nature of price setting is thus forward looking and the exchange rate effect depends on the relative share of local currency and producer currency pricing firms in the economy. The model is estimated with Finnish foreign trade price data for the period 1980–1998. The estimation results seem to support the model. The estimated share of local currency pricing is 40 per cent in the export sector and 60 per cent in the import sector implying that there is limited pass-through from exchange rate to destination-country prices in both sectors.

Contents

1 Introduction

This study investigates price setting behaviour in an open economy context. The importance of understanding pricing behaviour is underlined by the vast empirical literature on international pricing. One of the key issues is the evidence of systematic failures of the law of one price among internationally traded goods (see eg surveys by Rogoff 1996 and Goldberg and Knetter 1997). Instead of the traditional assumption of price-taking, it is often argued that these findings are best understood within a framework that incorporates imperfect competition, nominal rigidities, and international market segmentation. Krugman (1987) introduced the term 'Pricing to Market' to describe monopolistic firms that choose to set different prices in different national markets because of different market conditions.[1] The idea of pricing to market has been adopted in the new open economy macroeconomics literature in the form of local currency pricing (LCP), which refers to sticky prices in the currency of buyer. In this paper, we build a model for aggregate trade price inflation that incorporates sticky prices both in the currency of the buyer (LCP) and in the currency of the producer (PCP). Based on Finnish foreign trade price data for the period 1980–1998, we show that the estimated share of local currency pricing is 40 per cent in the Finnish export sector and 60 per cent in the import sector.

A number of papers examine price setting, nominal rigidities and the nature of inflation dynamics. For example, Galí and Gertler (1999) and Galí, Gertler and López-Salido (2001) have studied inflation dynamics in the United States and the euro area. They estimate a structural equation for inflation (also known as the New Phillips Curve) that evolves from a model of staggered nominal price setting by monopolistically competitive firms. The estimation results of Galí and Gertler (1999) and Galí, Gertler and López-Salido (2001) seem to support the forward looking nature of price setting behaviour. They argue that the model captures the pattern of both euro area and US inflation measured by the GDP deflator (although some signs of inertia can be found). However, these papers, although very insightful, ignore the open economy aspect of price setting.

Many important questions concerning the exact form of price setting and their implications for an open economy have been raised in the literature on the 'new open economy macroeconomics' (see Lane

[1] The same idea is found in Dornbusch (1987).

1999 for a survey). The new open economy macroeconomics literature was initiated by Maurice Obstfeld and Kenneth Rogoff in their 1995 article, 'Exchange Rate Dynamics Redux.'[2] This growing body of literature addresses open economy issues in a micro-founded general equilibrium framework. An important role also in this new approach is played by imperfect competition and nominal rigidities. In particular, there is an ongoing discussion on two pricing conventions and their implications for the economy, namely those of producer currency pricing (PCP) and local currency pricing (LCP).

The Obstfeld and Rogoff model is based on the conventional price setting assumption of producer currency pricing. In this case, prices are set in the seller's currency and the law of one price holds. Under producer currency pricing, because the producer sets prices in home currency but does not change them frequently (prices are sticky), prices faced by consumers in the export market fluctuate with changes in the nominal exchange rate, so that there is complete pass-through of exchange rates to destination-country prices.

The Obstfeld and Rogoff model has been modified in many aspects in the recent literature. One of the first modifications was by Betts and Devereux (1996) who incorporate local currency pricing into the Obstfeld and Rogoff framework. The alternative convention of local currency pricing means that prices are set and sticky in the buyer's currency. In this case, changes in nominal exchange rates do not affect goods prices in the local market of sale, ie there is zero pass-through of exchange rate changes to import prices (in the short run). In this case, deviations from the law of one price are possible, as exchange rate fluctuations have no impact on destination-country customer prices. Such rigid price levels mean that nominal exchange rate shocks pass through into real exchange rates.

It is important to note that local currency pricing limits the pass-through from exchange rate changes to import prices. Thus, it reduces the traditional expenditure-switching role of exchange rate changes. For example, in the case of currency depreciation, the shift of domestic demand away from imports and the shift of global demand towards domestic tradables is reduced. For this reason, Obstfeld and Rogoff (2000) argue in favor of producer currency pricing which they feel is a better approximation to reality. However, Obstfeld and Rogoff (2000) and Obstfeld (2000) stress the difference between responses of consumer prices vs firm level export and import prices, which are

[2] The paper by Svensson and van Wijnbergen (1989) is commonly acknowledged as a precursor of Obstfeld and Rogoff (1995).

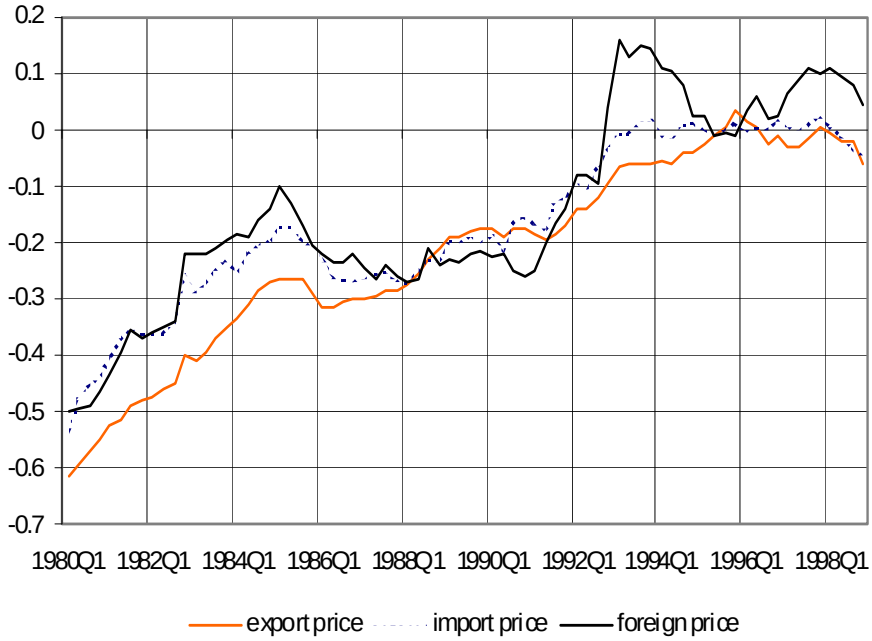

Figure 1: Logarithms of export price, import price and foreign price level in Finnish currency.

likely to be less sticky than consumer prices. It is thus possible that, at the same time when the consumer price level remains insulated from exchange rate fluctuation, the expenditure switching effect is at work in foreign trade conducted between firms. In this paper, the focus is on foreign trade prices, which may indeed exhibit different properties from consumer prices. The characteristics of Finnish foreign trade prices are presented and discussed in section 3.1.

This study combines the recent important advances in the theoretical modeling of inflation dynamics and the open economy aspects of price setting debated in the new open economy macroeconomics literature. Our aim is to reconsider the modeling of export and import price determination in the light of the recent literature. The starting point here is similar to what is typical for derivation of the New Phillips Curve, namely an environment of monopolistically competitive firms that face some type of constraints on price adjustment. Here, we focus on modeling the behaviour of forward-looking export and import firms.

Instead of trying to determine whether PCP or LCP is closer to reality, we assume that there are two types of price setters in an open economy: those who set prices in home currency and those who set prices in foreign currency. As a result, in an open economy setting, there are two sources of variation for trade price inflation: Firstly, changes in the exchange rate may lead to changes in trade price inflation. The size of the impact is the greater, the larger the fraction of firms that set their price in foreign currency. Secondly, variations in the real marginal cost lead to variation in trade price inflation - a property reflected also in Galí and Gertler (1999) and Galí, Gertler and López-Salido (2001).

The model developed in this study differs fundamentally from the traditional model of export and import price determination in a small open economy. Traditionally, small open economy export and import prices were assumed to follow exogenously given world market prices, due to a lack of pricing power. The lack of pricing power stems from perfect competition and homogeneity of goods. Figure 1 shows the relationship between Finnish trade prices (both export and import prices measured by corresponding deflators) and a measure of foreign prices, all in Finnish currency. Finnish import prices and foreign prices were apparently closely connected prior to the 1990s, after which the connection seems to have broken down. A similar pattern may also be seen for export prices, although the link before the 1990s was less stable than for import prices. We argue in this study that the 'anomalous' behaviour of Finnish foreign trade prices in the 1990s is easy to understand in the context of our model of trade price determination, which rejects the idea of price-taking behaviour and instead assumes forward-looking optimizing behaviour in the foreign trade sector. In addition to pricing power, we assume nationally segmented markets that allow exporters to set the price according to the currency of sale.

The structure of the study is as follows. Section 2 presents our model of export and import price determination. In section 3, we provide evidence on the fit of the model for Finnish data over the period 1980–1988. In particular, the empirical part of the study sheds light on the price-setting behaviour of Finnish exporters and importers by estimating the relative share of PCP and LCP firms in the economy. We apply the generalized method of moments (GMM) in estimating the parameters of the export and import pricing equations. Section 4 concludes.

2 A model of price setting in the foreign trade sector

In this section, we present our model of export and import price determination. Section 2.1. describes the monopolistic competitor's profit maximization in the export sector, while section 2.2. considers the import sector. The corresponding pricing decisions evolve explicitly from the optimization problem subject to the constraint on price adjustment.

We examine a small open economy that produces export goods for the rest of the world (referred to as the foreign country) and imports goods from the rest of the world. The analysis is partial in nature.

Small open economies have been studied, for example, by Kollman (1997) and Bergin (2001). We follow Bergin (2001) and assume that there are two types of monopolistically competitive goods suppliers in the small open economy. The first type produces goods for export whereas the second type of firm imports foreign goods to resell in the domestic market. Both types of firms are owned by domestic households and maximize their discounted profits. Furthermore, both export and import firms can set their prices either in home or foreign currency. Note that when an exporting firm sets its price in the home currency, this is referred to as producer currency pricing (PCP). However, an importing firm setting its price in home currency is exercising local currency pricing (LCP), since the imported goods are produced abroad.

After considering the optimization problem in both the LCP and PCP cases, we derive an estimable equation that incorporates both of the pricing conventions.[3] This is done by assuming that an exogenously given share of firms are LCP firms, while the rest are PCP firms.

To keep things simple, we assume that all goods produced in the home country are exported. Furthermore, we do not specify the production technology of the exporting firms but instead use a general form of cost function denoted by $c_t(x_t^d)$.[4]

[3]Bergin (2001) studies the cases of LCP and PCP separately, but does not derive a model for aggregate trade price inflation that incorporates both LCP and PCP firms.

[4]Bergin (2001) specifies a production technology and allows firms to sell products to both to home and foreign markets.

The problem of the monopolistic firm in this paper is similar to the problem considered in the papers by Galí and Gertler (1999) and Galí, Gertler and López-Salido (2001) who study inflation dynamics in a closed economy. The log-linearized price setting equations for LCP and PCP firms separately even resemble the equation for national inflation (measured by GDP deflator) obtained in Galí and Gertler (1999) and Galí, Gertler and López-Salido (2001). In fact, the New Phillips curve applies to exporting firms that set their prices in the producer currency but not to local currency pricing. However, it is important to note that the separate LCP firm and PCP firm pricing equations derived in this study are given in different currencies.

Thus, modeling of the aggregate export and import prices requires that LCP and PCP price setting be combined. As a result, we get a model that allows for less than perfect exchange rate pass-through at the aggregate level. We argue that this is important since it is unlikely that the pass-through is either zero, as under LCP, or one, as under PCP. On the other hand, we assume that initially the price has to be set either in home or foreign currency, ie, a firm has to make a choice. Overall, the model developed here emphasizes the external sector and combines both producer and local currency pricing, whereas Galí and Gertler (1999) and Galí, Gertler and López-Salido (2001) abstract from the existence of an external sector in the economy.

2.1 The Problem of the exporting firm

This section deals with the profit maximization of a representative exporting firm in two extreme cases: under local currency pricing and under producer currency pricing. Further, a model that combines the two cases is derived. Section 2.2. turns to the problem of the importing firm.

2.1.1 Case 1: Local currency pricing

The exporting firm chooses the price ($p^f_{xt}(z)$) for sale of its good z in the foreign market to maximize its profits ($\pi_{xt}(z)$) in home currency, knowing that the choice of price will determine the level of demand for the good ($x^d_t(z)$). The exporting firm faces production costs $c_t(x^d_t(z))$ that depend on the price it sets as well. Markets are assumed to be

segmented, and the foreign sale price ($p^f_{xt}(z)$) is in terms of the foreign currency (case 1: LCP). Superscript f is associated with foreign currency denomination. The foreign aggregate price level denoted by P^*_t is also denominated in foreign currency. Note that because prices are denominated in foreign currency, they must be multiplied by the exchange rate, e_t, to get the corresponding price in home currency. The nominal exchange rate, e_t, is the home currency price of one unit of foreign currency.

We assume that it is costly to reset prices because of quadratic menu costs a la Rotemberg (1982), $AC^f_{xt}(z)$, where ψ_x is the adjustment cost parameter. This assumption is important for obtaining forward looking behaviour. $\rho_{t,t+n}$ is the pricing kernel (stochastic discount factor) used to value random date $t+n$ payoffs. Since each firm is assumed to be owned by a representative household, it is assumed that firms value future payoffs according to the household's intertemporal marginal rate of substitution in consumption.[5]

The dynamic problem can thus be formulated as follows. The exporting firm maximizes discounted profits:

$$\max E_t \Sigma^{\infty}_{n=0} \rho_{t,t+n} \pi_{xt+n}(z) \tag{2.1}$$

$$\text{where } \pi_{xt}(z) = e_t p^f_{xt}(z) x^d_t(z) - c_t(x^d_t(z)) - e_t AC^f_{xt}(z) \tag{2.2}$$

subject to adjustment costs defined as

$$AC^f_{xt}(z) = \frac{\psi_x}{2} \frac{\left(p^f_{xt}(z) - p^f_{xt-1}(z)\right)^2}{p^f_{xt-1}(z)} x^d_t(z) \tag{2.3}$$

and to a downward sloping demand curve:

$$x^d_t(z) = \left(\frac{p^f_{xt}(z)}{P^*_t}\right)^{-\theta} X_t \tag{2.4}$$

where P^*_t is the aggregate foreign price level and X_t is the aggregate demand for exports.

The steady state solution to the problem is

$$p^f_x(z) = \left(\frac{\theta}{\theta - 1}\right) \frac{c'(x^d(z))}{e}. \tag{2.5}$$

[5] $\rho_{t,t+n} = \beta^n U'_{C,t+n}/U'_{C,t}$, where $U'_{C,t+n}$ is the household's marginal utility of consumption in period $t+n$.

The steady state equilibrium is thus characterized by a constant optimal (desired) markup. This property is due to the isoelastic demand curve.

The solution to the dynamic problem of the LCP exporting firm is given in Appendix 1. Letting lower case letters denote per cent deviations from the steady state and denoting the log difference of variable p_t by $\triangle p_t$, we obtain the following log-linearized version of the first order condition:

$$\left(\frac{\psi_x}{1+r}\right) E_t\{\triangle p^f_{xt+1}\} - \psi_x \triangle p^f_{xt} + (\theta - 1)\left[c'_t(x^d_t) - e_t - p^f_{xt}\right] = 0 \quad (2.6)$$

where r is the real interest rate, which is assumed constant throughout the study.[6] Note that the index z is left out because all LCP firms set the same price since they face an identical problem, ie, $p^f_{xt}(z) = p^f_{xt}$ for all z.

Rearranging yields

$$\triangle p^f_{xt} = \left(\frac{1}{1+r}\right) E_t\{\triangle p^f_{xt+1}\} + (\frac{\theta - 1}{\psi_x}) mc_t \quad (2.7)$$

where mc_t denotes the per cent deviation of the firm's real marginal cost from its steady state value.

2.1.2 Case 2: Producer currency pricing

In the case of producer currency pricing, we assume that the price set for exported home goods, p^h_{xt}, is denominated in home currency. The superscript h refers to home currency. The problem of the PCP exporting firm is of the same form as for LCP exporting firm presented above.

[6] We know from the consumer Euler equation for the representative consumer that the stochastic discount factor equals $\frac{1}{1+r}$ where r is the constant real interest rate.

In this case, the steady state solution is

$$p_x^h(z) = \left(\frac{\theta}{\theta - 1}\right) c'(x^d(z)). \tag{2.8}$$

The steady state solution in the PCP case is the same as for local currency pricing after converting to the same currency. In other words, equation (2.5) times the exchange rate yields the same solution as in the equation above (equation (2.8)).

The optimal price setting rule for exports in the case of producer currency pricing is given in Appendix 1. It is given in log-linearized form below:

$$\left(\frac{\psi_x}{1+r}\right) E_t\{\triangle p_{xt+1}^h\} - \psi_x \triangle p_{xt}^h + (\theta - 1)\left[c_t'(x_t^d) - p_{xt}^h\right] = 0. \tag{2.9}$$

After rearranging we get

$$\triangle p_{xt}^h = \left(\frac{1}{1+r}\right) E_t\{\triangle p_{xt+1}^h\} + (\frac{\theta - 1}{\psi_x}) mc_t. \tag{2.10}$$

2.1.3 Combining case 1 & case 2

The two log-linearized price setting equations (2.7) and (2.10) are rewritten here: (2.11) is the equation for PCP firms and (2.12) for LCP firms. The two equations are now in different currencies since $\triangle p_{xt}^h$ is denominated in home currency, while $\triangle p_{xt}^f$ is denominated in foreign currency. Here, we denote as $\left(\frac{1}{1+r}\right) \equiv \beta$ the subjective discount factor and as $(\frac{\theta-1}{\psi_x}) \equiv \delta$ the slope coefficient for the real marginal cost, so that we have the following two price setting equations:

$$\triangle p_{xt}^h = \beta E_t\{\triangle p_{xt+1}^h\} + \delta\left[c_t'(x_t^d) - p_{xt}^h\right] \tag{2.11}$$

and

$$\triangle p_{xt}^f = \beta E_t\{\triangle p_{xt+1}^f\} + \delta\left[c_t'(x_t^d) - e_t - p_{xt}^f\right]. \tag{2.12}$$

Let us assume there are both LCP and PCP firms in the country and combine the two log-linearized first-order conditions above. In order to combine the two equations above, we must convert the LCP firms' price setting rule, $\triangle p_{xt}^f$, into home currency by multiplying it

by the exchange rate e_t. The aggregate price, p_t^x, can be written as a geometric average of the LCP and PCP price setting rules. Thus in logarithms we use

$$p_t^x \equiv \omega p_{xt}^h + (1-\omega)p_{xt}^f + (1-\omega)e_t \tag{2.13}$$

where the weight ω captures the share of exports priced in home currency, namely the share of PCP firms in the export sector. In this model, the relative shares of LCP and PCP firms are assumed to be exogenously given and constant. This assumption will be further discussed later.

The result of the combination is the equation

$$\triangle p_t^x = \beta E_t\{\triangle p_{t+1}^x\} + (1-\omega)[\triangle e_t - \beta E_t\{\triangle e_{t+1}\}] + \delta\left[c_t^{'}(x_t^d) - p_t^x\right] \tag{2.14}$$

where $c_t^{'}(x_t^d) - p_t^x$ is the real marginal cost (in per cent deviation from its steady state level). ω is the share of exports priced in home currency, ie, the fraction of PCP firms. δ is a slope coefficient, which depends on the primitive parameters of the model, namely on ψ_x, which is the parameter that governs the degree of price stickiness, and on price elasticity, θ. Given constant export price inflation expectations, we see that short-run fluctuations in export price inflation are due to either exchange rate fluctuation (the impact of which is the greater, the greater the share of exporters that price in foreign currency, ie the lower the value of ω) or variation in the real marginal costs. The latter source of variation can also be found in the model of Galí and Gertler (1999) and Galí, Gertler and López-Salido (2001).

Iterating equation (2.14) forward yields

$$\triangle p_t^x = (1-\omega) \triangle e_t + \delta \int_{k=0}^{\infty} \beta^k E_t\{mc_{t+k}\}. \tag{2.15}$$

Because the firm's markup price over marginal cost is forward looking due to price adjustment costs, the firm bases its pricing decision on the expected future behaviour of marginal costs. Here, we see that fluctuation in the exchange rate leads to short-run variation in export price inflation, while expected changes in the path of real marginal costs lead to permanent changes in export price inflation. Marginal cost is thus the driving force of the model. We will estimate this model with Finnish data and present the results in section 3.

2.2 The problem of the importing firm

2.2.1 Case 1: Local currency pricing

The importing firms choose the resale price to maximize their profits, where they too are subject to quadratic menu costs. The price in this case is set in the currency of the small open economy and denoted by $p^h_{mt}(z)$, where the superscript h refers to the home currency of the small country. Since production of the goods actually takes place in the foreign country, pricing in home currency is in this case associated with local currency pricing.

The problem of the representative import firm may be summarized as follows. The importing firm maximizes discounted profits (in home currency):

$$\max E_t \Sigma_{n=0}^{\infty} \rho_{t,t+n} \pi_{mt+n}(z) \tag{2.16}$$

$$\text{where } \pi_{mt}(z) = (p^h_{mt}(z) - e_t P^*_t) y^d_{mt}(z) - AC^h_{mt}(z) \tag{2.17}$$

subject to adjustment costs defined as

$$AC^h_{mt}(z) = \frac{\psi_m}{2} \frac{\left(p^h_{mt}(z) - p^h_{mt-1}(z)\right)^2}{p^h_{mt-1}(z)} y^d_{mt}(z) \tag{2.18}$$

and to the downward sloping demand curve,

$$y^d_{mt}(z) = \left(\frac{p^h_{mt}(z)}{P_t}\right)^{-\theta} Y_t \tag{2.19}$$

where P_t is the aggregate home country price level and Y_t the aggregate demand for imports. Note that in the import sector, the nominal marginal cost consists of $e_t P^*_t$, ie the price of foreign goods in foreign currency multiplied by the exchange rate.

The steady state solution is

$$p^h_m = \left(\frac{\theta}{\theta - 1}\right) eP^*. \tag{2.20}$$

The optimal pricing rule is given in Appendix 1. The log-linearized version of the first order condition is

$$\left(\frac{\psi_m}{1+r}\right) E_t\{\triangle p^h_{mt+1}\} - \psi_m \triangle p^h_{mt} + (\theta - 1)\left[e_t + p^*_t - p^h_{mt}\right] = 0. \tag{2.21}$$

Rearranging gives

$$\triangle p^h_{mt} = \left(\frac{1}{1+r}\right) E_t\{\triangle p^h_{mt+1}\} + (\frac{\theta-1}{\psi_m})mc_t. \tag{2.22}$$

2.2.2 Case 2: Producer currency pricing

Under producer currency pricing, the importing firms choose the resale price $p^f_{mt}(z)$ (now denominated in foreign currency) to maximize their (home-currency) profits. In this case, the steady state solution is

$$p^f_m = \left(\frac{\theta}{\theta-1}\right) P^* \tag{2.23}$$

which is equal to the steady state solution in the LCP case (equation (2.20)) after multiplication by the exchange rate, e_t.

The optimal pricing rule is given in Appendix 1. After log-linearization, we obtain

$$\left(\frac{\psi_m}{1+r}\right) E_t\{\triangle p^f_{mt+1}\} - \psi_m \triangle p^f_{mt} + (\theta-1)\left[p^*_t - p^f_{mt}\right] = 0. \tag{2.24}$$

which can be rearranged as

$$\triangle p^f_{mt} = \left(\frac{1}{1+r}\right) E_t\{\triangle p^f_{mt+1}\} + (\frac{\theta-1}{\psi_m})mc_t. \tag{2.25}$$

2.2.3 Combining case 1 & case 2

Let us rewrite here the two log-linearized price setting equations (2.22) and (2.25). (2.26) is the equation for LCP firms, while (2.27) is the equation for PCP firms. We denote as $\left(\frac{1}{1+r}\right) \equiv \beta$ the subjective discount factor and as $(\frac{\theta-1}{\psi_m}) \equiv \delta$ the slope coefficient on real marginal cost. Once again, the two equations are in different currencies since $\triangle p^h_{mt}$ is denominated in home currency, while $\triangle p^f_{mt}$ is denominated in foreign currency:

$$\triangle p^h_{mt} = \beta E_t\{\triangle p^h_{mt+1}\} + \delta\left[e_t + p^*_t - p^h_{mt}\right] \tag{2.26}$$

and

$$\triangle p_{mt}^{f} = \beta E_t\{\triangle p_{mt+1}^{f}\} + \delta \left[p_t^* - p_{mt}^{f}\right]. \tag{2.27}$$

Let us assume that also in the import sector there are both LCP and PCP firms in the country and take a linear combination of the log-linearized first-order conditions, as we did in the case of export prices. The result of the combination is the following equation where the weight ω captures the share of imports priced in home currency, namely the share of LCP firms in the import sector. The relative shares of LCP and PCP firms are exogenous and assumed to be constant, as in the export sector.

$$\triangle p_t^m = \beta E_t\{\triangle p_{t+1}^m\} + (1-\omega)[\triangle e_t - \beta E_t\{\triangle e_{t+1}\}] + \delta\left[e_t + p_t^* - p_t^m\right]. \tag{2.28}$$

$e_t + p_t^* - p_t^m$ is the real marginal cost (in per cent deviation from its steady state level) and ω is the share of imports priced in home currency, which for import firms is the fraction of LCP firms. δ is a slope coefficient, which depends on the primitive parameters of the model (ψ_m, the parameter that governs the degree of price stickiness, and price elasticity, θ). The interpretation of the equation is similar to the corresponding export price equation: Given constant import price inflation expectations, short-run fluctuations in import price inflation are due to either exchange rate fluctuation (the impact of which is the greater, the greater the share of importers that price in foreign currency, ie, the lower the value of ω) or variation in the real marginal costs.

Iterating equation (2.28) forward yields

$$\triangle p_t^m = (1-\omega) \triangle e_t + \delta \int_{k=0}^{\infty} \beta^k E_t\{mc_{t+k}\} \tag{2.29}$$

Once again, because the firm's markup price over marginal cost is forward looking due to price adjustment costs, the firm bases its pricing decision on the expected future behaviour of marginal costs. Furthermore, fluctuation in the exchange rate leads to short-run variation in the import price inflation, while expected changes in the path of real marginal cost lead to permanent changes in import price inflation. We will estimate this model and present the results in section 3.

2.3 Discussion

Our model of import and export pricing combines monopolistic producers with nominal rigidities in a dynamic context with forward-looking economic actors. Due to the fact that the firms face constraints on adjusting the prices of the goods they produce or import, the nature of trade price inflation is forward looking. Firms find it optimal when making their current pricing decisions to take into account their expectations regarding the future path of marginal costs. In the steady state, the price is determined as a constant markup over (current) marginal cost.

In an open economy model, nominal rigidity may take the form of price stickiness in the currency of either the buyer (local currency pricing) or the seller (producer currency pricing). In the case of producer currency pricing, the domestic price of imports moves one-to-one with the exchange rate (full pass-through). When firms set the price of their goods in the currency of the market where they sell their products, the domestic price of imports does not change with the exchange rate and pass-through is zero. Instead of assuming either of the polar cases of nominal rigidities, we derive a model for aggregate trade price inflation that allows for intermediate degrees of pass-through. This is done by assuming the existence of both LCP and PCP firms in the economy. Several new open economy articles investigate the implications of the two polar cases theoretically (see eg Lane 1999). However, at least Betts and Devereux (1996 and 2000) and Corsetti and Pesenti (2001) complement and generalize the analysis by allowing for intermediate degrees of pass-through.

The short-run variation in trade price inflation thus has two sources: the exchange rate and variations in markups. Let us first discuss the role of the exchange rate. A key idea in the model presented in this section is that the impulse from the exchange rate is the stronger, the greater the share of goods priced in foreign currency. The greater the share of LCP firms in the export sector and the greater the share of PCP firms in the import sector, the greater the effect of exchange rate fluctuation on trade prices measured in home currency. It is important to note that allowing for less than perfect pass-through of the exchange rate weakens the expenditure shifting effect of the exchange rate compared to the polar case, where exports are priced in home currency and imports in foreign currency, ie both are priced in the currency of the producer.

Let us now turn to the variations in markups (or, equivalently, in real marginal costs) as a source of trade price inflation. Whereas the role played by the exchange rate is a feature of our open economy price setting model, markup variation is a source of inflation also in Galí and Gertler (1999) and Galí, Gertler and López-Salido (2001). Since the desired markup in the model is constant, any deviation from the optimal level of markup leads to price adjustment towards the optimum, as firms try to correct for misalignments between actual and desired markup.

The modeling approach could be extended to cover the following cases. Firstly, due to CES preferences, which lead to an isoelastic demand curve, the optimal markup over marginal cost is constant. This implies that in the export sector production costs, mainly consisting of labor inputs and also imported inputs, determines the price. In other words, competitors' prices play no role in export price determination. If the markup were not constant, but rather a function of foreign prices, there would be a role for competitors' prices in export price determination. In this case, however, the assumption concerning CES preferences would have to be altered. In general, a model that would allow for a non-constant optimal markup would be interesting. Secondly, the choice of denomination currency could be explicitly studied and the assumption of exogeneity of relative shares of PCP and LCP firms relaxed. This kind of analysis has been conducted eg by Friberg (1998), who studies the choice of price setting currency under exchange rate uncertainty. In particular, an interesting question is how the exchange rate regime affects the relative shares of PCP and LCP firms. A recent paper by Devereux and Engel (2001) presents a two-country general equilibrium model in which the currency of price setting is endogenous. They argue that exporters will generally choose the currency of the country that has the most stable monetary policy. Thirdly, whereas Galí and Gertler (1999) and Galí, Gertler and López-Salido (2001) allow a subset of firms to use a backward looking rule to set prices, our model is purely forward looking. However, Galí and Gertler (1999) and Galí, Gertler and López-Salido (2001) find in their empirical studies that although there are some signs of inertia, forward-looking behaviour is dominant. Furthermore, they argue that searching for explanations for inflation inertia is preferable to relying on backward looking behaviour.

In the next section, where we present the data that we use for estimating our model empirically, we will see that some of the assumptions made in the theoretical model might be too restrictive.

In particular, the constancy of the optimal markup and the constancy and exogeneity of the shares of PCP and LCP firms might be questioned. Furthermore, one should bear in mind that the results obtained by linear approximations are only locally valid. It is possible that the exchange rate changes are not sufficiently small to ensure model validity for wide exchange rate fluctuations. Let us now turn to the estimation of the model with Finnish data.

3 The determination of Finnish foreign trade prices

We now have two equations that we are about to estimate. First, we discuss the data and then the estimation method. Sections 3.3. and 3.4. present and discuss the results.

3.1 Data

This section presents the empirical variables used to study Finnish export and import price determination. A list and details of operational counterparts of theoretical variables can be found in Appendix 2. The data is quarterly and covers 1980:1–1998:4. The base year for the variables is 1995.

Compared to some other price series, such as domestic inflation measured by the GDP deflator, the foreign trade price series appear to be fairly volatile (see Figure 2). This feature makes the task of finding a general model that explains the export and import price data challenging. It is often argued that one key factor behind such volatility is the exchange rate. However, as can be seen in Figure 2, the volatility of trade prices was large also during the period 1980–1991, when the exchange rate was fixed and relatively stable. During that period there were dramatic movements in the price of oil, which could help explain some of the volatility of trade prices. On the other hand, the exchange rate volatility of the 1990s is not clearly reflected in the foreign trade prices. The role of the exchange rate and other factors in determining Finnish foreign trade prices are the key issues in this section.

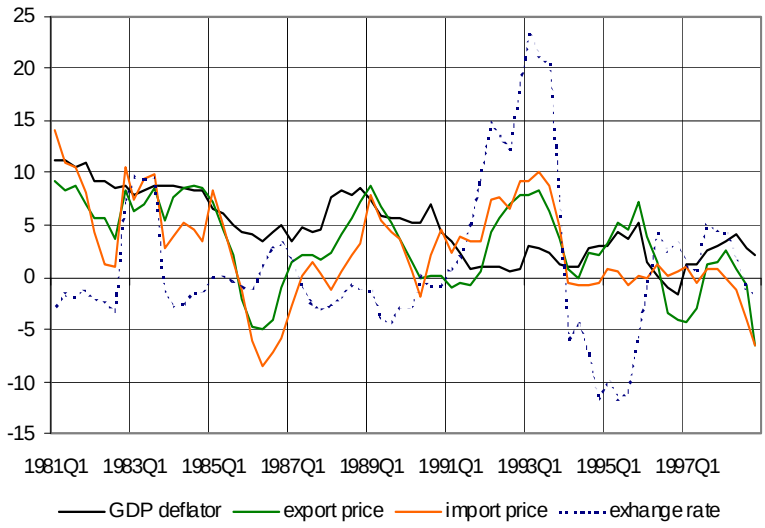

Figure 2: Annual rate of change of GDP deflator, export price deflator, import price deflator and trade-weighted exchange rate.

Before moving on to a more detailed presentation of the data, let us make some general remarks about the estimation period. Firstly, the estimation period includes different exchange rate regimes. The exchange rate was fixed from the beginning of the estimation period (1980:1) until the third quarter of 1992 when the markka was allowed to float. However, the fixed exchange rate period (1980:1–1992:2) includes some exchange rate realignments such as a devaluation in 1982:4 and in 1991:4. The decision to switch into a floating exchange rate in 1992:3 preceded a crises leading to an excessive depreciation of the Finnish currency followed by a recovery. In 1996:4 the markka became part of the exchange rate mechanism of the European Union. The estimation period ends at 1998:4, since the adoption of the euro at the start of 1999 led to a structural change the impact of which would require another careful study. The likely effects of the adoption of the euro are twofold: Firstly, the euro suddenly became the euro area countries' home currency, which led to an increase in trade conducted in the home currency of all these countries. Secondly, the importance of the euro in world trade is likely to increase as its role as an important world currency becomes better established. Therefore, as a result of the adoption of the euro the foreign trade prices of the

euro area countries have probably become, or are becoming, more insulated from exchange rate fluctuation.

Secondly, the Finnish economy and production structure experienced profound changes during the estimation period, implying that the content of trade and characteristics of traded goods did not remain unchanged. In particular, it is often noted that recovery from the deep recession that Finland experienced in the early 1990s is associated with a rise of the electronics and information technology industry. Earlier on, exports had been had been more dependent on forest industry output. The structure of imports has also changed so that the role of raw material and intermediate good imports, though still important, has gradually declined since the beginning of the estimation period.

In contrast to the theoretical framework presented in the previous chapter, it is possible that changes in the structure of trade mean that the optimal aggregate level markup has not remained unchanged during the estimation period as assumed. We discuss this possibility in section 3.1, where the data is presented, and also in section 3.3.3, which considers the robustness of the estimation results. The possible impact of the exchange rate regime shifts is taken up in section 3.3.3.

Baring all this in our mind, we attempt to build a general model of pricing behaviour that will explain the behaviour of Finnish foreign trade prices over the whole estimation period. Section 3.3. reports the estimation results of the theoretical model presented in section 2. Section 3.3.3. presents the robustness analysis. Finally, section 3.4. discusses and evaluates the results obtained in the empirical estimation of the model.

3.1.1 Import prices

Figure 3 plots the logarithms of the three time series that are used in the empirical estimation of our import pricing model presented in section 2. Our import price measure is the Finnish import price deflator. For the nominal exchange rate, e_t, we use the trade-weighted exchange rate. Nominal marginal costs in the Finnish currency are measured by foreign prices and the exchange rate (see Appendix 2 for details).

As we see, the exchange rate fluctuated considerably in the 1990s. It is also clear that the nominal marginal cost measured by foreign prices and the exchange rate has been dominated by the movement

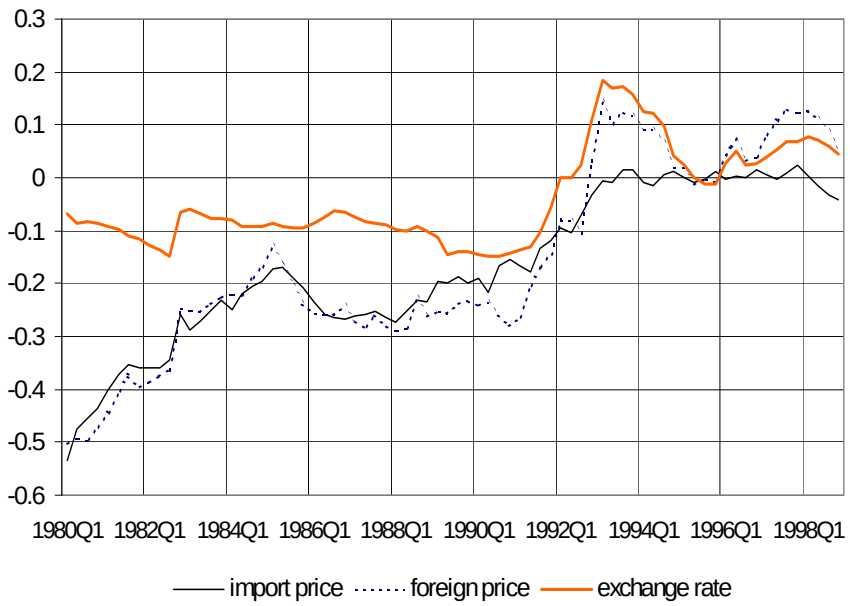

Figure 3: Logarithm of import price deflator, foreign price (in Finnish currency) and the trade-weighted exchange rate.

in the exchange rate. Import prices, on the other hand, did not follow movements of the exchange rate. The observation of a weak link between the exchange rate and import prices is often considered evidence of local currency pricing.

The relationship between foreign prices (incl. the exchange rate) and import prices, however, remained fairly stable before the 1990s, raising the question whether after 1990 there has been a change in pricing behaviour towards local currency pricing. This change might have been either gradual or related to the exchange rate regime. We will discuss these possibilities further in section 3.3.3. However, it is difficult to determine whether a change in pricing behaviour has taken place, since the stable link between foreign prices (incl. the exchange rate) and import prices before 1990s might as well be due to the fairly stable exchange rate during the fixed exchange rate regime and not due to price setting of import prices in foreign currency.

Before moving on, let us analyze the data from the perspective of our theoretical model. An increase in the nominal marginal cost

without a proportional increase in the import price implies an increase in the real marginal cost. According to our model, an increase in the real marginal cost puts upward pressure on import prices, as importers try to get back to the optimal level of markup. However, if the expected path of future real marginal costs remains unchanged, there is only a short-run impact from the real marginal cost to import prices. One could thus argue that the increase in the real marginal cost of the import sector was due to exchange rate depreciation that was considered temporary so that there was no permanent change in import prices.

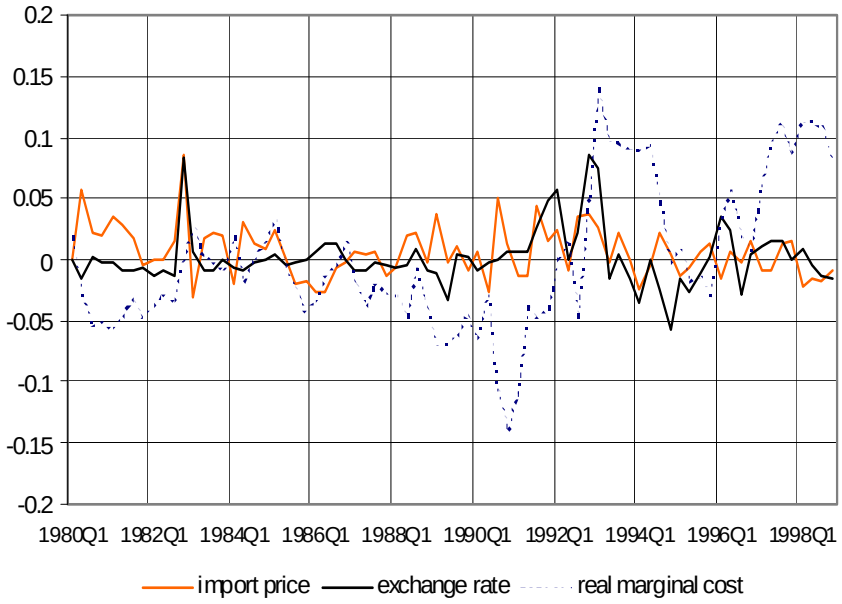

Figure 4: Log difference of import price deflator, log difference of trade-weighted exchange rate, and real marginal cost.

Figure 4 plots the log differences of the exchange rate and import prices, and the real marginal cost. In the short run, both exchange rate depreciation and an increase in the real marginal cost put upward pressure on import prices. According to our model the greater the share of imports priced in home currency, the weaker the short-run impact from exchange rate depreciation/appreciation to import prices. The contemporaneous correlation between a change

in the exchange rate and a change in the import price is positive, around 0.35, giving support neither to full local currency pricing nor to full producer currency pricing. On the other hand, if we look at the exchange rate devaluation in 1982:4 we see that the change in the exchange rate was in fact almost exactly matched by a change in import prices (evidence of PCP). However, import prices responded only partially to the devaluation of 1991:4 and during the float of the Finnish markka (1992:4–1996:4). This evidence suggests that there could have been a change in the pricing behaviour or that import prices respond fully to a change in the exchange rate only if the change is considered permanent, as is more likely in a fixed exchange rate regime.

Figure 4 also plots the real marginal cost, which was constructed in the following manner: For importing firms, our measure of nominal marginal cost is foreign prices including the exchange rate. This measure consists of foreign export price deflators converted into Finnish currency. The calculation of this variable has been carried out by the ECB (Appendix 2 describes in more detail how this variable is constructed). Our measure of real marginal cost is the nominal marginal cost divided by import prices. To be exact, we use the log deviation of the real marginal cost measure from its mean as a measure of mc_t^m.

Since real marginal costs are not directly observable, obtaining a measure for such a variable is tricky. Naturally, all the results are conditional on the measure of real marginal costs used in the estimation. It is also likely that there is an error in our measure of real marginal cost for imports. Although it is common practise to use weighted foreign export prices as a proxy for foreign price level rather than a cost variable, foreign export prices already include markups of foreign producers, and these markups are not solely for products sold to Finland. The use of a foreign cost variable does not suffer from such drawbacks, as it does not depend on the particular export market targeted. However, we leave the construction of such a variable for further research.

Our estimation method presented in section 3.2. requires that the empirical counterparts (ie the three series in Figure 4) of the theoretical variables of the import pricing model are stationary. As we can see in Figure 4, the log differences of both import prices and the nominal (trade-weighted) exchange rate appear stationary. This is confirmed by formal tests for unit roots. The results of an augmented Dickey-Fuller test indicate that the null hypothesis of a unit root is

rejected at the 5 per cent level of significance, meaning that the first differences of import price and exchange rate are stationary. Although less clear from Figure 4, the null hypothesis of nonstationarity is also rejected at the 5 per cent level of significance for the real marginal cost variable.

As already mentioned, our theory assumes that the optimal level of markup is constant, although there may be short-run variation around the long-run steady state markup. As we can see in Figure 4, the real marginal cost (ie the inverse of markup) has indeed fluctuated particularly in the 1990s when the real marginal cost increased, ie the markup decreased well below the optimal level (here normalized to zero). The obvious reason behind this phenomenon is the float of the Finnish markka in 1992:4, which increased nominal marginal costs but did not lead to a proportionate increase in import price. However, an important question is whether the optimal level of markup has in fact remained unchanged during the estimation period. If this was not the case and eg the optimal level of markup decreased after the markka was allowed to float (mc_t^m is a stationary series with a structural break), the increase in the real marginal cost that we see in Figure 4 would not put such strong upward pressure on the price level.

Several explanations may be offered for the changing optimal markup, one of them stemming from the fact that, even if the optimal markup of an individual firm or even a whole industry remained constant over time, changes in the production structure would lead to variation in the optimal markup at the aggregate level. Another explanation is that the optimal markup may be countercyclical. Whatever the explanation, one should also examine whether the change has been gradual or is due to the change in the exchange rate regime. The variation in the markup that we see in Figure 4 is in our opinion due to exchange rate depreciation related to the change in the exchange rate regime. Thus, we believe that a good approximation to reality is to start with the assumption that the real marginal cost is a stationarity variable.

Alternatively, one might offer an explanation for the decrease in the markup in the 1990s with a more strategic perspective on price setting behaviour. Namely, as Finland was undergoing an economic depression in the early 1990s there was only very mild upward movement in the domestic price level, which might have been optimal to take into account and set the import prices accordingly in order not to loose too many customers. This issue will be further discussed in section 3.3.

This section has touched upon many questions that we try to answer in the following sections. Before that, let us however first turn to the data for the export pricing equation, which shares many similar features with the import price data.

3.1.2 Export prices

Figure 5 plots the logarithms of the three time series that are used in the empirical estimation of our model for export prices. Our export price measure is the Finnish export price deflator. For the nominal exchange rate, e_t, we use the trade weighted exchange rate (details in Appendix 2). For the export sector, we use and compare three alternative measures for nominal marginal costs. Figure 5 plots the benchmark nominal marginal cost series constructed from unit labor costs (0.6) and import prices (0.4) (weights in parentheses).

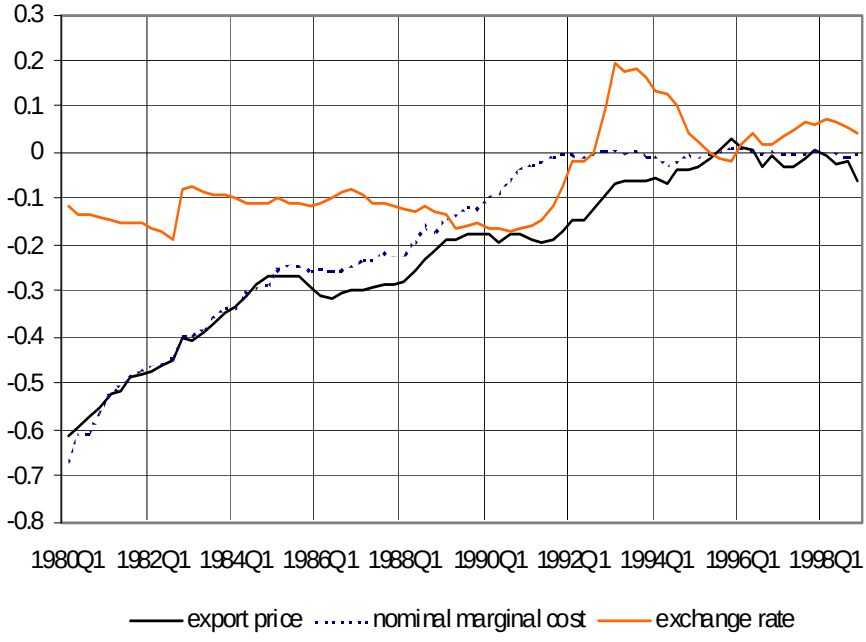

Figure 5: Logarithm of export price deflator, nominal marginal cost (MC1) and trade-weighted exchange rate.

As opposed to import prices, it is not necessarily surprising that the export price did not fully respond to exchange rate fluctuations in the 1990s if we believe in the traditional pricing convention, namely that export prices are set and sticky in the producer's currency. Instead, the depreciation of the 1990s had a positive impact on export sector competitiveness, as the depreciation led to a decrease in the price that foreign consumers face. Furthermore, the impact from exchange rate depreciation that might come via an increase in nominal marginal cost is definitely smaller in the case of export prices, due to the relatively smaller role of imported goods in export sector marginal cost. In other words, in contrast with the import price data, we can see in Figure 5 that there is no clear connection between the exchange rate and nominal marginal cost series.

Concerning the link between real marginal cost and export prices, the situation is similar to that for import prices, as one can question the mild reaction of export prices to increasing real marginal cost. However, the timing of the real marginal cost increase is different from the case of import prices: There is a period that starts in the middle of the 1980s and peaks around 1991, when nominal marginal costs increased relative to export prices, ie the real marginal cost increased (see Figure 6). The timing of the increase in the real marginal cost of the export sector is not, however, related to the change of exchange rate regime. The explanation behind the recovery of the real marginal cost to a lower level after the peak is probably related to the economic depression of the early 1990s.

Figure 6 presents the three measures of real marginal cost used in this study as empirical proxies for mc_t^x. As we can see, these series resemble each other. The benchmark case (MC1), as already discussed, uses a combination of unit labor costs and import prices to measure export sector nominal marginal costs. The two other measures are the following: case (2) MC2 uses the private sector GDP deflator at factor prices, while case (3) MC3 consists of unit labor costs alone. The real marginal cost series are obtained by dividing nominal marginal cost by export price. To be exact, we use the log deviation from mean of the real marginal cost measure as a measure of mc_t^x.[7]

[7]We follow Gali and Gertler (1999) in the construction of both mc_t^x and mc_t^m. Gali and Gertler (1999, p.205–206) base their measure of real marginal cost on a Cobb-Douglas technology and obtain a measure for real marginal cost, namely real unit labor costs, that is consistent with the theory.

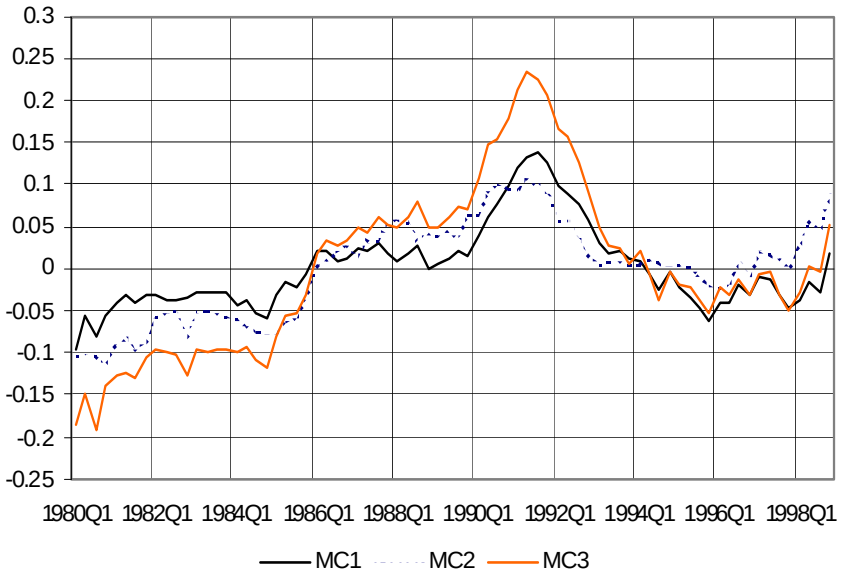

Figure 6: Three measures of real marginal cost

Figure 6 shows us that the markup has experienced dramatic changes during the estimation period. What we also observe is substantial inertia in the movement of the markup. Galí, Gertler and López-Salido (2001) have examined factors that drive the real marginal cost variable by a simple decomposition. They argue that labor market frictions are the key factor behind the evolution of the real marginal cost both in the euro area and in United States. In the case of Finland, one should also recall the economic depression of early 1990s and the change in the production structure (incl. the collapse of trade with the Soviet Union), which have contributed to the real marginal cost series in Figure 6.

An important question is once again whether the optimal level of markup has remained unchanged as assumed by our theory. There are several possible reasons why the (aggregate level) optimal markup did not necessarily remain constant during the estimation period, such as countercyclicality of optimal markup or a change in the optimal aggregate level of markup due to changes in the production structure. The issue of constancy of optimal aggregate level markup over time

is important since, if the peak in the real marginal cost is in fact associated with a decrease in the optimal level of markup (eg if the optimal markup is countercyclical), the upward pressure on the price level would be weaker than with a constant optimal markup. This issue will be tackled in section 3.3.3. where we examine the possibility of a structural change in the optimal level of markup.

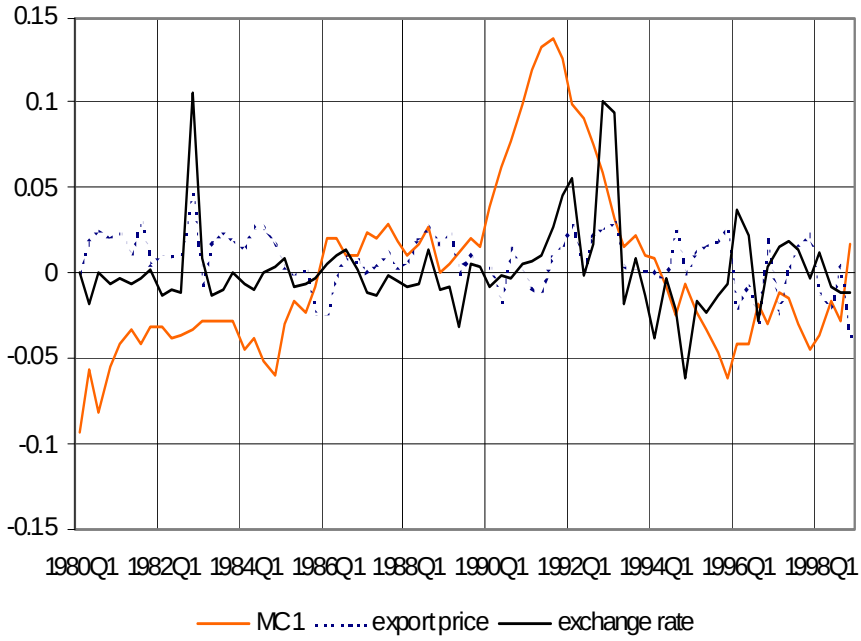

Figure 7: Log difference of export price deflator, log difference of trade-weighted exchange rate, and real marginal cost (MC1).

Figure 7 plots the log differences of the exchange rate and export prices, and the benchmark real marginal cost series (log deviation from the steady state). In the short run, both exchange rate depreciation and an increase in the real marginal cost put upward pressure on export prices measured in Finnish currency. Note that for export prices measured in Finnish currency the impact of exchange rate fluctuation is the smaller, the greater the share of exports priced (and sticky) in home currency. In fact, the contemporaneous correlation between a change in the exchange rate and a change in the export price is positive (about 0.27) but smaller than in the case

of import prices (0.35). Furthermore, the impact from the exchange rate to export price is the greater, the greater the share of imported inputs (the price of which reacts to exchange rate fluctuation) used in export sector production.

Looking at the exchange rate devaluation in 1982:4, we see that the export price did indeed increase (evidence of local currency pricing) but the change did not fully reflect the change in the exchange rate (evidence of producer currency pricing). Furthermore, export prices responded only partially to the devaluation of 1991:4 and during the float of the Finnish markka (1992:4–1996:4). In the light of this evidence, we cannot distinguish clearly between local currency pricing and producer currency pricing, but one can readily argue that pricing behaviour is likely to be a combination of both. The question remains whether the shares of producer and local currency pricing have remained unchanged and whether this share is related to the exchange rate regime.

The log differences of both export prices and the nominal (trade-weighted) exchange rate appear stationary (see Figure 7), as is confirmed by formal tests of nonstationarity. The augmented Dickey-Fuller test rejects the null of a unit root at the 5 per cent level of significance. Figure 7 also plots our benchmark real marginal cost, MC1.The formal tests also reject the null hypothesis of a unit root for MC1 at the 5 per cent level of significance. For MC2 and for MC3 the null of unit root is rejected at the 10 per cent level of significance. However, especially in case (2) and case (3) this result is not robust to different lags. Furthermore, looking at the graphs of case (2) and case (3) real marginal cost series, the question arises whether there has been a change in the mean of an otherwise stationary series. For example, one might suspect that there was a structural change around 1986 after which the optimal level of markup has decreased. If this is the case, when there are structural breaks, the augmented Dickey-Fuller test statistic is biased towards not rejecting the null of a unit root even though the series is stationary within each of the subperiods.[8]

[8]Enders 1995, p. 243.

3.2 Choice of econometric method

We apply the generalized method of moments (GMM) in estimating equations (2.14) and (2.28). GMM is a standard approach for estimating rational expectations models.[9] For a reference, see eg Mátyás (1999), Davidson and MacKinnon (1993, Chapter 17) and Favero (2001, Chapter 7). The generalized method of moments proposed by Hansen (1982) estimates model parameters directly from moment conditions imposed by the theoretical model.

The starting point of our GMM estimation is the two theoretical relations (2.14) and (2.28) that the parameters should satisfy. The idea of GMM is to choose the parameter estimates so that the theoretical relation is satisfied as closely as possible.[10]

The theoretical relations that the parameters should satisfy are given by the two orthogonality conditions (between residuals of the Euler equation and a set of instrumental variables z_t) below. Let z_t denote a vector of variables observed at time t (dated t and earlier). Then under rational expectations, we have the orthogonality condition for import prices,

$$E_t\{(\triangle p_t^m - \beta^m \triangle p_{t+1}^m - (1-\omega^m)[\triangle e_t^m - \beta^m \triangle e_{t+1}^m] - \delta^m mc_t^m)z_t\} = 0 \tag{3.1}$$

and for export prices

$$E_t\{(\triangle p_t^x - \beta^x \triangle p_{t+1}^x - (1-\omega^x)[\triangle e_t^x - \beta^x \triangle e_{t+1}^x] - \delta^x mc_t^x)z_t\} = 0. \tag{3.2}$$

The unknown parameters can now be estimated by applying GMM to the orthogonality conditions, (3.1) and (3.2).

After choosing the data used in the estimation, we have to solve a second empirical problem, namely the choice of the instruments.

[9] We also tried Ordinary Least Squares (OLS) but this method proved problematic and yielded parameter estimates that were not in line with our theory.

[10] The model is characterized by a set of orthogonality conditions, $E\{f(x_t,\theta)z_t\} = 0$, where x_t is the observed sample ($t = 1,...,T$), θ is the parameter vector and z_t is the vector of instruments orthogonal to $f(x_t,\theta)$. The sample equivalent of the orthogonality condition above is given by $f_T(\theta) = \frac{1}{T}\sum_{t=1}^{T}[f(x_t,\theta)z_t]$. The estimator for θ is chosen to so that the vector of sample moments is as close as possible to zero in the sense that a quadratic form in $f_T(\theta)$ is minimized, ie $\min Q_T(\theta) = \min f_T(\theta)' W_T f_T(\theta)$. The solution to this problem provides the GMM estimator for θ. The optimal weighting matrix, W_T, is the inverse of the covariance matrix of the sample moments. The estimation of the covariance matrix is discussed briefly in Section 3.3.1.

The validity of the instruments can be tested using the J-statistic (in the case of overidentification). To enable overidentification, the number of orthogonality conditions should be larger than the number of unknown parameters. For example, if we have five instruments to estimate two parameters, there are three overidentifying restrictions. Under the null hypothesis that the overidentifying restrictions are satisfied, the J-statistic is asymptotically χ^2 distributed with degrees of freedom equal to the number of overidentifying restrictions.[11] We report the results of these tests in the same table with the estimation results in section 3.3.

The vector of instruments, z_t, is the vector of variables that are within the decision makers' information set at the time the prices are set (variables that are either exogenous or predetermined may be used as instruments). It is required that the instruments not be correlated with the error term of the Euler equation but correlated with the regressors. Before choosing our set of instruments, we studied simple correlations between potential instruments and variables, and formed simple regression models to find links between the variables and the instrument set. However, since the choice of instruments matters, we discuss the robustness of our empirical results to different instrument sets in section 3.3.

Our vector of instruments, z_t, for the import price equation includes the constant, lags of import price, interest rate differential, foreign export prices (in Finnish currency), oil price (in Finnish currency), lags of real marginal cost, and domestic GDP deflator. The interest rate differential is the difference between the Finnish and foreign (12 countries, trade-weighted) three-month interest rates. This was chosen to represent expectations of exchange rate movement since, according to the (uncovered) interest rate parity condition, a positive interest rate differential (nominal interest rate in domestic country greater than in foreign country) is matched by expected depreciation of the exchange rate.

The instrument set for export prices is similar to that for import prices. We use the constant, lags of export price, the interest rate differential, foreign export prices (in Finnish currency, export-weighted) and oil price (in Finnish currency).

[11] Note that the J-test also tests whether the model is correcly specified. It indicates whether the moment conditions of the theoretical model are consistent with the data. If the test statistic is significantly larger than it should be under the null hypothesis, it is likely that either some of the instruments are invalid or the model is incorrectly specified.

Our method of estimation is based on the stationarity of the variables. See section 3.1. for a discussion of the stationarity of the time series used in the estimation.

Note that equations (2.14) and (2.28) contain an estimate of the overall slope coefficient on marginal cost and do not allow us to obtain direct estimates for the structural parameters θ and ψ. In other words, the parameters θ and ψ are unidentifiable.

3.3 Estimation results

3.3.1 Import prices

In this section, we report estimation results for the import price equation (2.28), rewritten here as

$$\triangle p_t^m = \beta^m E_t\{\triangle p_{t+1}^m\} + (1-\omega^m)[\triangle e_t^m - \beta^m E_t\{\triangle e_{t+1}^m\}] + \delta^m mc_t^m \quad (3.3)$$

The results are reported below in Table 1. There are three columns reporting estimates of the parameters of the model, namely β^m, ω^m, and δ^m. Under the point estimates, we report the standard errors (in parentheses). The final column displays Hansen's J statistic of the overidentifying restrictions with the associated p-values in parentheses.

For robustness, we consider three cases associated with three different sets of instruments. Briefly, case (1) is treated as a benchmark. The instrument set for case (2) is narrower than that for case (1), while case (3) adds the domestic GDP deflator to the set of case (1) instruments (for details, see the discussion below). Furthermore, in each case we also report the results when the estimate of the subjective discount factor, β^m, is restricted to 0.99, which is a typical value for this parameter used in the literature. We have chosen to consider and report the results obtained by using different instrument sets, to get an idea of the range of values that the point estimates take. We argue that this is important since the standard errors are fairly large and the results seem to be somewhat sensitive to variations in the set of instruments.

Estimation of the equation is implemented using EViews 3.0. Estimation of the covariance matrix is carried out using the correction for heteroscedasticity and autocorrelation of unknown form (HAC

covariance matrix). In this case, the choice of kernel (used to weight the covariances) and the choice of bandwidth (which determines how the weights given by the kernel change with the lags in the covariance matrix estimation) must be specified. The results reported in this paper are obtained using Bartlett weights and Variable-Newey-West bandwidth selection method (for case (1) we also report the results obtained using a fixed bandwidth, referred to as fixed NW).[12]

Table 1: Estimates for the import price model.

	β^m	ω^m	δ^m	J-Test
Case (1):	0.826	0.657	0.049	6.622
	(0.193)	(0.121)	(0.024)	(0.357)
Fixed β	0.99	0.574	0.042	6.336
	-	(0.161)	(0.026)	(0.501)
Fixed NW	0.994	0.587	0.043	6.989
	(0.231)	(0.161)	(0.023)	(0.322)
Case (2):	1.134	0.631	0.022	1.213
	(0.233)	(0.253)	(0.035)	(0.750)
Fixed β	0.99	0.649	0.023	1.349
	-	(0.217)	(0.027)	(0.853)
Case (3):	1.107	0.713	0.067	6.000
	(0.150)	(0.125)	(0.030)	(0.740)
Fixed β	0.99	0.663	0.051	6.293
	-	(0.118)	(0.022)	(0.790)

Overall, the results in Table 1 are reasonable. All the parameter values have the right sign and plausible values (especially after taking into account the standard error). Unfortunately, some of the estimates for $\delta^m$are not significantly different from zero at the 5 per cent level of significance.

Let us analyze the results by starting with the estimate of β^m. Plausible values for the estimate (using quarterly data) of the coefficient of expected import price inflation, ie the subjective discount factor, β^m, are close to one, 0.99 implying an annual subjective real interest rate of around 4 per cent. We argue that our point estimates for $\beta^m$are reasonable since they are within two (estimated) standard deviations of the typical values for this parameter in the literature (eg 0.99). Furthermore, although the point

[12]For details of covariance matrix estimation, consult the EViews manual.

estimates of β^m are somewhat large in cases (2) and (3) and somewhat low in case (1), taking into account the standard errors of estimates for β^m, we consider our exercise of fixing β^m to 0.99 justified.

We estimate the share of imports priced in domestic currency, ω^m, to be slightly over 60 per cent. Although the results are somewhat imprecise, we would argue that, since more than half of the imports are priced in domestic currency, the impact from exchange rate fluctuation is not fully reflected in the import prices in the short term.

The slope coefficient, δ^m, for real marginal cost is positive, which is consistent with the theory. Unfortunately, the standard errors appear fairly large so that in some cases the estimate is not significantly different from zero at the 5 per cent level of significance. Note that we estimate the overall slope coefficient for marginal costs, δ^m, and not the structural parameters that underlie the slope coefficient (θ and ψ_m). In their paper, Galí and Gertler (1999) also obtain an estimate of the marginal cost parameter (similar to δ^m in our case) that is only slightly greater than zero. They argue that if the markup in the frictionless benchmark model were countercyclical (rather than constant), desired price setting would be less sensitive to movements in marginal cost, which could help account for the low overall sensitivity of import price inflation to real marginal cost. For further discussion, see section 3.3.3.

The model works well in the sense that we do not reject the overidentifying restrictions in any case. The p-values for the null hypothesis that the error term is uncorrelated with the instruments are all reasonably large (in the range of 0.35 or higher).

We now turn to the different instrument sets and their impact and to the impact of restricted β^m. As already mentioned, varying the instrument set affects somewhat the point estimates of the parameters. The benchmark case uses the following instruments: the constant, the first two lags of import price inflation, the interest rate differential and its first lag, the log difference of foreign export prices (in Finnish currency), the log difference of oil price (in Finnish currency), and three lags of the real marginal cost. The case (2) instrument set is narrower and it consists of the constant, the first lag of import price inflation, the interest rate differential and its first lag, the log difference of foreign export prices (in Finnish currency), and one lag of the real marginal cost. We thus show that the point estimates are almost unaltered despite a narrow instrument set, although the results are less precise. In case (3), we add the

domestic GDP deflator (and its first lag) to the case (1) instrument set. The point estimates are slightly modified but the test for validity of instruments does not reject the null. In fact, the deflator seems to improve the p-value of the J-test. In the light of this evidence we can conclude that the domestic price level measured by the GDP deflator affects the agents' behaviour as a leading indicator for future import price inflation but not as an independent argument of the pricing equation.[13]

We next explore the implications of fixing β^m equal to 0.99. Overall, the effect is minimal and thus we would argue that restricting $\beta^m$to a plausible range does not affect the results in any significant way. Considering the estimates of ω^m when the value of β^m is restricted to 0.99, we see that case (3) yields the highest estimate of ω^m (around 0.66) with the smallest standard error. Altogether, the estimates of ω^m are fairly similar across the different cases.

To conclude, it appears that our model provides a reasonable description of import price inflation. Considering that the time series for import prices is somewhat volatile, we argue that the model fits the data fairly well for the period 1980–1998. Furthermore, the results are reasonably robust to different instrument sets and to fixed β^m. However, the imprecision of the point estimates remains a problem.

3.3.2 Export prices

This section presents estimation results for the export price equation (2.14), rewritten here as

$$\triangle p_t^x = \beta^x E_t\{\triangle p_{t+1}^x\} + (1-\omega^x)[\triangle e_t^x - \beta^x E_t\{\triangle e_{t+1}^x\}] + \delta^x mc_t^x \quad (3.4)$$

The results are reported below in Table 2. There are three columns reporting estimates of the parameters of the model, namely β^x, ω^x, and δ^x. The standard errors are given in parentheses below each estimate. The final column displays Hansen's J statistic of overidentifying restrictions with the associated p-value in parentheses.

Rather than studying the robustness of the results by considering different instrument sets, as we did for the import price equation, we concentrate on the impact of three different measures of real marginal cost. Case (1) is once again the benchmark. The marginal cost

[13]See also Favero 2001 (chapter 7, p. 234-235).

measure of case (1) consists of unit labor costs and import prices with weights 0.6 and 0.4, respectively. Case (2) uses the private sector GDP deflator at factor prices as a measure of marginal cost, while in case (3) the unit labor cost alone is taken to represent marginal costs in the export sector. These measures were already discussed in section 3.1.2. In each case we also report the results when the estimate of the subjective discount factor, β^x, is restricted to 0.99, which is a typical value for this parameter in the literature.

The set of instruments that was maintained throughout the exercise reported in Table 2 consists of the constant, two lags of export price, the interest rate differential with four lags, two lags of the logarithm of oil price (in Finnish currency), and the logarithm of foreign export prices (in Finnish currency) with one lag.

The estimation of the equation was implemented using EViews 3.0. As for import prices, the estimation of the covariance matrix was carried out by using the correction for heteroscedasticity and autocorrelation of unknown form with Bartlett weights and the Variable-Newey-West bandwidth selection method.

Table 2: Estimates for the export price model.

	β^x	ω^x	δ^x	J-Test
Case (1): MC1	0.948	0.625	0.053	5.514
	(0.083)	(0.077)	(0.027)	(0.787)
Fixed β	0.99	0.655	0.054	5.455
	-	(0.077)	(0.026)	(0.859)
Case (2): MC2	0.957	0.613	0.021	5.388
	(0.086)	(0.074)	(0.019)	(0.799)
Fixed β	0.99	0.632	0.013	5.030
	-	(0.074)	(0.020)	(0.889)
Case (3): MC3	0.961	0.616	0.018	5.372
	(0.086)	(0.075)	(0.011)	(0.801)
Fixed β	0.99	0.635	0.011	5.092
	-	(0.075)	(0.011)	(0.885)

All the parameter values reported in Table 2 have the right sign and plausible values. Moreover, the model's overidentification restrictions are not rejected under any specification. The p-value of the J-test statistic is in all cases fairly large (in the range of 0.79 or higher), implying that the null hypothesis that the overidentifying restrictions

are valid is not rejected. However, the estimation of the slope coefficient, δ^x, proved slightly problematic, as we will discuss below.

We argue that our point estimates for β^x , ie the subjective discount factor, are reasonable since they are within two (estimated) standard deviations of typical values for this parameter in the literature. Although the point estimates of β^x are somewhat low, taking into account the standard errors of estimates we consider our exercise of fixing beta at 0.99 justified.

We estimate the share of exports priced in domestic currency, ω^x, to be around 60 per cent, with relatively small standard errors. We can thus argue that the export prices measured in domestic currency are fairly insulated from fluctuation of the exchange rate since the majority of prices are set in the producer's currency.

The estimates of the slope coefficient, δ^x, for real marginal cost reported in Table 2 are positive, as is consistent with the a priori theory. However, except in case (1), they are not statistically significant at the 10 per cent level of significance. Furthermore, this parameter seemed to be somewhat sensitive to the set of instruments used. As the two other parameters remained reasonably stable across different instrument sets, the point estimate for the parameter on marginal cost seemed to shift easily closer to zero and even into negative territory. Obviously, this phenomenon requires further investigation. One of the explanations could be related to countercyclical markups already mentioned in section 3.1. Let us, however, postpone the discussion of this issue to section 3.3.3.

We now turn to the different measures of real marginal costs and their impact on the estimates and to the impact of restricted β^m. Varying the real marginal cost measure seems to have hardly any impact on the estimates of β^x and ω^x. However, compared to case (1), the point estimates of δ^x appear to shift closer to zero, both in case (2) and in case (3). Otherwise, the results are reasonably robust across variations in the real marginal cost measure.

We next explore the implications of fixing β^x equal to 0.99. Overall, the effect is minimal and thus we would argue that restricting $\beta^x$to a plausible range does not affect the results in any significant way. The estimates of ω^x when the value of β^x is restricted to 0.99 are similar across the marginal cost measures, although fixing β^x seems to lead to slightly higher point estimates than in the unrestricted case. Overall, the estimates of ω^x remain nearly unaltered across the different cases.

Although there are some issues that need further investigation, we may conclude that our model appears to capture the essence of price setting behaviour in the export sector.

3.3.3 Robustness analysis

The underlying theory assumes a constant markup of price over marginal cost in the absence of price rigidities. Thus, the empirical counterpart for the real marginal cost as a deviation from the steady state has been constructed so that the mean of the logarithm of the real marginal cost measure (representing the steady state level of markup) is subtracted from the logarithm of the real marginal cost series. However, the assumption of a constant optimal markup may be questioned. In this section, we discuss two possibilities, namely a structural change in the level of optimal markup and the possibility of a non-constant optimal markup. Furthermore, the stability of the share of goods priced in domestic currency is discussed. The sensitivity of results regarding instrument sets, different measures of real marginal cost and fixing the coefficient of the subjective discount factor at a plausible value were already studied in the previous section.

Let us start by considering the three real marginal cost series for the export sector that are plotted in Figure 8. As opposed to Figure 6 in section 3.1.2, these three series are the logarithms of the real marginal cost without subtraction of a constant mean. Furthermore, the figure shows the Hodrick-Prescott trend for each series.

Looking at Figure 8, one could argue that there may have been changes in the means of all three series, since these do not appear to exhibit any tendency to return to the low levels of the early 1980s. In other words, it appears that the means of all three series increased, meaning that the average markup decreased. If, instead of a constant optimal level of markup, there has been a structural change in the optimal level of markup, one should naturally take this into account in the estimation.

We studied the possibility that there were changes in the means of the three series by considering the subperiod 1986:1–1998:4. The three series for log real marginal cost as a deviation from steady state were recalculated so that the associated means of the series are from the period 1986:1–1998:4. We dropped only 5 years from the estimation period, so that there remain enough data points for GMM estimation. The instrument set used in the estimation is unaltered.

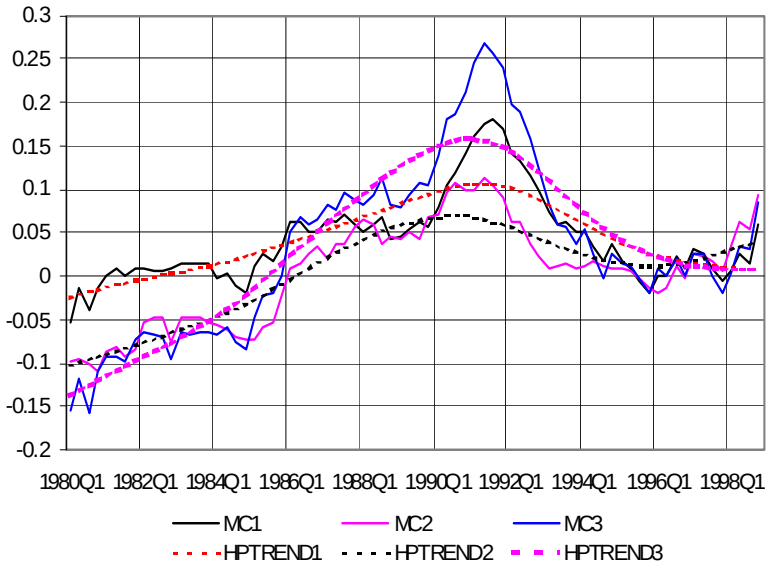

Figure 8: Logarithm of three measures of real marginal cost and their associated Hodrick-Prescott trends.

Unfortunately, this exercise did not help in the estimation of δ^x since the same problem of a low or negative δ^x remained. For case (2), which uses the private sector GDP deflator at factor prices as the measure for the nominal marginal cost, the results were the following: with β^x fixed at 0.99, the estimate for ω^x is 0.709 (0.050), which is slightly higher than in the baseline, and the estimate for $\delta^x$is 0.016 (0.040), which is about the same as in the baseline. However, the standard error for δ^x(shown in parentheses) is relatively large. The J-test statistic is 6.757 (0.748), implying that the overidentifying restrictions are not rejected. Overall, problems similar to those already reported in the baseline case remained for the subperiod 1986:1–1998:4, where the increase in the mean of the average markup was taken into account.

Another exercise is related to the possible non-constancy of the optimal markup. If the markup in the frictionless model were not constant, the steady state optimal markup, which is subtracted from the logarithm of real marginal cost, would not be a constant either but should be approximated eg by a Hodrick-Prescott trend. We have plotted the Hodrick-Prescott trends of the three marginal cost

series in Figure 8.[14] The HP-trend was then subtracted from the associated real marginal cost series to get a new measure for the log real marginal cost as a deviation from steady state. The instrument set used in the estimation is unaltered. The point estimates for $\beta^x$and ω^x appear similar to the baseline values. The parameter δ^x proved still difficult to estimate, the point estimate having a large standard error or even obtaining a negative value. For case (1) we obtained the following results: For β^x fixed at 0.99, the estimate for ω^x is 0.644 (0.067) and the estimate for $\delta^x$is 0.107 (0.132). Thus the estimate for δ^x is not statistically significant. The J-test statistic is 5.009 (0.891), implying that the overidentifying restrictions are not rejected. It is however important to remember that this exercise is in fact based on a totally different underlying theory, namely a theory that assumes a non-constant optimal markup. Thus, no direct comparison to baseline results can be made.

Another interesting question is the stability of the share of goods priced in domestic currency. For example, one could ask whether there has been a gradual change in ω^x or whether the possible shift is related to the exchange rate regime. In this section we only report some preliminary results that consider the issue of parameter instability. The first experiment was conducted using a dummy variable that is zero for the period 1980:1–1990:4 and one for the period 1991:1–1998:4, so that the first period contains less exchange rate fluctuation than the second. The instrument set used in the estimation is unaltered. We studied the stability of ω^x by first investigating whether the dummy is significant, which was unfortunately not the case. However, by using the dummy for estimating ω^x for each period, we obtained a higher point estimate, 0.761 (0.212), for the period 1980:1–1990:4 and a lower point estimate, 0.408 (0.249), for the period 1991:1–1998:4, than for the whole estimation period benchmark case, 0.625 (0.077). However, the standard errors are so large that we cannot say whether these estimates are statistically different from the baseline results or from each other. Thus it seems that further research is needed to obtain reliable results for the stability of ω^x.

[14]The smoothing parameter is 1600.

3.4 Discussion

The empirical results suggest that our forward-looking model of price setting behaviour in an open economy provides a reasonably good description of both export and import price determination. The share of firms that set their price in the home currency was estimated at slightly over 60 per cent for both import and export firms. For exporting firms this implies that roughly 60 per cent of firms price in producer currency, while 40 per cent price in local currency. As a result, for the 60 per cent that price in the producer's currency, the pass-through of the exchange rate to destination-country prices is complete. Furthermore, for these 60 per cent of firms, profits in home currency are relatively insulated from exchange rate fluctuation. However, a firm's profits may be affected by the exchange rate if it uses imported inputs in the production of its good.

Furthermore, the results suggest that about 40 per cent of firms in the export sector and 60 per cent of firms in the import sector use local currency pricing, which implies zero pass-through of the exchange rate in the short run. To the extent that there are local currency pricing firms, the prices that buyers face remain stable. However, local currency stability comes at a cost of profit exposure to exchange rate fluctuation. In other words, the price that these firms get for their product fluctuates one-to-one with the exchange rate.

From Finland's perspective, it seems that both export prices and import prices measured in domestic currency are relatively stable with respect to exchange rate fluctuation, with 60 per cent of foreign trade prices set in home currency. For the export industry this also means that the expenditure-shifting effect of exchange rate fluctuation is still relatively large, so that for 60 per cent of exporting firms exchange rate depreciation would lead to an improvement in competitiveness. At the same time, however, for 40 per cent of the firms, only profits are affected by movements in the exchange rate. In any case, the share of local currency pricing in Finnish foreign trade seems to be large enough for us to argue that producer currency pricing is not a good approximation of reality.

The finding that neither LCP nor PCP provides a full description of Finnish foreign trade price dynamics is in line with empirical literature on exchange rate pass-through. These empirical studies suggest that pass-through is positive but substantially below one (see eg Goldberg and Knetter 1997). In our model, which nests the two polar cases of PCP and LCP, the share of goods priced in home

currency should be one instead of 0.60 for export prices and zero instead of 0.60 for import prices, in order to have full exchange rate pass-through. Even after taking into account the standard errors it is not likely that this would be the case. To sum up, both LCP and PCP assumptions are extreme in the light of our empirical evidence for Finland.

Unfortunately, our results do not shed light on the choice between local currency pricing and producer currency pricing. As we know, exporters and importers who want to keep the price faced by the buyer stable in order not to loose customers when the exchange rate fluctuates would choose local currency pricing. At the same time they have to accept that their profit margin is exposed to exchange rate fluctuation. On the other hand, firms that appreciate a stable profit margin might want to choose producer currency pricing. The choice between LCP and PCP is not very important if the exchange rate is fixed and the probability of realignments low. However, under a floating exchange rate regime, the firm must consider the implications of its choice more carefully. Still, more research is needed to determine how the exchange rate regime and other factors would affect this choice.[15]

4 Conclusions

The main contribution of this paper is to develop a theoretical framework in which pricing behaviour in an open economy can be analyzed and to examine aggregate Finnish trade price data within this framework. The model we develop draws on both the new open economy literature and the inflation dynamics literature. It is a rational expectations model of price setting behaviour. Instead of price-taking, there is monopolistic competition in the goods markets and firms face a downward sloping demand curve that allows them to set their prices above marginal cost. Within this model we accommodate two different price setting regimes: local currency pricing and producer currency pricing.

[15] Devereux and Engel (2001) have recently raised the issue of endogenous choice of currency of price setting in a two-country general equilibrium model. In their setup, exporters generally choose the currency of the country with the most stable monetary policy.

Due to the assumption of nominal price rigidity, export and import price inflation are determined in a forward looking manner. Price setting decisions are influenced by current and anticipated marginal costs. In the short run, the price dynamics depend on the relative shares of LCP and PCP firms in the economy. This is an additional feature of our model compared to eg Galí and Gertler (1999) and Galí, Gertler and López-Salido (2001), who study inflation dynamics in a closed economy. In the export sector, the greater the share of firms setting their price in foreign currency (share of LCP firms), the larger the impact from exchange rate fluctuation to export prices measured in domestic currency. The same applies to the import sector except that the firms that set their prices in foreign currency are exercising producer currency pricing. It is important to note that implicit in producer currency pricing is that export prices in foreign currency will be lowered (raised) by the full amount of the depreciation (appreciation) at the moment of the exchange rate change. Allowing for local currency pricing means that we allow for exporters to adjust foreign currency prices by less than the full extent of any exchange rate change. However, at the same time, under local currency pricing, all producers who hold their foreign-currency prices constant, allow their profit margins to adjust in proportion to unexpected exchange rate movements.

Since both LCP and PCP are extreme assumptions (LCP implies zero and PCP full exchange rate pass-through in the short run), our model is built on an assumption that allows for intermediate degrees of pass-through, ie the existence of both LCP and PCP firms in the economy. This is also in line with empirical evidence that pass-through to import prices is generally less than one but seldom zero. The implications of the two extreme assumptions have been studied theoretically and debated in the new open economy literature.

Confronting our model with Finnish data allows us to estimate the relative shares of LCP and PCP firms in the economy. We show that the model that assumes forward looking price setting and incorporates two types of firms (LCP and PCP) fits the data reasonably well for the period 1980–1998. For the export sector, the estimated share of LCP firms is approximately 40 per cent, and for the import sector, 60 per cent. The results obtained thus suggest that the expenditure shifting effect of the exchange rate is weaker than in the pure producer currency pricing case often assumed in theoretical models such as the Mundell-Fleming model. Furthermore, exchange rate volatility is not

clearly reflected in the Finnish trade prices since roughly 60 per cent of both exports and imports are priced in home currency.

Although the estimate of the relative shares of LCP and PCP firms seemed to be fairly robust, this issue requires further study. For example, it is possible, that the choice of denomination currency depends on the exchange rate regime. The assumption of exogenous shares of LCP and PCP firms could thus be relaxed and the choice of currency naturally made endogenous. Furthermore, the model generates pricing to market by assuming that goods prices are sticky in the currency of the importer. As a result, it is unable to explain pricing to market in the context of a monetary union with only one currency. A recent theoretical paper by Bergin (2000) tackles this issue. Introduction of the euro also raises the question of insularity of euro area trade prices from exchange rate fluctuations. If more and more trade is carried out in euros, it is likely that prices in the euro area are more and more insulated from exchange rate fluctuation. Naturally, the likely increased insularity of trade prices since 1999 applies to Finnish foreign trade prices as well, although currently the share of trade with countries outside the euro area remains larger than in most other euro area countries.

There is also a need for more analysis on the nature of optimal markups. It is worth recalling that our model is based on the assumption of a constant desired markup. This is a simplifying assumption. Perhaps a more realistic assumption would be that firms set prices as a variable markup on marginal costs, so that a model that accounts for variation in the desired markup would be more appropriate.

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Appendix 1

The problem of the exporting firm

Case 1: Local currency pricing

The solution to the dynamic problem giving the optimal price setting rule for exports in the case of local currency pricing is

$$\mathrm{E}_t\left\{\frac{\rho_{t,t+1}}{\rho_{t,t}}\left(\frac{\psi_x}{2}\right)\frac{e_{t+1}}{e_t}\left[\left(\frac{p^f_{xt+1}(z)}{p^f_{xt}(z)}\right)^2-1\right]\frac{x^d_{t+1}(z)}{x^d_t(z)}\right\}-\psi_x\left(\frac{p^f_{xt}(z)}{p^f_{xt-1}(z)}-1\right)$$

$$+\theta\left(\frac{\psi_x}{2}\right)\left(\frac{p^f_{xt-1}(z)}{p^f_{xt}(z)}\right)\left[\frac{p^f_{xt}(z)}{p^f_{xt-1}(z)}-1\right]^2$$

$$+(1-\theta)\left[1-\left(\frac{\theta}{\theta-1}\right)\frac{c'_t(x^d_t(z))}{e_t p^f_{xt}(z)}\right]=0. \qquad \text{(A1.1)}$$

Case 2: Producer currency pricing

The optimal price setting rule for exports in the case of producer currency pricing is

$$\mathrm{E}_t\left\{\frac{\rho_{t,t+1}}{\rho_{t,t}}\left(\frac{\psi_x}{2}\right)\left[\left(\frac{p^h_{xt+1}(z)}{p^h_{xt}(z)}\right)^2-1\right]\frac{x^d_{t+1}(z)}{x^d_t(z)}\right\}-\psi_x\left(\frac{p^h_{xt}(z)}{p^h_{xt-1}(z)}-1\right)$$

$$+\theta\left(\frac{\psi_x}{2}\right)\left(\frac{p^h_{xt-1}(z)}{p^h_{xt}(z)}\right)\left[\frac{p^h_{xt}(z)}{p^h_{xt-1}(z)}-1\right]^2$$

$$+(1-\theta)\left[1-\left(\frac{\theta}{\theta-1}\right)\frac{c'_t(x^d_t(z))}{p^h_{xt}(z)}\right]=0. \qquad \text{(A1.2)}$$

The problem of the importing firm

Case 1: Local currency pricing

The optimal price setting rule for imports in the case of local currency pricing is

$$E_t\left[\frac{\rho_{t,t+1}}{\rho_{t,t}}\frac{\psi_m}{2}\left(\left(\frac{p^h_{m,t+1}(z)}{p^h_{mt}(z)}\right)^2-1\right)\frac{y^d_{mt+1}}{y^d_{mt}}\right]-\psi_m\left(\frac{p^h_{mt}(z)}{p^h_{mt-1}(z)}-1\right)$$

$$+\theta\left(\frac{\psi_m}{2}\right)\left(\frac{p^h_{mt-1}(z)}{p^h_{mt}(z)}\right)\left[\frac{p^h_{mt}(z)}{p^h_{mt-1}(z)}-1\right]^2$$

$$+(1-\theta)\left[1-\left(\frac{\theta}{\theta-1}\right)\frac{e_t P^*_t}{p^h_{mt}(z)}\right]=0. \qquad \text{(A1.3)}$$

Case 2: Producer currency pricing

The optimal pricing rule for imports in the case of producer currency pricing is

$$E_t\left[\frac{\rho_{t,t+1}}{\rho_{t,t}}\frac{\psi_m}{2}\frac{e_{t+1}}{e_t}\left(\left(\frac{p^f_{mt+1}(z)}{p^f_{mt}(z)}\right)^2-1\right)\frac{y^d_{mt+1}}{y^d_{mt}}\right]-\psi_m\left(\frac{p^f_{mt}(z)}{p^f_{mt-1}(z)}-1\right)$$

$$+\theta\left(\frac{\psi_m}{2}\right)\left(\frac{p^f_{mt-1}(z)}{p^f_{mt}(z)}\right)\left[\frac{p^f_{mt}(z)}{p^f_{mt-1}(z)}-1\right]^2$$

$$+(1-\theta)\left[\frac{1}{e_t}-\left(\frac{\theta}{\theta-1}\right)\frac{P^*_t}{e_t p^f_{mt}(z)}\right]=0. \qquad \text{(A1.4)}$$

Appendix 2

Theoretical variables and operational counterparts.

p_t^m Import prices of goods and services. Index 1995=1. Statistics Finland: National Accounts.

p_t^x Export prices of goods and services. Index 1995=1. Statistics Finland: National Accounts.

e_t^m Effective exchange rate (nominal, import-based). Index 1995=1. Calculated by the ECB.

e_t^x Effective exchange rate, (nominal, export-based). Index 1995=1. Calculated by the ECB.

mc_t^m Real marginal cost on the import side. Obtained by dividing nominal marginal cost by p_t^m. Nominal marginal cost consists of competitors' prices on the import side. It is a weighted sum of trading partners' export prices in Finnish currency. The weights are the import shares, and their geographical coverage is the whole world. Calculated by the ECB.

mc_t^x Real marginal cost on the export side. Obtained by dividing nominal marginal cost by p_t^x. There are three measures for nominal marginal cost 1) Unit labor costs and import prices, respective weights 0.6 and 0.4. Unit labor costs, total, 1995=1. Statistics Finland: National Accounts. Import prices of goods and services, Index 1995=1. Statistics Finland: National Accounts. 2) private sector GDP deflator at factor prices, 1995=1. Statistics Finland: National Accounts. 3) Unit labor costs , total, 1995=1. Statistics Finland: National Accounts.

Chapter 3

Financial market disturbances as sources of business cycle fluctuations in Finland

Abstract

This paper studies financial market disturbances as sources of investment fluctuations in Finland during 1995–2008. We construct a DSGE model of the Finnish economy that incorporates financial frictions in the form of the BGG financial accelerator and two domestic financial market shocks. We investigate empirically the importance of financial market frictions and disturbances by estimating the model using a Bayesian Maximum Likelihood approach. The empirical evidence points to an operative financial accelerator mechanism in Finland. Our key result is that disturbances originating in the financial sector have played a significant role in the historical variation of investment activities in Finland. Even allowing for several shocks stemming from both domestic sources and the international economy, domestic financial market shocks emerge as key drivers of recent business cycle fluctuations in Finland.

Contents

1 Introduction

The relevance of changes in financial conditions for real activity has become clear during the 2007–2008 financial crisis. A key issue is the understanding of channels through which financial markets can influence macroeconomic fluctuations. One way of linking the financial markets and business investment decisions is the financial accelerator mechanism developed by Bernanke, Gertler and Gilchrist (1999). The financial accelerator mechanism links the balance sheet conditions of borrowers to real activity by adding an external finance premium to the model. The premium that firms pay for external funds depends inversely on borrower balance sheets. However, empirical work is needed to quantify the strength of this mechanism. More importantly, the 2007–2008 financial crisis has also shown that the analysis should focus on new sources of shocks stemming from the financial market itself and on assessing the importance of financial market disturbances for understanding macroeconomic dynamics.

This paper investigates empirically the strength of the financial accelerator and the role of financial market shocks in the small open economy of Finland. To this end, we construct a DSGE model that incorporates the financial accelerator mechanism of Bernanke, Gertler and Gilchrist (1999) and a rich shock structure, including two domestic financial market shocks. We estimate the model using Bayesian Maximum Likelihood methods. The time period studied from 1995 to 2008 includes episodes where financial factors are likely to have played a role in economic fluctuations. As did many other countries, Finland experienced a stock market boom and bust from the late 1990s to early 2000s. Furthermore, the time period stretches to the global financial market crisis starting in the second half of 2007. Moreover, our analysis takes into account the key feature of the small open economy of Finland that as part of the euro area Finland lacks two important channels that help a standard small open economy to adjust to economic shocks, namely the policy rate

set independently by the central bank and the corresponding nominal exchange rate channel.[1]

In our empirical work, we provide evidence of an operative financial accelerator in Finland. The parameter governing the strength of the financial accelerator is positive and close to values obtained in other estimated DSGE models with the BGG financial accelerator. The presence of the financial accelerator links the financial market and the real economy for example by linking movements in asset prices to the real economy via corporate balance sheets. The financial accelerator thus acts as an amplifying mechanism for many disturbances to the economy.

Our main result is that disturbances stemming from the financial market itself contributed significantly to Finnish cyclical fluctuations between 1995 and 2008. We show that domestic financial market shocks hitting entrepreneurs and their demand for capital are key driving forces behind the fluctuations in investment and thus explain particular episodes in the Finnish business cycle, such as the boom and bust of the stock market the late 1990s and early 2000s and the subsequent early millennium slowdown and, more recently, the sudden reversal of investment activity in 2008 due to the global financial crisis.

Our starting point is the closed economy DSGE model of Christensen and Dib (2008) that has been extended to an open economy framework by Lopez, Prada and Rodriguez (2008). Christensen and Dib (2008) study the financial accelerator in a closed economy and use the maximum likelihood method to estimate the model on US data. Lopez, Prada and Rodriguez (2008) estimate the open economy version of the model using Bayesian Maximum Likelihood methods and Colombian data. Both papers find evidence of an operative financial accelerator and illustrate the workings of the model both with and without the financial accelerator. A related paper is Gertler, Gilchrist and Natalucci (2003) who develop a small open economy DSGE model with the financial accelerator and calibrate it to South Korea in order to study the interaction between the exchange rate regime and financial crises. The strenght

[1]Finland joined the euro area in the beginning of 1999. Since the euro area key policy rate depends on average euro area developments, it is exogenous from the point of view of a small euro area country. In addition, the nominal exchange rate fluctuations are also determined exogenously from Finland's point of view and affect only trade in goods and assets with non-euro area countries (or not denominated in euros).

of the financial accelerator in South Korea is estimated with Bayesian methods in a paper by Elekdag, Justiniano and Tchakarov (2005).

This paper focuses on the role of financial market shocks to the real economy. We extend the framework of Christensen and Dib (2008) and Lopez, Prada and Rodriguez (2008) by two domestic financial market shocks in order to empirically assess their role in the Finnish economy. Firstly, following Christiano, Motto and Rostagno (2003) we introduce a financial wealth shock to the creation of firms' net worth. The financial wealth shock exogenously destroys or creates firms' aggregate net worth. This captures the effects stemming from exogenous movements in asset values to investment through firms' balance sheet. Secondly, we include an exogenous risk premium shock in the relation describing the development of firm's external financing cost, along the lines eg of Dib, Mendicino and Zhang (2008). We follow Gilchrist, Ortiz and Zakrajsek (2009) and refer to this shock as a credit supply shock. This is a financial disturbance that captures exogenous changes in the domestic financial intermediation. It is a shock that exogenously increases or decreases the external finance premium to a level different from that endogenously implied by the firms' balance sheets.

Several recent papers show that financial market shocks are empirically relevant. Christiano, Motto and Rostagno (2008, 2009) highlight the crucial role of financial factors in explaining US and euro area business cycles. Dib, Mendicino and Zhang (2008) estimate their small open economy model on Canadian data and find evindence of financial shocks being among the main sources of macroeconomic fluctuations in Canada. A recent paper by Gilchrist, Ortiz and Zakrajsek (2009) estimates a closed economy (Smets and Wouters) model that incorporates the same two domestic financial market shocks as in this paper. They use US data, including a measure of corporate credit spread, and conclude that over the period from 1973 to 2008 shocks originating in the financial sector explain a substantial fraction of cyclical fluctuations in output and investment.

In contrast to Gilchrist, Ortiz and Zakrajsek (2009), we study a small open (euro area) economy where shocks from the international economy play an important role. The relative importance of shocks stemming from both the international economy and domestic sources (both financial markets and other sources) is evaluated. We find that even allowing for several shocks stemming from both domestic sources and the international economy, domestic financial market shocks emerge as key drivers of recent business cycle fluctuations

in Finland. Moreover, our results are obtained without using any financial market data in the estimation, whereas Gilchrist, Ortiz and Zakrajsek (2009) construct and use a highly sophisticated measure of credit spread in the estimation of the model. We are thus able to assess the performance of our model by investigating the match between the model outcome and financial market data.

Moreover, in the empirical DSGE literature, investment-specific shocks often turn out be the most important drivers of economic fluctuations. However, as Justiniano, Primiceri and Tambalotti (2008) argue, an investment-specific technology shock may actually hide unmodeled frictions in the capital accumulation process. In order to study the explanatory power of financial disturbances and to avoid having several shocks that may originate from the same source, we follow Gilchrist et al (2009) and omit the investment-specific technology shock from the analysis.This is different eg from Dib, Mendicino and Zhang (2008), who conclude that both financial and investment-specific shocks appear to be the main sources of Canadian cyclical fluctuations.

We present the details of the model in section 2. Section 3 discusses the data, estimation procedure and empirical results. In section 4 we conclude and offer suggestions for future work.

2 The model

The model builds on Christensen and Dib (2008) and Lopez, Prada and Rodriguez (2008), which in turn is a small open economy version of the Christensen and Dib (2008) model. We incorporate two additional shocks that stem from the domestic financial markets. The investment-specific shock is omitted since it can be argued to actually capture shocks stemming from the financial market (see Justiniano, Primiceri and Tambalotti, 2008). Furthermore, as opposed to Lopez, Prada and Rodriguez (2008), our model is modified to take into account that during most of the estimation period Finland was part of the euro area. Therefore, we exclude the Taylor rule from the model and treat the foreign price level in euros as exogenous. We thus assume a fixed exchange rate regime but include the foreign price level in euros as an exogenous shock process (see section 2.4).

There are 4 types of domestic agents in the model: households, entrepreneurs, capital producers and monopolistically competitive

retailers. Foreign behaviour is modelled as exogenous. Households and entrepreneurs are separated in order to explicitly motivate lending and borrowing. Entrepreneurs have special skills in operating and managing capital. Therefore, it is optimal for the entrepreneurs to borrow additional funds to use more capital than their own resources can support. The two domestic financial market shocks are shocks to entrepreneurs and their demand for capital. These shocks are explained in Section 2.2.

2.1 Households

2.1.1 Preferences

Households live forever, and they work, consume and save. They hold both real money balances and interest bearing assets.

The representative household's expected life-time utility is given by

$$U_0 = E_0 \sum_{t=0}^{\infty} \beta^t U\left(c_t, \frac{M_t}{P_t}, h_t\right) \tag{2.1}$$

where c_t denotes consumption, $\frac{M_t}{P_t}$ real balances (M_t is holdings of nominal money balances and P_t is the consumer price level) and $(1 - h_t)$ is leisure. $\beta \in (0, 1)$ is the discount factor.

The momentary utility function is given by

$$U(\cdot) = \frac{\gamma e_t}{(\gamma - 1)} \log\left[c_t^{\frac{\gamma-1}{\gamma}} + b_t^{1/\gamma}\left(\frac{M_t}{P_t}\right)^{\frac{\gamma-1}{\gamma}}\right] + \eta \log(1 - h_t) \tag{2.2}$$

where γ denotes the constant elasticity of substitution between consumption and real balances and η is the weight of leisure in the utility function. The utility function is non-separable in consumption and real balances. e_t is a preference shock and b_t a money demand shock. These shocks follow first-order autoregressive processes given by

$$\log e_t = \rho_e \log(e_{t-1}) + \epsilon_{et} \tag{2.3}$$

$$\log b_t = (1 - \rho_b) \log(b) + \rho_b \log(b_{t-1}) + \epsilon_{bt} \tag{2.4}$$

where ϵ_{et} and ϵ_{bt} are uncorrelated and normally distributed innovations with zero mean and standard deviations σ_e and σ_b. ρ_e and ρ_b are autoregressive coefficients and b is a constant.

In the open economy model, the consumption good c_t is a composite of tradable goods. Each household consumes domestically produced goods as well as imported goods, which are supplied by domestic firms and importing firms, respectively. The following CES index defines household preferences over home goods c_t^H and foreign goods c_t^F:

$$c_t = \left[(\omega)^{\frac{1}{\rho}}(c_t^H)^{\frac{\rho-1}{\rho}} + (1-\omega)^{\frac{1}{\rho}}(c_t^F)^{\frac{\rho-1}{\rho}}\right]^{\frac{\rho}{\rho-1}} \tag{2.5}$$

where c_t^H is produced by domestic monopolistically competitive retailers and c_t^F are (imported) foreign goods sold by foreign-goods retailers. ω is the share of domestic goods in the consumption composite. The intratemporal elasticity of substitution between domestic and foreign goods ρ captures the sensitivity of consumption allocation between home and foreign goods with respect to the relative price of home to foreign goods.

The corresponding consumer price index, P_t is given by

$$P_t = \left[(\omega)(p_t^H)^{1-\rho} + (1-\omega)(p_t^F)^{\frac{1}{\rho}}\right]^{\frac{1}{1-\rho}} \tag{2.6}$$

2.1.2 Budget constraint

The budget constraint of the representative household is

$$c_t = \frac{W_t}{P_t}h_t + \frac{T_t}{P_t} + \frac{\Omega_t}{P_t} - \frac{M_t - M_{t-1}}{P_t} - \frac{B_{t+1} - R_t B_t}{P_t} - \frac{B^*_{t+1} - \Gamma_t R^*_t B^*_t}{P_t} \tag{2.7}$$

where c_t is real consumption, W_t/P_t is the real wage, h_t is labour hours ($\frac{W_t}{P_t}h_t$ is real earnings from work), $T_t = M_t - M_{t-1}$ is the newly created money transferred to households as a lump-sum transfer and Ω_t represents dividend payments from retailers.

There is a restricted number of assets in the economy. Some of the earnings are allocated to money, which is an asset that does not earn interest. In addition to holding cash, households have access to international and domestic bond markets. Households can save in domestic bonds B_t and foreign bonds B^*_t. The foreign and the

domestic gross nominal interest rates are respectively denoted by R_t and R_t^*.

As in a standard open economy model, we assume that households are able to trade financial assets with agents located in other countries. However, we make the simplifying assumption that both foreign bonds B_t^* as well as the domestic bonds B_t are denominated in euros (hence, there is no need to multiply foreign-bond holdings by the nominal exchange rate). The effective gross interest rate at which the agent can borrow or lend in the international asset market, given by $\Gamma_t R_t^*$, depends on the foreign interest rate R^* and a country-specific borrowing premium Γ_t. Domestic (euro denominated) bonds are held only by domestic agents. Foreign (euro denominated) bonds are traded internationally.

By limiting the number of foreign assets to one international bond, we are assuming that international asset markets are incomplete. Incomplete market models of small open economies imply non-stationary equilibrium dynamics.The steady-state level of the choice variable net foreign assets is not pinned down by the model's optimality conditions. We need a means of closing the model that ensures stationarity. Closing the model means finding a single stationary state equilibrium and a log-linear approximation of the dynamic model around the stationary state. Following Schmitt-Grohe and Uribe (2003), this is achieved by introducing a small friction, a country borrowing premium, in the world capital market (see also Lubik, 2007). As explained above, need for such a friction is mainly technical: The country borrowing premium ensures that the model has a unique steady state and ensures stationarity. As in Lopez, Prada and Rodriguez (2008), we assume that the premium Γ_t households pay to obtain funds from abroad is an increasing function of the country's net foreign indebtedness, given by

$$\Gamma_t = \exp(-\kappa(a_t - \bar{a})) \tag{2.8}$$

where $a_t \equiv B_t^*/P_t$ is the real net foreign indebtedness (in euros), $\bar{a}$ is the steady state level of real foreign indebtedness and κ is the elasticity of borrowing premium with respect to net foreign indebtedness. κ is set close to zero so that the real net foreign assets a_t will revert to the steady state following a shock without having a marked impact on the short run dynamics of the model.

2.1.3 First-order conditions

The equations below give the optimality conditions for the household's optimization problem

$$\frac{e_t c_t^{-\frac{1}{\gamma}}}{c_t^{\frac{\gamma-1}{\gamma}} + b_t^{1/\gamma}\left(\frac{M_t}{P_t}\right)^{\frac{\gamma-1}{\gamma}}} = \lambda_t \tag{2.9}$$

where λ_t is the Lagrangian multiplier associated with the budget constraint.

The money demand function is given by

$$\frac{e_t b_t^{\frac{1}{\gamma}}\left(\frac{M_t}{P_t}\right)^{-\frac{1}{\gamma}}}{c_t^{\frac{\gamma-1}{\gamma}} + b_t^{1/\gamma}\left(\frac{M_t}{P_t}\right)^{\frac{\gamma-1}{\gamma}}} = \lambda_t - \beta E_t\left(\frac{\lambda_{t+1}}{\pi_{t+1}}\right) \tag{2.10}$$

where $\pi_{t+1} = P_{t+1}/P_t$. The labour supply is given by

$$\frac{\eta}{1-h_t} = \lambda_t w_t \tag{2.11}$$

which equates the marginal cost of supplying labour to the marginal utility of consumption generated by the corresponding increase in labour income.

The intertemporal decision for optimal holdings of bonds is given by

$$\frac{\lambda_t}{R_t} = \beta E_t\left(\frac{\lambda_{t+1}}{\pi_{t+1}}\right) \tag{2.12}$$

The optimal allocation of consumption between home and foreign goods is given by

$$\frac{c_t^H}{c_t^F} = \frac{\omega}{1-\omega}\left(\frac{p_t^H}{p_t^F}\right)^{-\rho} \tag{2.13}$$

The optimality condition governing the choice of foreign bonds combined with (2.12) yields the uncovered interest rate parity (UIP) condition

$$E_t\{\frac{\lambda_{t+1}}{\pi_{t+1}}\left[R_t - \Gamma_t R_t^*\right]\} = 0 \tag{2.14}$$

In a small open economy model with flexible exchange rate, the uncovered interest rate parity condition is an arbitrage condition that pins down the expected exchange-rate changes. As opposed to the standard UIP, in the small open euro area case the nominal exchange rate is fixed with respect to euro area countries and is independent of economic conditions in the small open euro area country. Nominal exchange rate movements, exogenous to the small open euro area economy, do however affect trade with countries outside the euro area. The UIP condition in the small open euro area economy case means that the domestic nominal interest rate R_t is determined by the exogenous foreign interest rate R_t^* and the endogenous country-borrowing premium Γ_t. The exogenous foreign variables are discussed in Section 2.4.

2.2 Entrepreneurs

The entrepreneurs produce a wholesale product that is sold to domestic good retailers in competitive markets at a price equal to its nominal marginal cost.

The firm chooses capital K and labour hours h to minimize its total costs, taking factor prices $\frac{W_t}{P_t}$ and z_t as given

$$\min \frac{W_t}{P_t} h_t + z_t K_t \tag{2.15}$$

subject to a Cobb-Douglas production function

$$Y_t = K_t^{\alpha} (A_t h_t)^{(1-\alpha)} \tag{2.16}$$

where A_t is an exogenous productivity process common to all entrepreneurs and referred to as a (neutral) technology shock. It is assumed to follow the stationary first-order autoregressive process

$$\log A_t = (1 - \rho_A) \log(A) + \rho_A \log(A_{t-1}) + \epsilon_{At} \tag{2.17}$$

where ρ_A is an autoregressive coefficient and $A > 0$ is a constant. The error term ϵ_{At} is normally distributed with zero mean and standard deviation σ_A.

The first order conditions for this optimization problem are

$$\frac{W_t}{P_t} = \xi_t (1 - \alpha) \frac{Y_t}{h_t} \tag{2.18}$$

$$z_t = \xi_t \alpha \frac{Y_t}{K_t} \tag{2.19}$$

$$Y_t = K_t^{\alpha}(A_t h_t)^{(1-\alpha)} \tag{2.20}$$

where $\xi_t > 0$ is the Lagrangian multiplier associated with the production function (2.20) and gives the real marginal cost. z_t is the real marginal productivity of capital and W_t/P_t the real wage. α denotes the share of capital in the production function.

The model incorporates a version of the financial frictions of Bernanke, Gertler and Gilchrist (1999) (BGG). This type of financial friction implements a new interest rate in the model, one that entrepreneurs have to pay for borrowing in order to finance the capital used in the production process. Due to asymmetric information between entrepreneur (borrower) and financial intermediary (lender), the lender charges the borrower a premium to cover the expected bankcruptcy cost. For a detailed presentation of the financial arrangements between entrepreneur and lender, we refer the reader to Bernanke, Gertler and Gilchrist (1999) and Gertler, Gilchrist and Natalucci (2003).

The financing of capital is divided between net worth and debt, as shown in the accounting identity below. The purchase of capital $q_t K_{t+1}$, where q_t is the real price of the capital, is financed partly by net worth n_{t+1} and partly by borrowing B_{t+1}^f:[2]

$$q_t K_{t+1} = \frac{B_{t+1}^f}{P_t} + n_{t+1} \tag{2.21}$$

Net worth n_{t+1} is the equity of the firm, ie the gross value of capital net of debt. At the end of period t entrepreneurs sell old capital to capital producers and pay off debt (the loan contract lasts for one period only). After that, entrepreneurs' net worth for period $t+1$ is unveiled. As in Christiano et al (2003), we assume that debt contracts are in nominal terms. This assumption implies that there is a Fisher debt-deflation channel in the model, so that an unexpected change

[2]Without an explicit financial sector, the household lends directly to the domestic entrepreneurs and accumulates bonds that pay the nominal interest rate R_t . In equilibrium, household deposits at domestic financial intermediaries (ie, domestic bonds B_t) equal total loanable funds supplied to entrepreneurs, $B_t = B_t^f$, where B_t^f is entrepreneurs' debt.

in price level reallocates income between households (lenders) and entrepreneurs (borrowers).[3]

Entrepreneurs are risk neutral. They have a finite planning horizon. The expected survival rate of entrepreneurs is ν_t, which gives them an expected lifetime of $1/(1-\nu_t)$. This assumption ensures that entrepreneurial net worth will never be enough to fully finance the desired capital acquisitions.

The entrepreneur's demand for capital depends on the expected marginal return and expected marginal financing cost $E_t f_{t+1}$. For an entrepreneur who is not fully self-financed, the expected return to capital in equilibrium will equal the marginal cost of external finance:

$$E_t f_{t+1} = E_t[\frac{z_{t+1} + (1-\delta)q_{t+1}}{q_t}] \tag{2.22}$$

The right hand side gives the expected marginal return on capital, which consists of the real marginal product of capital z_t (an income gain) and a capital gain due to asset-price fluctuations q_t. The capital gain drops out of the equation if there are no capital adjustment costs and the real price of capital q_t remains unchanged. δ is the capital depreciation rate.

The entrepreneur's overall expected marginal cost of funds $E_t f_{t+1}$ depends on the gross external finance premium $S(\cdot)$ and the gross real opportunity cost of funds. Furthermore, we assume in this paper that the cost of external funds also depends on an exogenous financial disturbance ϵ_{ft}:

$$E_t f_{t+1} = E_t[S(\cdot)\frac{R_t}{\pi_{t+1}}\epsilon_{ft}] \tag{2.23}$$

The external finance premium is the difference between the cost of external funds and the opportunity cost of internal funds (risk-free real interest rate). The real opportunity cost of internal funds in the small euro area economy is determined by the expected rate of inflation π_{t+1} and the effective foreign interest rate faced by households $R_t = R_t^* \Gamma_t$ where R_t^* is the exogenous foreign interest rate and Γ_t is a country-borrowing premium.

The presence of BGG financial frictions implies that the external finance premium varies inversely with the aggregate financial

[3]For simplicity, we impose the condition that entrepreneurs rely only on domestic sources (households) for external financing. In *2007Q3,* Finnish non-financial firms raised 30 per cent of their funds in foreign financial markets.

condition of entrepreneurs, as measured by the ratio of net worth to gross value of capital $\frac{n_{t+1}}{q_t K_{t+1}}$:

$$S_t(\cdot) = S(\frac{n_{t+1}}{q_t K_{t+1}}), \quad S\prime(\cdot) < 0, S(1) = 1 \tag{2.24}$$

The financial accelerator thus relates the external finance premium negatively to the strength of entrepreneurs' balance sheets.[4]In this paper, the size of the external finance premium depends on both the leverage ratio and a shock process ϵ_{ft}. Following Dib et al (2008) and more recently Gilchrist et al (2009), we have included an exogenous risk premium shock ϵ_{ft} in the relation describing the development of the firm's external finance premium. We refer to this shock as a credit supply shock, as in Gilchrist et al (2009). This is a financial disturbance that captures exogenous disturbances in domestic financial intermediation. It is a shock that increases or decreases the external finance premium to a level different from that warranted by current economic conditions.

The credit supply shock is assumed to follow an AR(1) process given in log-linearized form:

$$\epsilon_{ft} = \rho_f \epsilon_{ft-1} + \epsilon_{fft} \tag{2.25}$$

where ρ_f is an autoregressive coefficient vector and ϵ_{fft} is an uncorrelated and normally distributed innovation with zero mean and a standard deviation σ_f.

The log-linearized version of equations (2.23) and (2.24) is given by

$$\hat{f}_{t+1} = \hat{R}_t - \hat{\pi}_{t+1} + \psi(\hat{q}_t + \hat{K}_{t+1} - \hat{n}_{t+1}) + \epsilon_{ft} \tag{2.26}$$

where variables with hats are in log-deviations from steady state, $\hat{x}_t = \log x_t - \log \bar{x}$.

We denote as ψ the elasticity of the risk premium to changes in the net worth-to-capital ratio, a measure of entrepreneurial financial health. This parameter could be interpreted as a summary statistic indicating how vulnerable the economy is to shocks affecting aggregate balance sheets. It is noteworthy that fluctuations in the price of

[4]The specific form of $S_t(\cdot)$ depends on the primitive parameters of the costly state verification problem (see Bernanke et al 1999).

capital q_t may have significant effects on the leverage ratio and thus on the cost of funds.[5] Because the external finance premium affects the overall cost of finance, it therefore influences the overall demand for capital. When the elasticity of external finance premium ψ is exactly zero, the financial accelerator ceases to exist and there is no premium on firms' external finance.

The equation above is the first basic component of the financial accelerator describing how movements in net worth influence the cost of capital. The second key component of the financial accelerator is the relation that describes the evolution of entrepreneurial net worth, n_{t+1}, given below.

Let V_t denote the value of entrepreneurial capital net of borrowing costs carried over from the previous period:

$$V_t = f_t q_{t-1} K_t - E_{t-1} f_t (q_{t-1} K_t - n_t) \tag{2.27}$$

In this expression, f_t is the ex-post real return on capital and $E_{t-1} f_t$ the cost of borrowing implied by the loan contract signed in time $t-1$. Movements in net worth stem from unanticipated movements in returns (earnings effect) and in borrowing costs (Fisher effect). On the asset side (returns), unforecastable changes in asset price q_t constitute the principle source of fluctuations in the return to capital.Regarding the liability side (borrowing costs), we assume as in Christiano et al (2003) that entrepreneurs sign a nominal debt contract (in BGG (1999) the contract is specified in terms of the real interest rate). This assumption implies that an unanticipated increase in inflation reduces the real debt burden and thus increases net worth. This is the so-called Fisher effect.

To illustrate, a shock that reduces the market value of capital q_t (asset prices) produces a fall in investment by reducing entrepreneurial net worth. Similarly, a shock that lowers the aggregate price level reduces net worth by raising the real value of entrepreneurial debt payments. As a result, a shock that reduces the value of entrepreneur's capital net of borrowing costs reduces their ability to borrow by enlarging the external finance premium. The increase in external finance premium amplifies business cycles via an accelerator effect on investment, production and spending.

[5]The effect of asset price q_t on net worth is greater than its effect on total assets. This implies that the leverage ratio moves countercyclically.

The aggregate entrepreneurial net worth evolves according to

$$E_t n_{t+1} = \nu_t V_t + (1 - \nu_t) g_t \tag{2.28}$$

where ν_t is the survival probability of entrepreneurs. A fraction $(1-\nu_t)$ of entrepreneurial financial wealth is destroyed exogenously each period. This is to ensure that entrepreneurs do not grow out of the financial constraint by accumulating enough wealth. The new entrepreneurs receive only a small transfer g_t from entrepreneurs who exit. As the number of entrepreneurs who exit is always balanced by the number that enter, who have less net worth than those who exit, the greater the share of exiting entrepreneurs, the smaller the aggregate net worth of entrepreneurs.

We introduce a shock to the survival probability of entrepreneurs, a financial wealth shock, along the lines of Christiano et al (2003). In the log-linearized version of the model the parameter governing the survival probability of entrepreneurs takes the form

$$\nu_t = \nu + \epsilon_{\nu t} \tag{2.29}$$

where $\epsilon_{\nu t}$ can be seen as a shock to the discount rate of entrepreneurs. It is an exogenous disturbance affecting the financial wealth of entrepreneurs. Thus, the fraction of surviving entrepreneurs is itself subject to stochastic fluctuations $\epsilon_{\nu t}$, which are assumed to follow an AR(1) process, given in log-linearized form as

$$\epsilon_{\nu t} = \rho_{\nu} \epsilon_{\nu t-1} + \epsilon_{\nu\nu t} \tag{2.30}$$

where $\rho_{_{\nu t}}$ is an autoregressive coefficient vector and $\epsilon_{\nu\nu t}$ an uncorrelated and normally distributed innovation with zero mean and standard deviation σ_{ν}.

When a shock drives down the survival probability, the rate of destruction of entrepreneurial wealth increases, resembling the bursting of a stock market bubble. Entrepreneurs as a group are left with less wealth under their control. With less net worth, the need for external financing increases and the demand for capital decreases. The entrepreneurs purchase less capital, which drives down its price and leads to a further decrease in entrepreneurial net worth. As eg in Christiano et al (2007), we interpret the financial wealth shock as a way of describing exogenous movements in asset values. The financial wealth shock affects investment through the balance sheet

by exogenously creating or destroying the aggregate net worth of entrepreneurs.

2.3 Capital producers

The actual production of physical capital is carried out by capital-producing firms, which combine old capital and investment goods to produce new capital. The production of new capital involves adjustment costs. Capital producers purchase final goods from domestic-goods retailers and use them as material input to produce investment goods i_t. The aggregate capital stock evolves according to

$$K_{t+1} = i_t + (1 - \delta)K_t \tag{2.31}$$

where δ is the rate of depreciation. The investment goods i_t are combined with existing capital goods, $(1 - \delta)K_t$, to produce new capital goods, K_{t+1}.

There are real rigidities in capital formation due to quadratic capital adjustment costs. Capital producers' optimization problem, in real terms, consists of choosing the quantity of investment i_t to maximize profits, subject to quadratic adjustment costs:

$$\max_{i_t} \left[q_t i_t - i_t - \frac{\chi}{2} \left(\frac{i_t}{K_t} - \delta \right)^2 K_t \right] \tag{2.32}$$

The supply of capital is given by the first-order condition

$$q_t - 1 - \chi \left(\frac{i_t}{K_t} - \delta \right) = 0 \tag{2.33}$$

This is the standard Tobin's Q equation relating the price of capital to marginal adjustment costs. In the absence of capital adjustment costs, the price of capital is constant and equal to one. Capital adjustment costs slow the response of investment to different shocks, which directly affects the price of capital. Therefore, capital adjustment costs allow the price of capital to vary, which contributes to the volatility of entrepreneurial net worth.

2.4 Foreign behaviour

We assume that the foreign demand for the home tradable goods is

$$c_t^{H*} = [\left(\frac{p_t^H}{P_t^*}\right)^{-\zeta} y_t^*]^{\tau} (c_{t-1}^{H*})^{1-\tau} \tag{2.34}$$

It is a decreasing function of the relative price and an increasing function of foreign ouput y_t^*. We assume that the export sector prices in the producer's currency. The term $(c_{t-1}^{H*})^{1-\tau}$ represents inertia in foreign demand for domestic goods.

The foreign price level P_t^* is exogenous and stated in euros. The foreign price level in euros P_t^*consists of the euro area price level P_t^E and the extra-euro area price level P_t^U multiplied by the corresponding nominal exchange rate s_t. ω^E and $(1-\omega^E)$ are the shares of intra and extra-euro area trade, respectively.

$$P_t^* = (P_t^E)^{\omega^E} (s_t P_t^U)^{(1-\omega^E)} \tag{2.35}$$

The nominal exhange rate is exogenous in the small open euro area case since it is independent of economic conditions in the small open euro area country. However, exogenous changes in the nominal exchange rate are reflected in the euro-stated foreign price level according to the share of extra-euro area trade.

We assume that the foreign price level P_t^*, the foreign output y_t^* and the foreign interest rate R_t^* are exogenous and follow an AR(1) process given in log-linearized form:

$$x_t = \rho_x x_{t-1} + \epsilon_{xt} \tag{2.36}$$

where $x_t = \{P_t^*, y_t^*, R_t^*\}$, ρ_x is an autoregressive coefficient vector and ϵ_{xt} a vector of uncorrelated and normally distributed innovations with zero mean and standard deviation σ_x.

2.5 Retailers

There are two types of retailers in our open economy model: retailers of domestic and foreign goods. Domestic-goods retailers buy wholesale goods from domestic producers and foreign-goods retailers buy wholesale goods from abroad. Both domestic and foreign-goods retailers differentiate the wholesale goods slightly and engage in

Calvo-style price-setting. The purpose of the retail sector is to introduce nominal rigidity into the economy. The domestic final goods are sold to domestic and foreign consumers and to domestic capital producers in a monopolistically competitive market. The imported foreign goods are sold to domestic consumers.

In Calvo price-setting the retailer cannot reoptimize its selling price unless it receives a random signal. The probability of not being able to reoptimize the selling price is ϕ. Thus with probability ϕ the retailer must charge the price that was in effect in the preceeding period indexed by the steady state gross rate of inflation, π. We assume that retailers of domestic and foreign goods face the same degree of price rigidity ϕ. With probability $(1-\phi)$ the retailer receives a signal to reoptimize and chooses the price $p_t^H(j)$ that maximizes the expected real total profits for l periods, where $l = 1/(1-\phi)$ is the average length of a time a price remains unchanged. Details of the retailer's optimization problem are given in Christensen and Dib (2008).

The (aggregate) price of the domestic final good p_t^H is thus

$$p_t^H = [\phi(\pi p_{t-1}^H)^{1-\theta} + (1-\phi)(p_t^H(j))^{1-\theta}]^{\frac{1}{1-\theta}} \tag{2.37}$$

The solution of the domestic firms' price setting problem results in a Phillips curve-type relatioship between domestic inflation and real marginal cost ξ_t:

$$\hat{\pi}_t^H = \beta E_t \hat{\pi}_{t+1}^H + \frac{(1-\beta\phi)(1-\phi)}{\phi}\hat{\xi}_t \tag{2.38}$$

where variables with hats are in log-deviations from steady state, $\hat{x}_t = \log x_t - \log \bar{x}$.

The price setting problem of foreign-goods retailers is analogous to that of the domestic-goods retailers. The foreign-goods retailers transform a homogeneous foreign good into a differentiated import good, which they sell to domestic households. Similarly to domestic-goods retailers, foreign-goods retailers operate under Calvo-style price setting. Foreign-goods retailers purchase foreign goods at world-market prices P_t^*, which are set by their respective producers in their own currency. The law of one price holds at the wholesale level. By allowing for imperfect competition, we create a wedge between the wholesale and retail price of foreign goods.The real marginal cost of acquiring foreign goods is $\xi_t^F = \frac{P_t^*}{P_t^F}$.

The price-setting problem of foreign-goods retailers results in a Phillips-curve relationship between import-price inflation and the corresponding real marginal cost:

$$\hat{\pi}_t^F = \beta E_t \hat{\pi}_{t+1}^F + \frac{(1-\beta\phi)(1-\phi)}{\phi}\hat{\xi}_t^F \tag{2.39}$$

In an open economy, CPI inflation is a composite of domestic and foreign-goods inflation:

$$\pi_t = (\pi_t^H)^{\omega}(\pi_t^F)^{(1-\omega)} \tag{2.40}$$

The inflation dynamics therefore depend on domestic driving forces as well as foreign factors.

2.6 Resource constraints

The resource constraint for the domestic tradable good sector is

$$Y_t = c_t^H + c_t^{H*} + i_t \tag{2.41}$$

The domestic final goods market clears when the demand from domestic households, foreign market and domestic capital producers can be met by the production of the intermediate good firm.

2.7 Current account

Net foreign assets at the aggregate level evolve as

$$B_{t+1}^* = p_t^H c_t^{H*} - P_t^* c_t^F + \Gamma_t R_t^* B_t^* \tag{2.42}$$

where B_{t+1}^* is the foreign net bond position, the $p_t^H c_t^{H*}$ are receipts from exports and the $P_t^* c_t^F$ are expenses on imports (retailer pays only the marginal cost for imported wholesale goods and keeps the profit) and $\Gamma_t R_t^*$ is the country premium-adjusted gross nominal interest rate. Households' accumulation of foreign assets plus acquisition of foreign goods must equal foreign acquisition of domestic output, $B_{t+1}^* - \Gamma_t R_t^* B_t^* + P_t^* c_t^F = p_t^H c_t^{H*}$. We assume balanced trade in the steady state and normalize the steady state real exchange rate at

unity. Note that the net foreign asset position affects the endogenous country premium (see equation (2.8)).

3 Empirical analysis

The empiricical analysis aims at establishing the role of financial frictions and various shocks in the small open economy of Finland. Our goal is to find out what drives business cycle fluctuations in the Finnish economy. We estimate the model in log-linearized form using Bayesian Maximum Likelihood methods as described eg in An and Schorfheide (2007). The method is based on maximization of the likelihood function. The likelihood function is estimated using the Kalman filter. To find the posterior distributions of the estimated parameters, we apply the Metropolis-Hastings algorithm.[6]

We set the values of the parameters that control the steady state so that the model reproduces key sample averages in the data. We discuss the steady state parameters in Section 3.1.2. The set of parameters that affect the dynamics are estimated using Bayesian methods. The estimated parameters include those that characterize the shock processes and frictions, namely the elasticity of external finance premium with respect to firm leverage, price frictions, and capital adjustment costs. We discuss the priors of these parameters in Section 3.1.3. The estimation results are presented and the model fit discussed in Section 3.2. To answer the question of the empirical relevance of financial market disturbances, we present the forecast-error variance decomposition of key model variables and the historical variance decomposition of investment fluctuations in Sections 3.2.2 and 3.2.3, respectively. Details on the entire equation system can be found in Appendix A.

[6] We use Dynare 4 (available on http://www.dynare.org) to solve and estimate the model.

3.1 Data, calibration and priors

3.1.1 Data

We estimate the model using quarterly Finnish data from 1995:1 to 2008:4. Our aim to study Finland as part of the euro area restricts the use of data from before the launch of euro in 1999. However, we include data from 1995:1 to 1998:4 in order to have a slighly longer sample, as it can be argued that the intent to join the Monetary Union practically limited the conduct of monetary policy in Finland already a couple of years before the start.[7]

The data set includes real private investment, real private consumption, CPI inflation rate and the real exchange rate. We also use data on the foreign observable shock processes (foreign demand and foreign interest rate) as observables.[8] We follow common practice and estimate the foreign observable AR(1) shock process standard-deviation and autoregressive parameters outside the DSGE model by single-equation OLS. The results are reported in Table 1. We then use these results to fix those parameters in the estimation procedure of the whole system. Becuase the foreign shocks are pre-estimated, we are able to match the model to more variables than estimated shocks.This improves the estimation procedure since the foreign variables are informative as to the parameters governing the propagation of foreign impulses to the domestic economy (see eg Adolfson et al, 2008).

We decided to use only non-financial data in the estimation since the available data on the external finance premium and net worth of firms are subject to large measurement errors. We have experimented by including some financial market data but came to the conclusion that more reliable data are needed.

The downside of leaving out financial market variables as observables is that the identification of some of the parameters becomes more challenging. However, overall the model seems to match the data reasonably well and tell a plausible story of historical developments in the Finnish economy. Furthermore, this approach allows us to assess the performance of the model by investigating the match between model outcome and financial market data. A similar analysis is done eg by De Graewe (2008), who is able to reproduce

[7] Finland became member of EU in 1995 and joined ERM in October 1996.

[8] The real exchange rate incorporates the foreign price level, which is assumed to be exogenous in the model.

US external finance premium data with his estimated model. Our estimation results are presented in Section 3.2.

The log-linearised model implies that all variables are stationary, fluctuating around constant means. However, some of the series described above are non-stationary and need to be detrended before estimation. Thus, the investment, consumption and foreign output series are measured as deviation from trend using a Hodrick-Prescott filter with smoothing parameter 1600 and data from 1980 to 2009:2 (until 2009:1 for foreign output). CPI inflation (expressed as a quarterly rate), the real exchange rate and the foreign interest rate are demeaned. Plots of the detrended data used in the estimation are presented in Figure 1. A detailed description of the data and data transformations can be found in the Appendix.

3.1.2 Calibration

Some parameters are fixed throughout the estimation exercise. Tables 2 and 3 report the calibrated parameters along with the implied steady state values of some key variables.

The discount factor is set at 0.993, implying an annualized steady-state real interest rate of around 3 per cent. The steady state quarterly gross inflation rate is 1.005, which matches the historical average over the estimation sample.

We assume that households allocate one-third of their time to market activities so that η is set at 1.3166. The capital depreciation rate is 0.025, a value commonly used in the literature.The parameter for the degree of monopoly power in the retail sector (domestic and import) is set at 6, which implies a 20 per cent markup in the steady state. The share of capital in the production function α is fixed at 0.4. The constant associated with money demand, b , is set at 0.02 to ensure that the steady state ratio of real balances to consumption is close to its sample average.[9]

The steady-state external finance premium S is set at 1.0025, which corresponds to the sample average spread between the business prime lending rate and three month euribor (helibor from 1995:1 to 1998:4). This corresponds to an annual risk spread of 100 basis points.The value for the survival rate of entrepreneurs ν is set at 0.9728 and the ratio of capital to net worth is calibrated to 2, implying

[9]M1 divided by CPI.

a firm leverage ratio (debt-to-assets) of 0.5. We follow Bernanke et al (1999) in setting the survival rate and the steady state leverage ratio.

We set ρ, the intratemporal elasticity of substitution for the consumption composite, at unity. With regard to the parameters of export demand, we set the price elasticity ζ at 1 and the share parameter τ at 0.25. This implies a relatively high degree of inertia in export demand.

We fix the elasticity of the country-borrowing premium with respect to net indebtedness κ at 0.001, so that the evolution of net foreign assets does not affect the dynamics, but guarantees that the net foreign asset position is stabilized at zero in the long run.

3.1.3 Priors

We estimate the remaining parameters in the model, which pertain to the financial, nominal and real frictions as well as the exogenous shock processes. Prior distributions of the parameters of non-observed exogenous shocks and other estimated parameters are displayed in Table 4.

The prior distributions for all the standard deviations of the shocks are inverted Gamma distributions with mean equal to 1 and 10 degrees of freedom. This distribution guarantees a positive standard deviation with a rather large domain. Prior distributions of autoregressive parameters are assumed to follow Beta distributions with mean 0.75 and standard error 0.15.

We set the prior mean of the elasticity of external finance premium to 0.06, which is close to the calibrated value in Bernanke et al (1999). The Gamma distribution is used for the elasticity of the external finance premium. Our prior for the Calvo parameter of consumer price setting follows a Beta distribution with mean 0.4 and standard deviation 0.05. Finally, the prior distribution for the capital adjustment cost parameter χ is set to follow a Gamma distribution with mean 0.5 and standard deviation 0.2.

3.2 Estimation results

3.2.1 Parameter estimates and model fit

Table 4 reports the results of the Bayesian estimation. The posterior means and 90 per cent confidence intervals for the posterior distributions of the parameters are calculated from the output of the Metropolis-Hastings algorithm. Posterior simulation is done via a random walk Metropolis-Hastings algorithm on three chains of 500'000 draws.[10] The plots of the prior and posterior densities are presented in Figure 2, which indicates how informative the observed data are as to the structural parameters. The prior and posterior densities clearly differ in most cases. As regards the autoregressive coefficient of the credit supply shock, its posterior is much more sharply peaked than our prior distribution, and the variance of the posterior distribution is smaller than for the prior distribution, implying that the data are reasonably informative as to the parameter. There are, however, some problems with identification of the autoregressive coefficient of the financial wealth shock. Overall, it appears that the data are quite informative as to the estimated parameters. Even though we did not use any financial market data in the estimation, we are able to identify reasonably well the financial market shocks and elasticity of the external finance premium parameter.

The estimated value of the key parameter in the financial accelerator, the elasticity of the external finance premium with respect to firm leverage ψ, is positive and close to values obtained in other estimated DSGE models with financial accelerator (eg Gilchrist et al, 2009; Christensen and Dib, 2008; Dib et al, 2008). The estimate of the elasticity of the external finance premium is 0.0461 at the posterior mean, which indicates that the financial accelerator was operative in the Finnish economy over the period of 1995 to 2008. For instance, Gilchrist et al (2009) and Christensen and Dib (2008) obtain a value of 0.04 for the US economy. It is important to recognize that when ψ is exactly equal to zero, the financial accelerator ceases to exist. Entrepreneurs will then borrow, but the cost associated with this source of finance will be given by the real riskless interest rate and will not be augmented by an endogenous risk premium depending on firms' balance sheets. Our results imply that financial frictions exist

[10] We checked convergence by the usual graphical criteria proposed by Dynare.

in the process by which firms seek external finance for investment purposes and that aggregate balance sheet vulnerabilities matter in Finland.

The capital adjustment cost parameter χ is estimated at 1.1, which is a relatively large value for this parameter. High capital adjustment costs make investment less responsive to shocks, while the price of capital will respond to shocks to a greater extent. The price of capital has a direct effect on firms' net worth (via capital gains and losses) and therefore on the cost of external finance. The more costly it is to adjust investments, the more volatile the price of capital and therefore the more volatile the external finance premium. Our results imply that strong fluctuations in Finnish asset prices feed through to the real economy via firms' balance sheets.

Our estimate of the degree of price stickiness is relatively low. The estimate of the Calvo probability of not resetting optimally prices ϕ is 0.48, which implies an expected price duration of about 2 quarters.

The estimated technology shock and preference shock are more volatile and more persistent than the two estimated financial shock processes. The standard deviation for the money demand shock is set at 1 per cent and the persistence parameter at 0.7. Becuase of identification problems, we do not estimate the parameters of the money demand shock.

We address the question of how well the model fits the data by comparing a set of statistics implied by the model to those derived from the data. Table 5 reports the relative standard deviations implied by the model along with the sample standard deviations based on the observed data over the estimation period.[11] The model matches investment and inflation variation relative to output well, but seems to overpredict the volatility of private consumption. In addition, the model captures very accurately the positive contemporaneous correlation in the data between investment and output. The model underestimates slightly the contemporaneous positive correlation between investment and consumption.We conclude that the model performs well in reproducing key features of investment data. This is an important result, because our main objective is to investigate the sources of fluctuation in investment.

Model validation can also be done by checking how accurately the model reproduces data that are not used as observable in the

[11] Data on output is not used as an observable in the estimation.

estimation procedure. A key variable in the model and in the financial accelerator theory is the aggregate net worth of firms. This can be proxied by stock market data. In Figure 3, we show that the model reproduces Finnish stock market data well.[12]The model tracks reasonably well the surge in the stock market and subsequent collapse related to the high-tech boom-bust episode at the end of 1990s and beginning of the 2000s. Furthermore, the model reproduces the rise in stock prices before the start of the recent global financial market crisis and stock market bust in 2008. The volatility of the actual stock market data is, however, greater than that produced by the model. As regards the external finance premium (Figure 4), we compare the premium implied by the model to a rough approximation of the external finance premium in Finland, namely the difference between the firms' external financing cost measured by the business prime lending rate and 3-month euribor.[13]Unfortunately, the data for the external finance premium is clearly less volatile than the premium produced by the model. On the other hand, our model predicts very accurately the surge in the external finance premium that occured when the global financial crisis escalated in the second half of 2008. However, to evaluate the model in this respect, we need better empirical measures of the external finance premium.

3.2.2 Variance decomposition

In order to assess the role of the various shocks included in the model, we report the forecast-error-variance decompositions in Table 6. The contributions of each shock to the variances of key model variables are reported for four horizons. After looking at the variance decompositions implied by the estimated model, we conclude that the financial shocks are important sources of business cycle fluctuations in Finland at all horizons. The two financial shocks combined account for the major part of investment fluctuation in both the short and long run. Output fluctuations are strongly affected in the short run by the credit supply shock and in the long run by the financial wealth shock. The credit supply shock seems to play a key role in the short-term investment and output fluctuations, while the financial wealth shock gains importance in the long run. Furthermore, in contrast to a model

[12]Detrended real (deflated by CPI) stock market price index.

[13]We use the 3-month helibor as our reference interest rate instead of the euribor before the start of the euro area in 1999.

without financial shocks, the variation in output in the long run is attributed not only to the technology shock but also to the financial shocks.

The foreign shocks combined with the technology shock account for a substantial portion of inflation fluctuations in both the short and long run. The foreign interest rate shock also plays a role in explaining investment variation. However, a key result is that, despite allowing for a wide range of shocks including foreign shocks, the financial market shocks emerge as central in explaining variation in investment. Our results so far suggest that to understand Finnish business cycles we need to understand financial market shocks, since these shocks are large contributors to fluctuations in key macroeconomic variables.

3.2.3 Historical variance decomposition

In this section, we assess the historical relevance of disturbances in financial markets for macroeconomic performance over the 1995–2008 period. In particular, we use our model to provide an interpretation of fluctuations in investment activity by decomposing the observed investment data into the contributions of its structural shocks.The historical variance decomposition is shown in Figure 5.

From Figure 5, it is evident that financial market shocks are key drivers of historical investment fluctuations. The figure suggests that financial factors contributed greatly to the boom-bust period from the late 1990s to early 2000s. In the beginning of the 2000s, there seems to have been a positive impact from credit supply shock that helped support investment for a while despite the slowdown in economic growth after the bursting of the high-tech stock market bubble in the second half of 2000. The contraction phase in investment activities after the stock market bust and subsequent economic downturn can be largely attributed to adverse financial market shocks. At the end of 2001, there was a reversal of the credit supply shock from positive to negative, reflecting an exogenous increase in risk premia that firms had to pay for external finance. At the same time, an adverse shock to the financial wealth of entrepreneurs gained importance, possibly due to the stock market bust. Both domestic financial market shocks were dragging investment down for several years during which expansionary monetary policy and to some extent also a positive technology shock (procyclical otherwise but not procyclical around this time) helped to alleviate the downturn and contributed

to the pickup in investment activity in 2006. The shock to the external finance premium seems to explain also the peak in investment activity before the global financial crisis induced a sudden reversal of investment in 2008. In the second half of 2008 there was a clearly negative contribution from financial market shocks to investment, along with a counteracting favourable monetary policy shock. Thus, the model seems to explain the recent events related to the global financial market crisis in a way that accords well with perceptions of the link between financial conditions and the real economy.

To conclude, domestic financial shocks seem to act as driving forces behind the historical fluctuations in investment. The role of domestic non-financial shocks, the technology shock and the preference shock, is clearly less significant. This result is in line with results obtained by Gilchrist et al (2009) for the US economy over the 1973–2008 period. In addition to the domestic shocks, in our open economy setup we can also study the relative importance of shocks stemming from the foreign economy. Interestingly, the only open-economy shock that seems to play a role in explaining fluctuations in investment activity is the foreign interest rate shock. The foreign interest rate shock, however, actually represents a monetary policy shock affecting Finland as part of the euro area.

3.3 Impulse responses

Figures 6 and 7 plot the estimated impulse responses of the model's variables to one-standard-deviation financial market shocks.

3.3.1 Credit supply shock

An increase in the external finance premium causes a drop in investment and in output. A one-standard-deviation shock to the external finance premium raises the premium by 70 basis points. Investment falls on impact by 2.5 per cent and output by 0.5 per cent. The increase in the cost of purchasing new capital reduces the demand for it and depresses the price of capital (ie asset prices fall). The initial drop in output is dampened by an increase in exports and also in consumption, as inflation falls initially and the real exchange rate depreciates by 0.3 per cent. Being part of the euro

area, nominal interest rate does not react to the falling inflation or output. There is only a marginal drop in the nominal interest rate due to the positive real net debt, as exports increase and imports fall. These initial positive effects on exports and consumption are reversed, as inflation soon picks up. The pickup in inflation reduces real debt of entrepreneurs (Fisher effect) and net worth recovers.

3.3.2 Financial wealth shock

A positive shock to the financial wealth of entrepreneurs has a long-lasting positive effect on investment and ouput because net worth propagates the shock long after the initial impact. The external finance premium shrinks, reflecting a decrease in firm leverage. Inflation picks up initially, causing an initial fall in exports and consumption. The long-lasting effect on investment results in an increase in the capital stock and a decrease in marginal cost. Inflation falls, which has a positive effect on consumption and exports and so boosts output further. Once again, these results are obtained without a nominal interest rate reaction, due to the lack of an independent monetary policy in Finland as part of the euro area.

4 Conclusions

This paper studies financial market disturbances as sources of investment fluctuations in Finland during 1995–2008. We construct a DSGE model of the Finnish economy that incorporates financial frictions, in the form of a BGG financial accelerator, and two domestic financial market shocks. We investigate empirically the importance of financial market frictions and disturbances by estimating the model using the Bayesian Maximum Likelihood approach.

We assess the strength of the financial accelerator mechanism by estimating the elasticity of the external finance premium with respect to firm leverage. The value obtained is positive and close to values obtained in other estimated DSGE models with financial accelerator (eg Gilchrist, Ortiz and Zakrajsek, 2009; and Christensen and Dib, 2008). We thus show that the financial accelerator is operative in Finland and that there is feedback between the financial and real sectors via aggregate firm balance sheets. The presence

of the financial accelerator affects the response of the economy and makes it vulnerable to shocks that impact aggregate firm balance sheets. For instance, changes in the valuation of financial assets may cause significant and protracted declines in investment and output via endogenous increases in the external finance premium paid by firms to obtain funds for financing purchases of capital. Our evidence thus suggests that asset values play a key role as determinants of investment behaviour in Finland.

In our empirical work, we focus on investigating the importance of financial market shocks in Finland. The two domestic financial market shocks considered are a shock to the credit supply (an exogenous change in the external finance premium) and a shock to the financial wealth of entrepreneurs (exogenously creating or destroying aggregate net worth). Our empirical analysis shows that financial market shocks are key drivers of investment and ouput fluctuations in both the short and long run.

Our key result is that disturbances originating in the financial sector have played a significant role in the historical variation of investment actitivity in Finland. A recent paper by Gilchrist et al (2009) obtains similar results for the US economy over the period 1973–2008. In contrast to Gilchrist et al (2009), our small open economy model incorporates several open economy shocks and therefore allows us to examine the relative importance of shocks stemming from both foreign and domestic sources. We find that, of the foreign shocks, only the foreign monetary policy shock has a significant impact on investment fluctuations. However, the presence of open economy shocks does not alter the conclusion that domestic financial shocks are central to explaining investment developments in Finland over the period 1995–2008.

Furthermore, our results are obtained without using any financial market data in the estimation, whereas Gilchrist et al (2009) construct and use a highly sophisticated measure of credit spread in the estimation of the model. Our approach allows us to assess the implications of the model as regards financial market data. It turns out that the aggregate net worth of firms as proxied by Finnish stock market data is reasonably well reproduced by the model. The model does slightly worse in matching the data on the extenal finance premium. However, there is uncertainty as to whether our data on the external finance premium correctly measures the premium.

It seems that the financial market shocks have taken over the role of an investment-specific shock, which generally accounts for

a large part of investment fluctuations. As argued by Justiniano et al (2008), the investment-specific technology shock seems to capture shocks actually stemming from financial markets.Therefore, by explicitly incorporating financial market shocks and omitting the investment-specific shock, we have shown that financial market shocks can explain particular episodes in the Finnish business cycle where financial frictions are most likely to have been important. These episodes are the boom and bust of the stock market the late 1990s and early 2000s and the subsequent early millennium slowdown and, more recently, the sudden reversal of investment activities in 2008, due to the global financial crisis. As emphasized by Christiano et al (2009), models that incorporate an investment-specific shock are clearly not well suited to explain such episodes as an investment-specific shock, which is a shock to the supply of capital as opposed to demand, predicts an investment-output boom coinciding with a stock market bust.

A model with financial frictions allows us to tell a story of the period from 1995 to 2008 that we would not be able to tell otherwise.We conclude that shocks originating in the financial sector and hitting entrepreneurs and their demand for capital lie at the core of understanding business cycle dynamics in Finland.

There are possibly several useful extensions to the model and to the empirical work. The financial intermediary could be modelled to incorporate the supply of credit. In this model, the capital stock includes both housing and business capital. Another extension would be to separate the household and the business sectors. The special features of a country belonging to a monetary union should be studied more carefully. In empirical work, the incorporation of carefully constructed financial market data should be considered. Finally, future work could assess the role of financial factors in the early nineties recession, which was particularly deep in Finland.

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Appendix

A. Euro area open economy model

Households

$$\frac{e_t c_t^{-\frac{1}{\gamma}}}{c_t^{\frac{\gamma-1}{\gamma}}+b_t^{1/\gamma}\left(\frac{M_t}{P_t}\right)^{\frac{\gamma-1}{\gamma}}} = \lambda_t$$

$$\frac{e_t b_t^{\frac{1}{\gamma}}\left(\frac{M_t}{P_t}\right)^{-\frac{1}{\gamma}}}{c_t^{\frac{\gamma-1}{\gamma}}+b_t^{1/\gamma}\left(\frac{M_t}{P_t}\right)^{\frac{\gamma-1}{\gamma}}} = \lambda_t - \beta E_t\left(\frac{\lambda_{t+1}}{\pi_{t+1}}\right)$$

$$\frac{\eta}{1-h_t} = \lambda_t w_t$$

$$\frac{\lambda_t}{R_t} = \beta E_t\left(\frac{\lambda_{t+1}}{\pi_{t+1}}\right)$$

$$\frac{c_t^H}{c_t^F} = \frac{\omega}{1-\omega}\left(\frac{p_t^H}{p_t^F}\right)^{-\rho}$$

$$E_t\{\frac{\lambda_{t+1}}{\pi_{t+1}}[R_t - \Gamma_t R_t^*]\} = 0$$

Country-borrowing premium

$$\Gamma_t = \exp(\text{-}\kappa(a_t - \bar{a}))$$

Entrepreneurs

$$Y_t = K_t^{\alpha}(A_t h_t)^{(1-\alpha)}$$

$$\frac{W_t}{P_t} = \xi_t(1-\alpha)\frac{Y_t}{h_t}$$

$$z_t = \xi_t \alpha \frac{Y_t}{K_t}$$

$$E_t f_{t+1} = E_t[\frac{z_{t+1}+(1-\delta)q_{t+1}}{q_t}]$$

Financial accelerator

$$E_t f_{t+1} = E_t[S(\frac{n_{t+1}}{q_t K_{t+1}})\frac{R_t}{\pi_{t+1}}\epsilon_{ft}]$$

$$E_t n_{t+1} = \nu_t[f_t q_{t-1} K_t - E_{t-1} f_t(q_{t-1}K_t - n_t)] + (1-\nu_t)g_t$$

Capital producers

$$q_t - 1 - \chi\left(\frac{i_t}{K_t} - \delta\right) = 0$$

$$K_{t+1} = i_t + (1-\delta)K_t$$

Domestic retailers

$$p_t^H(j) = \frac{\theta}{\theta-1}\frac{E_t\sum_{t=0}^{\infty}(\beta\phi)^l \lambda_{t+l} y_{t+l}(j)\xi_{t+l}}{E_t\sum_{t=0}^{\infty}(\beta\phi)^l \lambda_{t+l} y_{t+l}(j)\pi^l/p_{t+l}}$$

$$1 = \phi \left(\frac{\pi}{\pi_t}\right)^{1-\theta} + (1-\phi)(\frac{p_t^H(j)}{P_t})^{1-\theta}$$
$$\pi_t^H = \frac{P_t^H}{P_{t-1}^H}$$

Foreign-goods retailers

$$p_t^F(j) = \frac{\theta}{\theta-1} \frac{E_t \sum_{t=0}^{\infty} (\beta\phi)^l \lambda_{t+l} y_{t+l}(j) \xi_{t+l}^F}{E_t \sum_{t=0}^{\infty} (\beta\phi)^l \lambda_{t+l} y_{t+l}(j) \pi^l / p_{t+l}}$$
$$1 = \phi \left(\frac{\pi}{\pi_t}\right)^{1-\theta} + (1-\phi)(\frac{p_t^F(j)}{P_t})^{1-\theta}$$
$$\pi_t^F = \frac{P_t^F}{P_{t-1}^F}$$

Aggregate real marginal cost of imported foreign goods

$$\xi_t^F = P_t^* / P_t^F$$

Composite inflation: CPI

$$\pi_t = (\pi_t^H)^{\omega} (\pi_t^F)^{(1-\omega)}$$

Foreign demand for home retail consumption good

$$c_t^{H*} = [\left(\frac{p_t^H}{P_t^*}\right)^{-\zeta} y_t^*]^{\tau} (c_{t-1}^{H*})^{(1-\tau)}$$

Current account

$$B_{t+1}^* = p_t^H c_t^{H*} - P_t^* c_t^F + \Gamma_t R_t^* B_t^*$$

Resource constraint

$$Y_t = c_t^H + c_t^{H*} + i_t$$

Total consumption expenditure for the household

$$C_t^H + C_t^F = C_t$$

Money growth

$$\mu_t = \frac{m_t \pi_t}{m_{t-1}}$$

B. Data transformations

The data for foreign variables is constructed as follows: The foreign nominal interest rate is measured by the 3-month euribor, backdated before 1999. For the financial crisis during 2007Q3–2008Q4, when the interbank lending was distracted and euribor rates distorted, we use the eurepo. Aggregate foreign output is measured by an export share-weighted basket of imports of the following countries: USA, Japan, UK, Sweden, Germany, Italy (Germany and Italy are included to cover the euro area). The foreign price level in euros is a combination of euro area GDP deflator and an extra-euro area export share-weighted basket of foreign GDP deflators (USA, Japan, UK, Sweden) converted to euros via the respective nominal exchange rates. Data for the real exchange rate are constructed as the foreign price level in euros divided by the price of domestic private sector output.

Figures

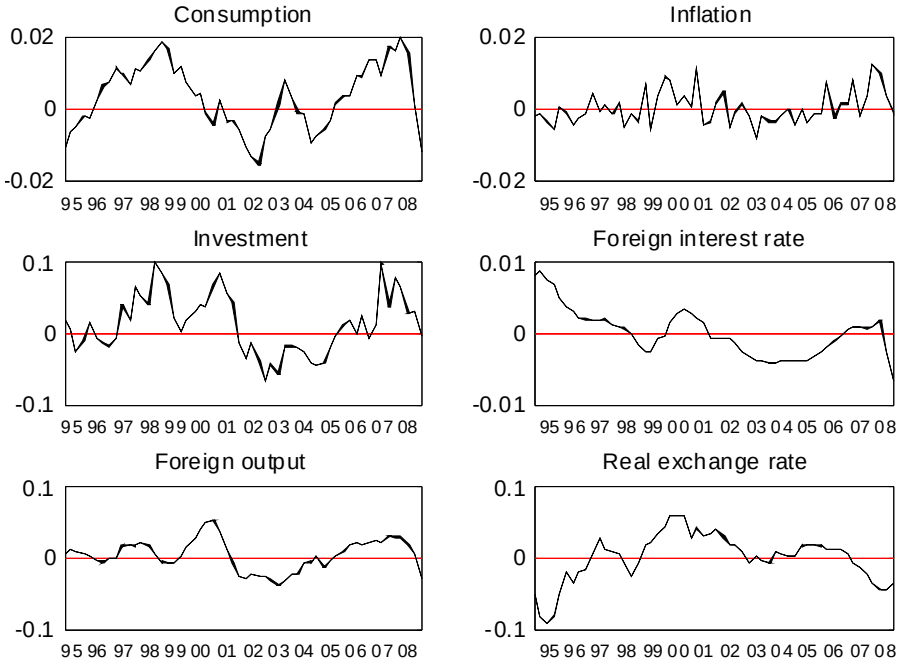

Figure 1. **The data**

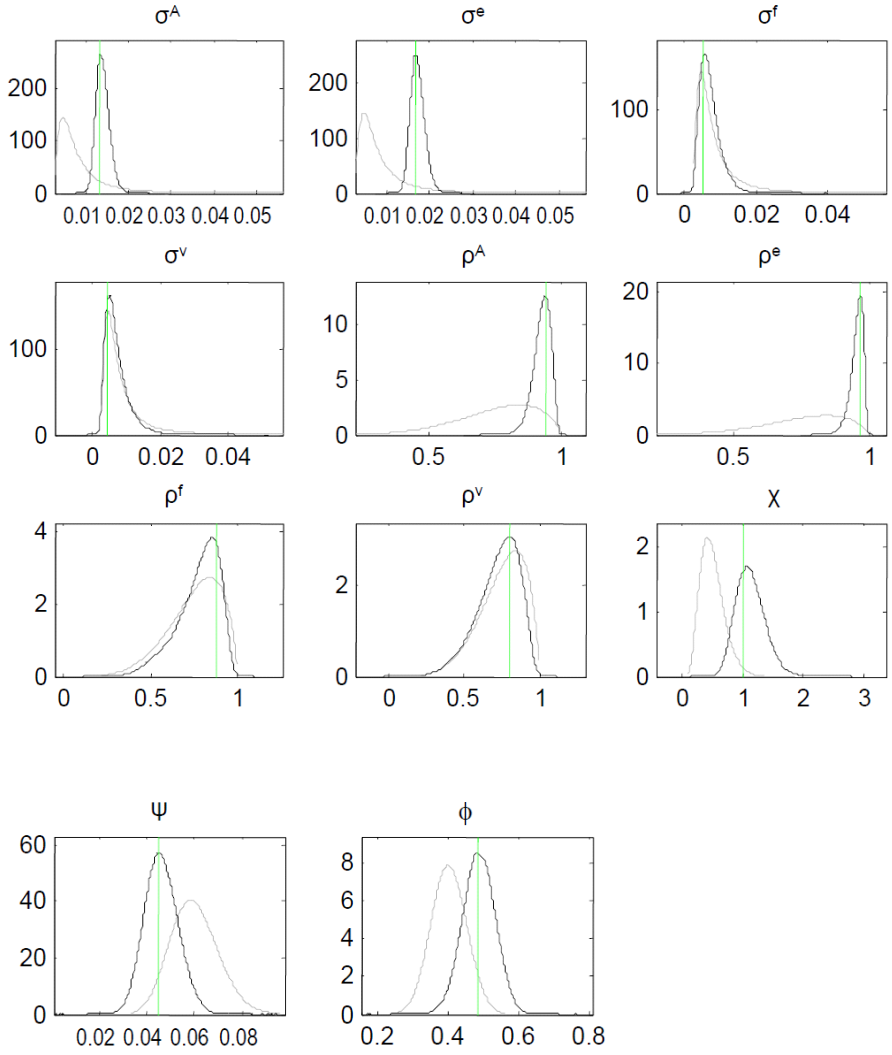

Figure 2. **Prior and posterior distributions of structural parameters**

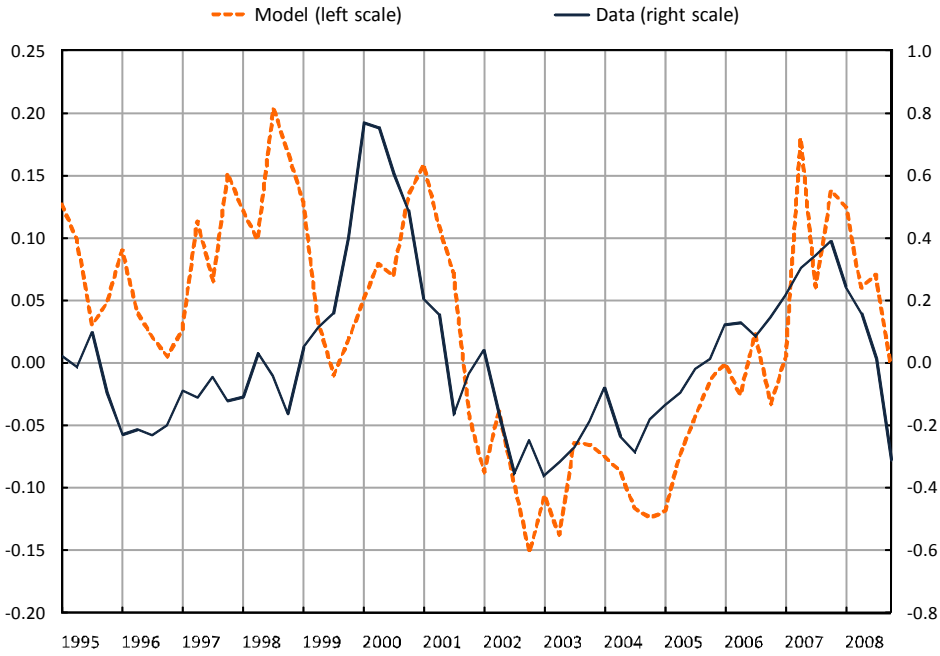

Figure 3. **Model-implied net worth and data on net worth**

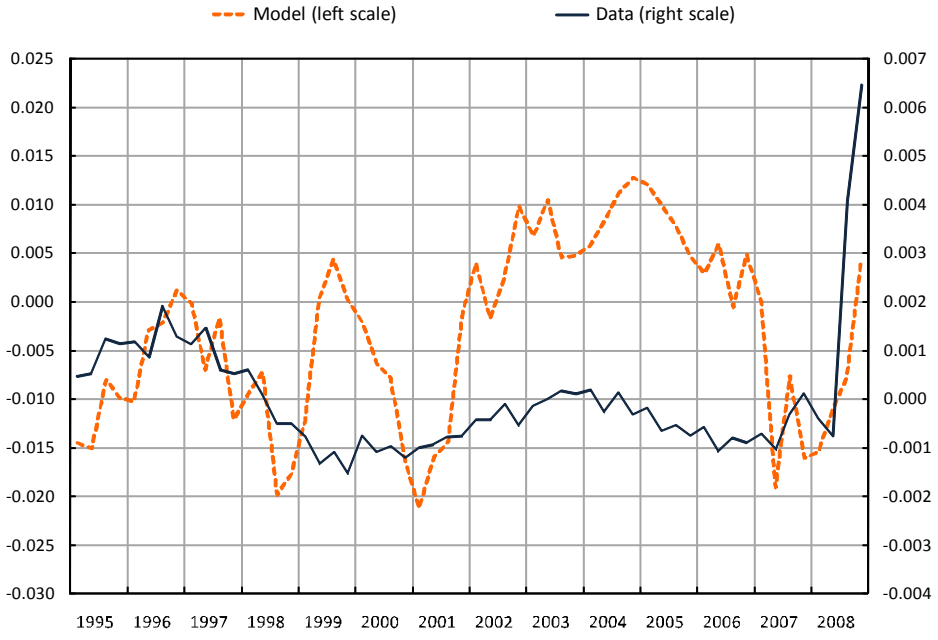

Figure 4. **Model-implied external finance premium and data on external finance premium**

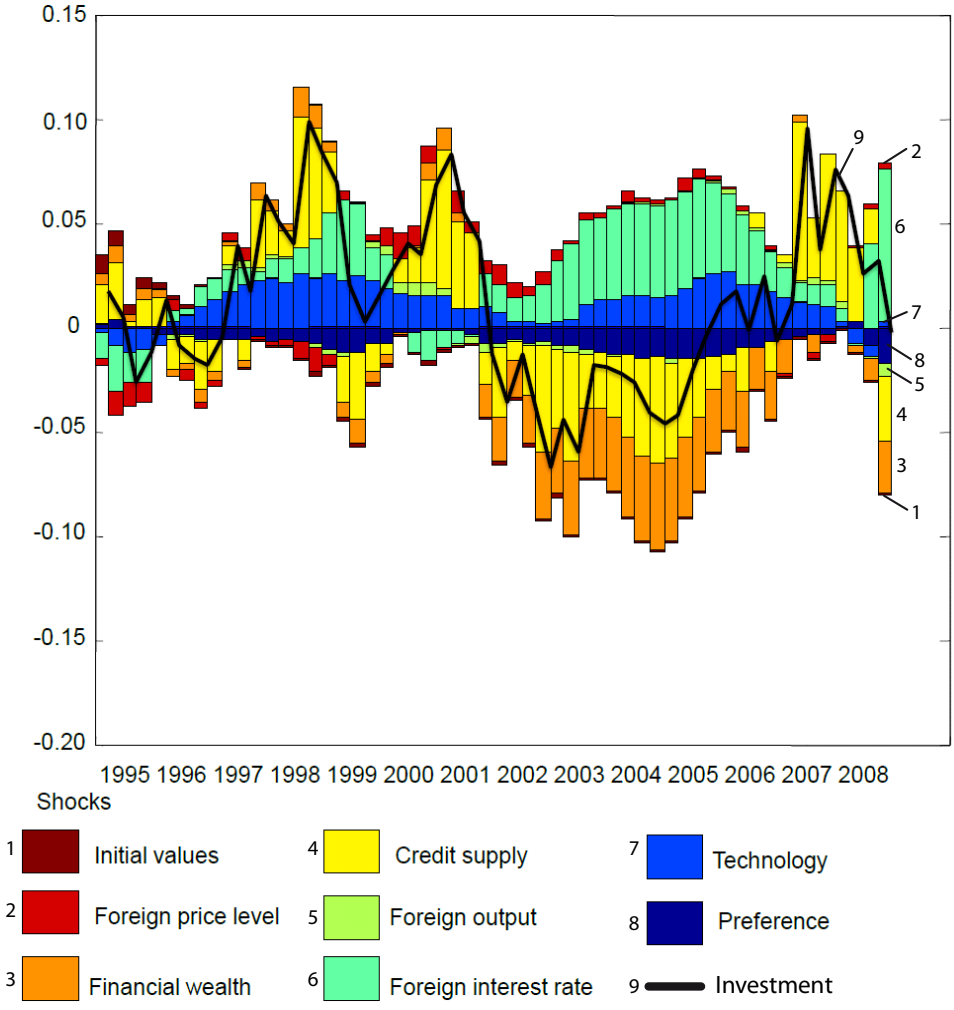

Figure 5. **Historical variance decomposition of investment**

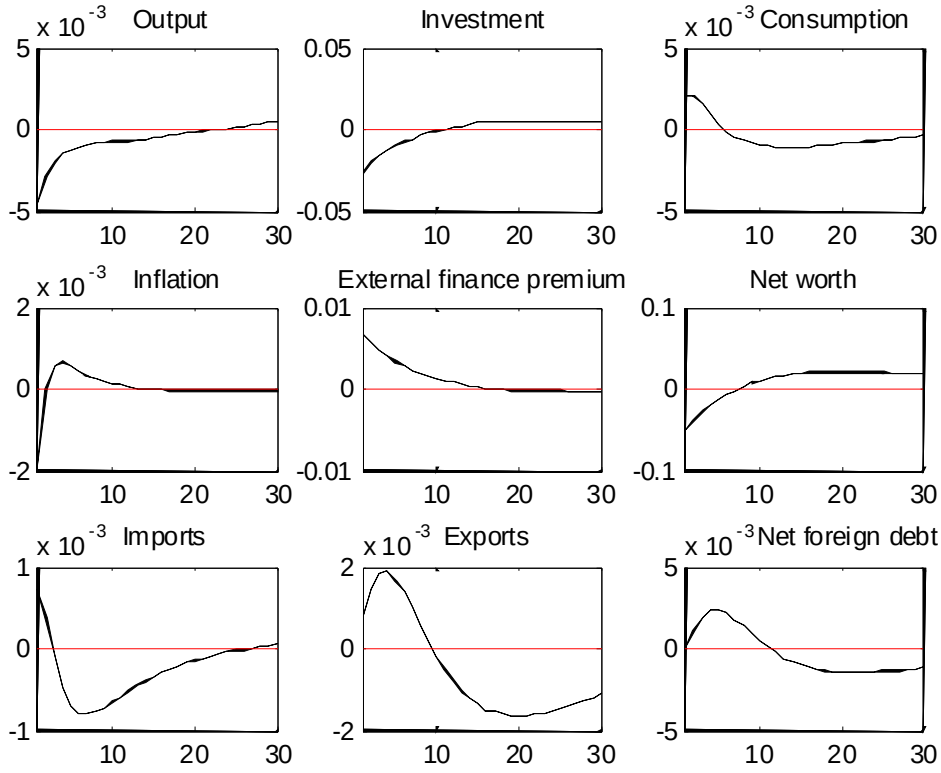

Figure 6. **Adverse credit supply shock**

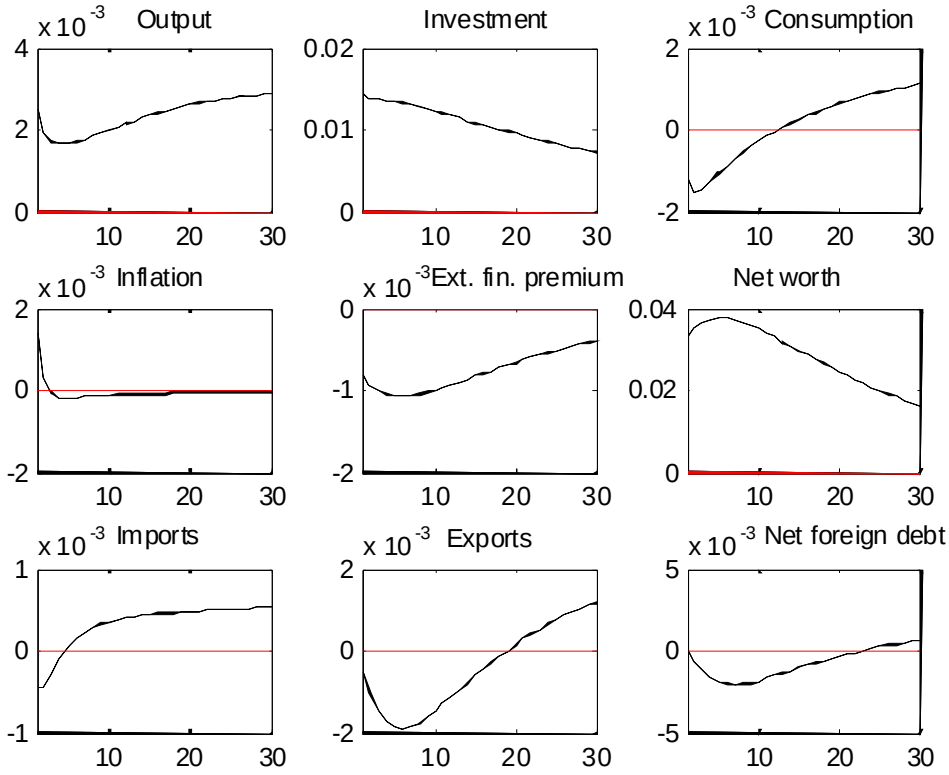

Figure 7. **Positive financial wealth shock**

Tables

Table 1. **Estimated foreign shocks**

Foreign shocks	
Foreign interest rate ρ^{R^*}	0.9190
Foreign output ρ^{y^*}	0.9035
Foreign price level ρ^{P^*}	0.8429
Foreign interest rate σ^{R^*}	0.0011
Foreign output σ^{y^*}	0.0100
Foreign price level σ^{P^*}	0.0119

Table 2. **Calibrated parameter values for the Finnish economy**

Symbol	Definition	Value
β	discount factor	0.993
θ	final goods elasticity of substitution	6
δ	capital depreciation rate	0.025
η	weight on leisure in utility function	1.3166
α	share of capital in production function	0.4
ν	survival rate of entrepreneurs	0.9728
S	steady state external finance premium	1.0025
k/n	steady state ratio of capital to net worth	2
Π	steady state gross inflation rate	1.005
b	constant associated with money demand	0.02
γ	constant elasticity of substitution between consumption and real balances	0.065
ρ	intratemporal elasticity of substitution between consumption of domestic and foreign goods	1
ω	share of domestic goods in consumption composite	0.35
ω^E	share of intra-euro area trade	0.4
$(1-\omega^E)$	share of extra-euro area trade	0.6
ζ	price elasticity of export demand	1
τ	share parameter of export demand	0.25
κ	elasticity of borrowing premium with respect to net indebtedness	0.001

Table 3. **Implied steady state relationships**

	Data (1995:1–2007:4)	model
$\frac{k}{y}$	3	9.64
$\frac{i}{y}$	0.23	0.24
$\frac{c}{y}$	0.71	0.76
$\frac{c^F}{y}$	0.47	0.42
$\frac{c^{H*}}{y}$	0.58	0.42
$\frac{c^H}{y}$	0.24	0.34
$\frac{wh}{y}$	0.49	0.5

Table 4. **Estimation results**

Parameter	**Prior distribution**			**Posterior distribution**		
	Type	**Mean**	**St. Dev.**	**Mean**	**5%**	**95%**
elasticity of external finance premium with respect to firm leverage ψ	Gamma	0.06	0.01	0.0461	0.0347	0.0575
capital adjustment cost parameter χ	Gamma	0.5	0.2	1.1247	0.7319	1.5040
sticky price parameter ϕ	Beta	0.4	0.05	0.4838	0.4102	0.5599
Auto-regressive coefficients of shocks						
Financial wealth ρ^{v}	Beta	0.75	0.15	0.7246	0.5140	0.9434
Credit supply ρ^{f}	Beta	0.75	0.15	0.7716	0.5815	0.9505
Preference ρ^{e}	Beta	0.75	0.15	0.9519	0.9176	0.9866
Technology ρ^{A}	Beta	0.75	0.15	0.9258	0.8764	0.9778
Standard deviations of shocks						
Financial wealth σ^{v}	Inv. Gamma	1	10	0.72	0.26	1.20
Credit supply σ^{f}	Inv. Gamma	1	10	0.71	0.30	1.13
Preference σ^{e}	Inv. Gamma	1	10	1.72	1.45	1.98
Technology σ^{A}	Inv. Gamma	1	10	1.40	1.14	1.64

Table 5. **Relative standard deviations**

Variable	Estimated model	Data
investment	2.13	2.47
consumption	1.35	0.55
inflation	0.19	0.28
output	1.00	1.00

Table 6. **Forecast-error-variance decompositions**

	Credit supply shock	Financial wealth shock	Technology shock	Preference shock	Foreign interest rate shock	Other foreign shocks
Variance decomposition (1-step ahead, %)						
Investment	69.11	20.21	1.03	0.85	6.74	2.08
Consumption	1.77	0.6	9.94	74.46	10.9	2.34
Output	29.59	8.18	23.7	25.69	5.44	7.4
Inflation	6.99	3.3	38.45	8.51	31.88	10.87
Variance decomposition (4-step ahead, %)						
Investment	59.71	28.94	2.75	0.75	6.35	1.5
Consumption	1.34	0.88	14.78	70.18	6.5	6.33
Output	12.93	5.25	53.69	14.43	2.51	11.19
Inflation	7.54	3.22	37.36	8.3	30.86	12.71
Variance decomposition (8-step ahead, %)						
Investment	48.19	39.03	3.25	0.94	7.28	1.31
Consumption	0.83	0.60	13.77	71.06	5.83	7.82
Output	7.74	4.93	62.06	10.35	2.8	12.12
Inflation	8.22	3.29	36.85	8.14	31.05	12.45
Variance decomposition (inf-step ahead, %)						
Investment	31.19	55.69	2.38	1.68	7.02	2.04
Consumption	1.44	4.89	9.6	74.22	4.66	5.19
Output	6.97	37.34	37.44	7.34	3.71	7.19
Inflation	8.16	3.42	36.45	8.06	30.8	13.11

Chapter 4

Financial factors in the boom-bust episode in Finland in the late 1980s and early 1990s

Abstract

This paper offers a framework for studying the boom and bust in Finland in the late 1980s and early 1990s. We develop a small open economy DSGE model with balance sheet constrained firms a la BGG and calibrate it to the Finnish economy. We use the model to simulate three events that are claimed to have played a key role in the Finnish boom-bust episode and compare the model outcome with actual Finnish data. Firstly, we assess the role of financial market deregulation in the 1980s boom that preceded the crisis. Secondly, we use our model to evaluate the negative impact of the collapse of the Soviet-Finnish trade in 1991. Thirdly, we investigate the effect of the collapse of the fixed exchange rate regime in 1992. We conclude that financial frictions combined with the shocks that hit the Finnish economy are able to produce a boom and a severe depression similar to the one observed in Finland. A key finding is the crucial role played by the financial accelerator mechanism in the model's ability to mimic the response of the Finnish economy to the shocks that it encountered. A key contribution is incorporating unconventional shocks into the model: domestic financial market shocks to capture the deregulation of the financial market; a capital obsolescence shock to model the sudden redundancy of Soviet-oriented manufacturing; and a shock from the international financial market, a

country borrowing-premium shock, to capture the collapse of the fixed exchange rate regime.

Contents

1 Introduction

Finland experienced an economic boom at the end of 1980s that was followed by a deep depression in the beginning of 1990s, with a protracted and persistent decline in output and investment. Finland's real GDP peaked at around 6 per cent above trend in the beginning of 1990 and fell to 5 per cent below trend in 1993: an overall contraction of about 11 per cent within about 3 years. The behaviour of private investment was even more dramatic: an investment boom of 20 per cent above trend in 1989 was followed by a collapse to 15 per cent below trend by 1993: an overall contraction of about 35 per cent within 4 years. The severity of the depression gives Finland a place among the 'Big Five' postwar rich-country large-scale financial crises identified by Reinhart and Rogoff (2008).

In this paper, we address the boom-bust period in Finland by focusing on the behaviour of private investment and on financial factors behind the large and persistent deviations of private investment from its trend. We show how financial factors combined with shocks to the Finnish economy produced first a boom followed by a severe depression.

This paper proposes a framework for studying both the boom late-1980s and the bust early-1990s in Finland. To this end, we construct a small open economy DSGE model with financial frictions in the form of the BGG (Bernanke, Gertler and Gilchrist, 1999) financial accelerator. A key contribution is to incorporate 'unconventional' shocks into the model to capture and evaluate the role played by three key events of the episode: financial market deregulation in the 1980s, the collapse of Soviet-Finnish trade in 1991 and the collapse of the fixed exchange rate regime in 1992. We calibrate the model to the Finnish economy and compare model outcomes with actual Finnish data.

Our analysis assigns an essential role to the balance sheet constrained firms a la Bernanke, Gertler and Gilchrist (1999) in capturing the magnitude and persistence observed in investment and output data during the Finnish boom-bust cycle. The BGG financial accelerator links the balance sheet conditions of firms to real activity via an external finance premium that depends inversely on the strength of the borrower balance sheets. In our model framework, we show how financial factors, either boosting or depressing economic activity, contributed first to the boom and later to the severity of

the crisis and the slow recovery. Absent credit market frictions, the initiating disturbances would have merely resulted in a mild upturn or downturn.

We further argue that the shocks that hit Finland were greatly amplified because they affected firm balance sheets. The results were sharp and persistent changes in firms' risk premia, which hindered their ability to invest and thus led to large and persistent swings of investment, first above and later below trend. We conclude that the shocks that hit the Finnish economy, combined with financial frictions, are able to produce a boom and a severe depression, matching key salient features of the actual boom-bust experienced in Finland.

The greater part of the financial deregulation process in Finland was carried out in the second half of the 1980s.[1] The deregulation process resulted in exceptionally rapid growth in bank lending and an overheating of the economy. In our model framework, we produce a boom similar to that observed in Finland in the late 1980s by modeling financial market deregulation as shocks from the domestic financial market that lower the cost of credit. Our model framework thus enables us to study formally the informal notion that financial market deregulation in the 1980s was at the core of the overheating of the economy.

In the beginning of 1991, the collapse of Soviet-Finnish trade and sudden redundancy of Soviet-oriented manufacturing wiped out part of the economically valuable capital from the economy and resulted in a dramatic weakening of firm balance sheets. In this paper, we argue that the collapse of Soviet-Finnish trade is best understood as a capital-obsolescence shock reducing the value of capital in the firm balance sheets, as opposed to a conventional trade shock. Here we draw on Gertler and Karadi (2009), who introduce a capital obsolescence shock into their model to capture the subprime crisis that wiped out part of the value of intermediary-sector balance sheets in the US, as the value of subprime-related assets collapsed. We illustrate in our model framework how a capital obsolescence shock, combined with balance sheet constrained firms, leads to a severe downturn similar to the one experienced in Finland.

The collapse of Soviet-Finnish trade was followed by the collapse of the fixed exchange rate regime in September 1992 and a depreciation of the currency. Despite the depreciation of the real exchange rate

[1] Economic developments in Finland from the 1970s to the end of the 1990s are described, for example, in Korhonen (2010).

and a pickup in net trade, investment contracted further and output remained depressed for several years.We illustrate in our model the role played by financial factors after the collapse of the fixed exchange rate regime. We argue that the indebtedness of the entrepreneurial sector in Finland and the fact that part of the loans were denominated in foreign currency resulted in a persistent decline in investent and a sluggish recovery of the economy despite an increase in net trade due to improved competitiveness.

The collapse of Soviet-Finnish trade has been studied by Gorodnichenko et al (2009) in a dynamic general equilibrium model that describes Soviet-Finnish trade linkages in great detail. Gorodnichenko et al (2009) treat the collapse of Soviet trade as a large exogenous trade shock and conclude that their model is able to match the aggregate dynamics reasonably well. The key mechanism that amplifies the initial shock in their model is rigid real wages. However, their model is not able to produce a drop in investment of similar magnitude and persistence as observed in the Finnish data. In this paper, we show that our model captures the effects and magnitude of the collapse of Soviet trade more accurately by treating it as a capital-obsolescence shock and combining this shock with balance sheet constrained firms.

Furthermore, Gorodnichenko et al (2009) are silent about the collapse of the exchange rate regime in August 1992. In this paper, we study the effects of the collapse of the fixed exchange rate regime and illustrate the role of firm indebtedness in the severity of the crises and the slow recovery. A similar analysis is carried out by Gertler, Gilchrist and Natalucci (2003), who study the collapse of the fixed exchange rate regime in Korea in an open economy DSGE framework similar to the one in this paper. Gertler et al (2003) focus on the role of the exchange rate regime in a model with the BGG financial accelerator and illustrate the response of the economy to a collapse of the fixed exchange rate regime with firm debt totally in either domestic or foreign currency. In this paper, we show that even if just a relatively small fraction of firm debt is denominated in foreign currency, this has a quantitatively significant negative effect on the economy that offsets part of the positive net trade effect from real exchange rate depreciation.

Another view of the Finnish depression is offered by Conesa et al (2007), who attribute the depression to a sharp fall in total factor productivity in 1989–1992 and argue that adverse labour-tax shocks

played also an important role. However, financial factors do not play a role in their approach.

Our key contribution is that, in contrast to the previous studies on the Finnish crises, our DSGE model allows us to examine both the boom and the bust in the same model framework. For example, Gorodnichenko et al (2009) ignore the boom that preceded the crisis. Honkapohja and Koskela (1999), on the other hand, offer an explanation for both the boom and the bust, which emphasizes the role of financial factors in the boom-bust cycle. Our paper complements their analysis by providing a DSGE model framework for studying qualitatively and quantitatively the boom-bust cycle and the role of financial factors. Our conclusions are, however, not similar. Honkapohja and Koskela (1999) treat the collapse of Soviet-Finnish trade as a trade shock and argue that it accounts for only a fraction of the decline in output. Instead, they emphasize the negative effect of defending the fixed exchange rate regime with high interest rates and the exchange rate shock following the collapse of the fixed exchange rate regime. In our model simulation, we take into account that Soviet-Finnish trade collapsed during the fixed exghange rate regime, so that the nominal interest rate and nominal exchange rate were not able to respond to the adverse shock from the collapse of Soviet-Finnish trade.

The paper proceeds as follows: In Section 2, we present the model framework. Section 3 describes the parameter calibration. Section 4 presents the results of our three boom-bust experiments: financial market deregulation, the collapse of Soviet-Finnish trade and the collapse of the fixed exchange rate regime. The model responses are then compared with the actual data. Section 4 concludes.

2 The model

In this section, we describe our small open economy DSGE model that builds on Gertler, Gilchrist and Natalucci (2003) and Freystätter (2010). The model incorporates a version of financial frictions proposed by Bernanke, Gertler and Gilchrist (1999), BGG from now on. The BGG financial accelerator mechanism introduces a balance sheet constraint on entrepreneurs' ability to obtain finance: entrepreneurs pay an external finance premium that depends inversely on their net worth. In our model, entrepreneurs are allowed

to borrow in both domestic and foreign currency to finance the capital used in the production process. In addition to the financial frictions, the model incorporates nominal and real rigidities, such as habit formation, flow investment adjustment costs, variable capital utilization rate, export inertia, and Calvo-style nominal price rigidities in the retail sector.

In addition to the commonly used supply and demand shocks, the model economy is subject to financial market shocks stemming from domestic and foreign financial markets. Furthermore, a key addition to the model is a disturbance to the quality of capital, following Gertler and Karadi (2009). In our model, the capital-obsolescence shock affects the balance sheets of non-financial firms, as opposed to the financial intermediary sector balance sheet in Gertler and Karadi (2009). We argue that these 'unconventional' shocks in conjunction with the financial accelerator give us a model environment suitable for analyzing the boom-bust episode in Finland.

The economy consists of households, a production sector, a central bank and a foreign sector. As in BGG, the production sector consists of entrepreneurs, capital producers and monopolistically competitive retailers. Foreign behaviour is modelled as exogenous.

2.1 Households

2.1.1 Preferences

Households work, save and consume domestic and foreign tradable goods. The representative household's expected life-time utility is given by

$$U_0 = E_0 \sum_{t=0}^{\infty} \beta^t U \left(e_t \log \left[c_t^i - b c_{t-1} \right] + \eta \log(1 - h_t) \right) \tag{2.1}$$

where c_t denotes consumption, $(1 - h_t)$ is leisure and $\beta \in (0, 1)$ is the discount factor. Parameter b measures the degree of external habit formation in consumption. Thus, the utility of household i depends positively on the difference between the current level of individual consumption c_t^i and the lagged economy-wide consumption level c_{t-1}

and negatively on the number of hours worked, h_t. η is the weight of leisure in the utility function and e_t is a preference shock. The preference shock follows a first-order autoregressive process written in log-linearized form as

$$\log e_t = \rho_e \log(e_{t-1}) + \epsilon_{et} \tag{2.2}$$

where ϵ_{et} is an uncorrelated and normally distributed innovation with zero mean and standard deviation σ_e, and ρ_e is an autoregressive coefficient.

In the open economy model, the consumption good c_t is a composite of tradable goods. Each household consumes domestically produced goods as well as imported goods, supplied respectively by domestic firms and importing firms. The following CES index defines household preferences over home goods c_t^H and foreign goods c_t^F:

$$c_t = \left[(\omega)^{\frac{1}{\rho}}(c_t^H)^{\frac{\rho-1}{\rho}} + (1-\omega)^{\frac{1}{\rho}}(c_t^F)^{\frac{\rho-1}{\rho}}\right]^{\frac{\rho}{\rho-1}} \tag{2.3}$$

where the c_t^H are produced by domestic monopolistically competitive retailers and c_t^F are imported foreign goods sold by retailers of foreign goods. ω is the share of domestic goods in the consumption composite. The intratemporal elasticity of substitution between domestic and foreign goods ρ captures the sensitivity of consumption allocation between home and foreign goods with respect to the relative price of home and foreign goods.

The corresponding consumer price index P_t is given by

$$P_t = \left[(\omega)(p_t^H)^{1-\rho} + (1-\omega)(p_t^F)^{\frac{1}{\rho}}\right]^{\frac{1}{1-\rho}} \tag{2.4}$$

2.1.2 Budget constraint

The budget constraint of the representative household is

$$c_t = \frac{W_t}{P_t}h_t + \frac{\Omega_t}{P_t} - \frac{B_{t+1} - R_{t-1}B_t}{P_t} - \frac{s_t B_{t+1}^* - s_t \Gamma_t R_{t-1}^* B_t^*}{P_t} \tag{2.5}$$

where c_t is real consumption, W_t/P_t is real wage, h_t is labour hours, and Ω_t represents the dividend payments from retailers.

Households can save in domestic bonds B_t and foreign bonds B_t^*. The foreign and the domestic gross nominal interest rates are respectively denoted R_t and R_t^*.The effective gross interest rate at which the agent can borrow or lend on the international asset market is given by $\Gamma_t R_t^*$, and it depends on the foreign interest rate R_t^* and a country-specific borrowing premium Γ_t. Following Schmitt-Grohe and Uribe (2003), we assume a premium on foreign bond holdings to ensure a well-defined steady state in the model. The country borrowing premium depends on the real aggregate net foreign asset position of domestic households and a country borrowing premium shock:

$$\Gamma_t = \exp(-\kappa(a_t - \bar{a}) + \epsilon_{\Gamma t}) \tag{2.6}$$

where $a_t \equiv s_t B_t^*/P_t$ is real net foreign indebtedness in home currency (s_t is the nominal exchange rate), $\bar{a}$ is the steady state level of real foreign indebtedness and κ is the elasticity of the borrowing premium with respect to net foreign indebtedness. κ is set close to zero, to make the real net foreign assets a_t revert to steady state following a shock, but it does not have a marked impact on the short run dynamics of the model. The country borrowing premium also depends on an exogenous shock $\epsilon_{\Gamma t}$, assumed to follow an AR(1) process written in log-linearized form as

$$\epsilon_{\Gamma t} = \rho_\Gamma \epsilon_{\Gamma t-1} + \epsilon_{\Gamma\Gamma t} \tag{2.7}$$

where ρ_Γ is an autoregressive coefficient and $\epsilon_{\Gamma\Gamma t}$ is an uncorrelated and normally distributed innovation with zero mean and standard deviation σ_Γ. The country borrowing premium shock is introduced to model sudden capital outflows, as in Gertler, Gilchrist and Natalucci (2003).

2.1.3 First-order conditions

The equations below present the optimality conditions for the household's optimization problem:

$$\frac{e_t}{c_t - bc_{t-1}} = \lambda_t \tag{2.8}$$

where λ_t is the Lagrangian multiplier associated with the budget constraint.

The labour supply is given by

$$\frac{\eta}{1-h_t} = \lambda_t w_t \tag{2.9}$$

which equates the marginal cost of supplying labour to the marginal utility of consumption generated by the corresponding increase in labour income.

The intertemporal decision for optimal holdings of bonds is given by

$$\frac{\lambda_t}{R_t} = \beta E_t \left(\frac{\lambda_{t+1}}{\pi_{t+1}} \right) \tag{2.10}$$

where $\pi_{t+1} = P_{t+1}/P_t$.

The optimal allocation of consumption between home and foreign goods is given by

$$\frac{c_t^H}{c_t^F} = \frac{\omega}{1-\omega} \left(\frac{p_t^H}{p_t^F} \right)^{-\rho} \tag{2.11}$$

The optimality condition governing the choice of foreign bonds combined with (2.10) yields the uncovered interest rate parity (UIP) condition

$$E_t \{ \frac{\lambda_{t+1}}{\pi_{t+1}} \left[R_t - \frac{s_{t+1}}{s_t} \Gamma_t R_t^* \right] \} = 0 \tag{2.12}$$

In a small open economy model with flexible exchange rate, the uncovered interest rate parity condition is an arbitrage condition pinning down expected exchange rate changes. In a fixed exchange rate regime, the domestic nominal interest rate R_t is determined by the exogenous foreign interest rate R_t^* and the endogenous country borrowing premium Γ_t. The exogenous foreign variables are discussed in Section 2.3.

2.2 Production sector

The production sector consists of entrepreneurs, capital producers and retailers. In this section, we first focus on the competitive entrepreneurs who produce a wholesale good. The wholesale good is sold to domestic retailers who repackage it and sell it to domestic

and foreign consumers and to capital producers. Capital producers carry out the production of capital goods.

The entrepreneurs borrow to finance the acquisition of capital needed in the production of the wholesale good. We allow for foreign currency denominated debt. Furthermore, we introduce a stochastic factor, a capital obsolescence shock, that affects the gross return on capital and capital accumulation. In Gertler and Karadi (2009), this shock captures a feature of the recent financial crises where financial instruments turned out to be worse than presumed, which impacted intermediaries' balance sheets. Here, the shock affects non-financial entrepreneurs' balance sheets.

2.2.1 Entrepreneurs

The entrepreneurs produce a wholesale product with the production technology

$$Y_t = (U_t K_t)^{\alpha} (A_t h_t)^{(1-\alpha)} \tag{2.13}$$

where capital services $U_t K_t$ are the product of the capital stock K_t and the utilization rate of capital U_t. h_t denotes hours of work, and α denotes the share of capital in the production function. A_t is a neutral technology shock, assumed to follow a stationary first-order autoregressive process:

$$\log A_t = (1 - \rho_A) \log(A) + \rho_A \log(A_{t-1}) + \epsilon_{At} \tag{2.14}$$

where ρ_A is an autoregressive coefficient and $A > 0$ is a constant. The error term ϵ_{At} is normally distributed with zero mean and standard deviation σ_A.

The entrepreneur's decision problem is as follows: The firm chooses the capital stock K_{t+1}, labour demand h_{t+1} and capacity utilization rate U_{t+1} to produce output Y_{t+1}.The firm's earnings in $t + 1$ consist of the value of output and the value of its remaining capital stock after deducting financing and labour costs.

$$\max E_t \beta \Lambda_{t,t+1}[P^h_{t+1} Y_{t+1} + (q_{t+1} - \delta(U_{t+1}))x_{t+1} K_{t+1} \quad (2.15)$$

$$- f_{t+1} q_t K_{t+1} - \frac{W_{t+1}}{P_{t+1}} h_{t+1}] \quad (2.16)$$

$$+ \xi_{t+1}[(U_{t+1} K_{t+1})^{\alpha} (A_{t+1} h_{t+1})^{(1-\alpha)} - Y_{t+1}] \quad (2.17)$$

$\beta \Lambda_{t,t+1}$ is the firm's stochastic discount factor where $\Lambda_{t,t+1} \equiv \lambda_{t+1}/\lambda_t$.The wholesale product Y_{t+1} is sold to domestic good retailers in competetive markets for the price $P^h_{t+1} = \xi_{t+1}$, where $\xi_{t+1} > 0$ is the Lagrangian multiplier associated with production function (2.13) and denotes the real marginal cost.

After production in period $t+1$ the firm can either sell its capital stock at the real market price of capital q_{t+1} or keep it for use in production in the next period.We assume that the replacement cost of capital is unity, so that the value of units of capital left over is given by $(q_{t+1} - \delta(U_{t+1}))x_{t+1} K_{t+1}$. Following Gertler and Karadi (2009) we assume that the quality of capital is affected by an exogeous factor x_{t+1}, a capital-obsolescence shock. This is an aggregate shock that affects the gross return on capital and the accumulation of aggregate capital stock in the economy.

Financing costs $f_{t+1} q_t K_{t+1}$ consist of the overall cost of external finance f_{t+1} (in optimum, equal to the return on capital) and the value of acquired capital $q_t K_{t+1}$ needed to produce the wholesale good. Labour costs consist of the real wage W_{t+1}/P_{t+1} and hours worked h_{t+1}.

Entrepreneurs choose an optimal level of capital utilization as well as capital and labour inputs. The optimality condition for the capital stock K_{t+1} is

$$E_t \beta \Lambda_{t,t+1} f_{t+1} = E_t[\beta \Lambda_{t,t+1} \frac{\xi_{t+1} \alpha (Y_{t+1}/K_{t+1}) + (q_{t+1} - \delta(U_{t+1}))x_{t+1}}{q_t}] \quad (2.18)$$

In optimum, the discounted overall cost of capital must equal the discounted return, given by the right hand side of the equation.The expected marginal return on capital consists of the real marginal product of capital (the first term) and a capital gain due to fluctuations in asset prices q_t. Moreover, the capital gain is affected by endogenous depreciation and the exogenous disturbance to the quality

of capital. The capital obsolescence shock is an aggregate shock to the gross return on capital.

The entrepreneur chooses its labour demand:

$$\frac{W_{t+1}}{P_{t+1}} = \xi_{t+1}(1-\alpha)\frac{Y_{t+1}}{h_{t+1}} \tag{2.19}$$

The optimality condition for capital utilization $U_{t+1}$is

$$\delta'(U_{t+1})x_{t+1}K_{t+1} = \frac{\xi_{t+1}\alpha Y_{t+1}}{U_{t+1}} \tag{2.20}$$

We assume that increases in the utilization rate of capital are costly because higher utilization rates imply faster depreciation. When selecting an optimal rate of utilization, firms must weigh the benefits of greater output against the costs of greater depreciation. In optimum, the marginal cost of a higher rate of utilization is equated to the marginal gain from higher utilization.

We follow Baxter and Farr (2001) and assume that the depreciation function is the following convex function of the utilization rate.

$$\delta(U_t) = \delta + \frac{m}{1+\xi^u}(U_t)^{1+}\xi^u \tag{2.21}$$

$$with\ \delta, m, \xi^u > 0 \tag{2.22}$$

The finance of capital is divided between net worth and debt, as shown in the accounting identity below. The purchase of capital $q_t K_{t+1}$, where q_t is the real price of the capital, is financed partly by net worth n_{t+1} and partly by borrowing B^f_{t+1}

$$q_t K_{t+1} = \frac{B^f_{t+1}}{P_t} + n_{t+1} \tag{2.23}$$

In this paper, we assume that borrowing occurs in either domestic or foreign currency. B^f_{t+1} denotes the amount borrowed in domestic currency. Foreign debt in domestic currency is given by $\frac{s_{t+1}B^{f*}_{t+1}}{P_t}$ where s_{t+1} is the nominal exchange rate. In both cases the amount borrowed (whether in domestic or foreign currency) is determined by $q_t K_{t+1} - n_{t+1}$.

At the end of period t entrepreneurs sell old capital to capital producers and pay off debt (loan contracts are for one period). After that we see the entrepreneur's net worth for period $t+1$. Net worth n_{t+1} is the equity of the firm, ie the gross value of capital net of debt.

The entrepreneur's demand for capital depends on the expected marginal return and expected marginal financing cost $E_t f_{t+1}$. The expected rate of return on capital is given by equation (2.18). The demand for capital should satisfy the optimality condition that the real return on capital is equal to the real cost on external funds. For an entrepreneur who is not fully self-financed, the expected return to capital in equilibrium will be equated to the marginal cost of external finance.

The entrepreneur's overall cost of external finance depends on the gross external finance premium $G(\cdot)$ and gross real opportunity cost of funds. The gross opportunity cost of funds is (for domestic debt) the domestic real interest rate or (for foreign debt) the real effective foreign interest rate, multiplied by the expected change in the nominal exchange rate. Γ_t is the country borrowing premium.

If the debt is in domestic currency, the cost of external finance is given by

$$E_t f^d_{t+1} = E_t[G(\cdot)\frac{R_t}{\pi_{t+1}}] \tag{2.24}$$

In case of foreign currency denominated debt, the overall cost of external finance is given by

$$E_t f^f_{t+1} = E_t[G(\cdot)\frac{\Gamma_t R^*_t}{\pi_{t+1}}\frac{s_{t+1}}{s_t}] \tag{2.25}$$

In equilibrium, the uncovered interest rate parity condition (see equation 2.12) equalizes these costs. However, the response of external finance costs to a shock depends on whether the debt is in domestic or foreign currency.

The external finance premium $G(\cdot)$ is the difference between the cost of external funds and the opportunity cost of internal funds (risk-free real interest rate). The presence of BGG financial frictions implies that the external finance premium varies inversely with the the aggregate financial condition of entrepreneurs, as measured by the ratio of net worth to gross value of capital $\frac{n_{t+1}}{q_t K_{t+1}}$. Furthermore, we assume that the external finance premium also depends on an exogenous financial disturbance ϵ_{ft}.

$$G_t(\cdot) = G(\frac{n_{t+1}}{q_t K_{t+1}}; \epsilon_{ft}), \quad G\prime(\cdot) < 0, G(1) = 1 \tag{2.26}$$

The financial accelerator mechanism thus relates the external finance premium negatively to the strength of entrepreneurs' balance sheets.[2] The size of the external finance premium varies endogenously vis-a-vis changes in the entrepreneurial sector leverage ratio and exogenously vis-a-vis the shock process ϵ_{ft}. We refer to such shocks as credit supply shocks, as in Gilchrist et al (2009). They are financial disturbances that capture exogenous disturbances in domestic financial intermediation and that raise or lower the external finance premium from that warranted by current economic conditions. The credit supply shock is assumed to follow an AR(1) process, log-linearized as

$$\epsilon_{ft} = \rho_f \epsilon_{ft-1} + \epsilon_{fft} \tag{2.27}$$

where ρ_f is an autoregressive coefficient vector and ϵ_{fft} an uncorrelated and normally distributed innovation with zero mean and standard deviation σ_f.

The log-linearized external finance premium is given by

$$\hat{G}_t = \psi(\hat{q}_t + \hat{K}_{t+1} - \hat{n}_{t+1}) + \hat{\epsilon}_{ft} \tag{2.28}$$

where variables with hats are in log-deviations from steady state, $\hat{x}_t = \log x_t - \log \bar{x}$.

We denote as ψ the elasticity of the risk premium with respect to changes in the net worth-to-capital ratio (a measure of entrepreneurial financial health). This parameter could be interpreted as a summary statistic of how vulnerable the economy is to shocks affecting aggregate balance sheets.When the elasticity of external finance premium ψ is exactly equal to zero, the financial accelerator mechanism ceases to exist and there is no premium on firms' external finance.

We allow for both domestic and foreign-currency denominated debt, by assuming a fixed share $(1- \omega^d)$ of debt denominated in foreign currency. With both domestic and foreign debt, the overall entrepreneurial sector cost of external finance $\hat{f}_{t+1}$evolves according to

[2]Due to asymmetric information between borrower and lender, the lender charges the borrower a premium to cover the expected bankcruptcy cost. The specific form of $G_t(\cdot)$ depends on the primitive parameters of the costly state verification problem (see Bernanke et al, 1999, and Gertler, Gilchrist and Natalucci, 2003). The financial contract implies an external finance premium $G_t(\cdot)$ that depends on the entrepreneur's leverage ratio. The underlying parameter values determine the elasticity of the external finance premium with respect to firm leverage.

$$\hat{f}_{t+1} = \omega^d[\hat{R}_t - \hat{\pi}_{t+1} + \hat{G}_t] + (1-\omega^d)[\Gamma_t + R_t^* - \hat{\pi}_{t+1} + \hat{s}_{t+1} - \hat{s}_t + \hat{G}_t] \quad (2.29)$$

Movements in net worth affect the cost of capital via the external finance premium $\hat{G}_t$. Furthermore, in case of foreign currency denominated debt, movements in the nominal exchange rate have a direct impact on the cost of external finance.

The aggregate entrepreneurial net worth n_{t+1} evolves according to

$$E_t n_{t+1} = \nu_t V_t + (1 - \nu_t) g_t \quad (2.30)$$

where V_t is the net worth of surviving entrepreneurs. Entrepreneurs are risk neutral and they have a finite planning horizon. The expected survival rate of entrepreneurs is ν_t, which gives them an expected lifetime of $1/(1 - \nu_t)$. A fraction $(1- \nu_t)$ of entrepreneurial financial wealth is destroyed exogenously each period. This ensures that entrepreneurs do not grow out of the financial constraint by accumulating enough wealth. The new entrepreneurs receive only a small transfer g_t from exiting entrepreneurs. As the number of entrepreneurs who exit is always balanced by the number that enter (having less net worth than those who exit), the greater the share of exiting entrepreneurs, the smaller the aggregate net worth of entrepreneurs.

We introduce a shock to the survival probability of entrepreneurs, a financial wealth shock, along the lines of Christiano et al (2007). In the log-linearized version of the model, the parameter governing the survival probability of entrepreneurs takes the form

$$\nu_t = \nu + \epsilon_{\nu t} \quad (2.31)$$

where $\epsilon_{\nu t}$ may be interpreted as a shock to the discount rate for entrepreneurs. It is an exogenous disturbance affecting the financial wealth in the hands of entrepreneurs. Thus, the fraction of surviving entrepreneurs is itself subject to stochastic fluctuations $\epsilon_{\nu t}$, assumed to follow an AR(1) process, given in log-linearized form as

$$\epsilon_{\nu t} = \rho_\nu \epsilon_{\nu t-1} + \epsilon_{\nu\nu t} \quad (2.32)$$

where $\rho_{\nu t}$ is an autoregressive coefficient vector and $\epsilon_{\nu\nu t}$ an uncorrelated and normally distributed innovation with zero mean and standard deviation σ_ν.

Like Christiano et al (2007), we interpret the financial wealth shock as a way of describing exogenous movements in asset values. The financial wealth shock affects investment through the balance sheet by exogenously creating or destroying entrepreneurs' aggregate net worth. When a shock raises the survival probability, the rate of destruction of entrepreneurial wealth decreases, resembling build-up of a stock market bubble. Entrepreneurs as a group now have more wealth under their control. Having more net worth reduces the need for external financing and increases the demand for capital. Entrepreneurs purchase more capital, which drives up its price and leads to a further increase in entrepreneurial net worth.

The net worth of surviving entrepreneurs evolves as

$$V_t = f_t q_{t-1} K_t - E_{t-1} f_t (q_{t-1} K_t - n_t) \tag{2.33}$$

Let V_t denote the value of entrepreneurial capital net of borrowing costs carried over from the previous period. f_t gives the real return on capital held in t. $E_{t-1} f_t$ is the cost of borrowing implied by the loan contract signed in time $t-1$. As in Christiano et al (2007) we assume that the debt contracts are in nominal terms (in BGG, 1999, the contract is specified in terms of the real interest rate). This assumption implies that an unanticipated increase in inflation decreases the real debt burden and thus increases net worth. This is the so-called Fisher effect. Furthermore, movements in borrowing costs depend on the fraction of debt denominated in foreign currency. Thus, in our model, unanticipated changes in the nominal exchange rate affect net worth. An unexpected depreciation of the nominal exchange rate reduces net worth by raising borrowing costs.

The evolution of net worth and the link from net worth to the real economy provides an endogenous propagation mechanism that amplifies the response of the economy to shocks. A shock that affects net worth negatively (positively) is able to initiate a bust (boom). A shock that reduces the value of entrepreneur's value of capital net of borrowing costs reduces their ability to borrow by increasing the external finance premium. The increase in external finance premium amplifies the effect via an accelerator effect on investment and production. A shock that reduces net worth, produces a fall in investment.

It is noteworthy that endogenous movements in asset prices impact the real economy. In this model, firms' balance sheets link the development of asset prices to the real economy. A shock that reduces

the market value of capital q_t (ie, asset prices) reduces entrepreneurial net worth and induces a fall in investment. Hence fluctuations in the price of capital q_t may have significant effects on the leverage ratio and thus on the cost of funds.[3]

2.2.2 Capital producers

The actual production of physical capital is carried out by capital-producing firms. Capital producers purchase final goods from domestic good retailers and use them as material inputs to produce investment goods i_t. They combine investment goods with the existing capital stock to produce new capital and sell capital to firms at the price q_t. We assume that the production of new capital involves flow investment adjustment costs.The objective of a capital producer is thus to choose the quantity of investment i_t to maximizeprofits:

$$\max_i E_t \Sigma_{\tau=1}^{\infty} \Lambda_{t,\tau} \left[q_\tau i_\tau - (1 + f(\frac{i_\tau}{i_{\tau-1}}))i_\tau \right] \tag{2.34}$$

where $f(\frac{i_t}{i_{t-1}})i_t$ reflects physical adjustment costs, with $f(1) = f^{'}(1) = 0$ and $f^{''}(1) > 0$. Thus, the optimal condition is

$$q_t = 1 + f(\frac{i_t}{i_{t-1}}) + f'(\frac{i_t}{i_{t-1}})(\frac{i_t}{i_{t-1}}) - E_t \Lambda_{t,t+1} f'(\frac{i_{t+1}}{i_t})(\frac{i_{t+1}}{i_t})^2 \tag{2.35}$$

which is the standard Tobin's Q equation relating the price of capital to marginal adjustment costs. In optimum, the price of capital goods is equal to the marginal cost of investment goods production. In the absence of capital adjustment costs, the price of capital is constant and equal to one. Capital adjustment costs have a slowing effect on the response of investment to various shocks, which directly affects the price of capital. Therefore, capital adjustment costs allow the price of capital to vary, which contributes to the volatility of entrepreneurial net worth. We specify the investment adjustment costs as $\frac{\chi}{2}(\frac{i_t}{i_{t-1}} - 1)^2 i_t$.

The aggregate capital stock evolves according to

$$K_{t+1} = x_t[i_t + (1 - \delta(U_t))K_t] \tag{2.36}$$

[3]The effect of asset price q_t on net worth is greater than its effect on total assets. This implies that the leverage ratio moves countercyclically.

As usual, the investment goods i_t are combined with the existing capital goods, $(1-\delta(U_t))K_t$ to produce new capital goods, K_{t+1}. In addition, the effective quantity of capital in the economy also depends on the capital obsolescence shock which captures the stochastic depreciation of capital, as in Gertler and Kiyotaki (2009). The capital obsolescence shock is a disturbance that renders worthless a part of the capital stock (ie that used to produce goods that turn out to be obsolete).[4]

2.2.3 Retailers

The retail sector introduces nominal price rigidities into the model. There are two types of retailers in our open economy model: Domestic good retailers buy wholesale goods from domestic producers and foreign good retailers buy wholesale goods from abroad. Both domestic and foreign good retailers differentiate the wholesale goods slightly and engage in Calvo-style price-setting. The domestic final goods are sold to domestic and foreign consumers and to domestic capital producers in a monopolistically competitive market. The imported foreign goods are sold only to domestic consumers.

The probability of not being able to reoptimize the selling price is ϕ. Thus with probability ϕ the retailer must charge the price that was in effect in the preceeding period indexed by the steady state gross rate of inflation, π. With probability $(1-\phi)$ the retailer receives a signal to reoptimize and chooses price $p_t^H(j)$

The (aggregate) price of the domestic final good p_t^H is thus given by

$$p_t^H = [\phi(\pi p_{t-1}^H)^{1-\theta} + (1-\phi)(p_t^H(j))^{1-\theta}]^{\frac{1}{1-\theta}} \tag{2.37}$$

The solution of the domestic firms' price-setting problem results in a Phillips-curve type relatioship between domestic inflation and real marginal cost ξ_t:

$$\hat{\pi}_t^H = \beta E_t \hat{\pi}_{t+1}^H + \frac{(1-\beta\phi)(1-\phi)}{\phi}\hat{\xi}_t \tag{2.38}$$

[4] Gertler and Kiyotaki (2009) motivate this disturbance by an example that assumes good-specific capital. Each period a random fraction of goods become obsolete and are replaced by new goods. The capital used to produce obsolete goods is now worthless and the capital for the new goods is not fully on line.

where variables with hats are in log-deviations from steady state, $\hat{x}_t = \log x_t - \log \bar{x}$.

The price-setting problem of the foreign-good retailers is analogous to that of the domestic-good retailers. The foreign-good retailers transform a homogeneous foreign good into a differentiated import good, which they sell to domestic households. Like domestic-good retailers, foreign good retailers operate under Calvo-style price setting. We assume that retailers of domestic and foreign goods face the same degree of price rigidity ϕ. Foreign good retailers purchase foreign goods at world-market prices P_t^*, which are set by their respective producers in their own currency. The law of one price holds at the wholesale level. By allowing for imperfect competition, we create a wedge between the wholesale and retail price of foreign goods and thus allow for incomplete exchange rate pass-through in the import sector. The real marginal cost of acquiring foreign goods is $\xi_t^F = \frac{P_t^*}{P_t^F}$.

The price-setting problem of foreign good retailers results in a Phillips-curve relationship between import-price inflation and the corresponding real marginal cost:

$$\hat{\pi}_t^F = \beta E_t \hat{\pi}_{t+1}^F + \frac{(1-\beta\phi)(1-\phi)}{\phi} \hat{\xi}_t^F \tag{2.39}$$

In an open economy, CPI inflation is a composite of domestic- and the foreign-good inflation

$$\pi_t = (\pi_t^H)^{\omega} (\pi_t^F)^{(1-\omega)} \tag{2.40}$$

CPI inflation dynamics therefore depend on domestic driving forces as well as foreign factors.

2.3 Foreign behaviour

We assume that the foreign demand for home tradable goods,

$$c_t^{H*} = [\left(\frac{p_t^H}{s_t P_t^*}\right)^{-\zeta} Y_t^*]^{\tau} (c_{t-1}^{H*})^{1-\tau} \tag{2.41}$$

is a decreasing function of the relative price and an increasing function of foreign ouput. We assume that the export sector is prices in the

producer's currency. The term $(c_{t-1}^{H*})^{1-\tau}$ represents inertia in foreign demand for domestic goods.

We assume that the foreign price level P_t^*, the foreign output Y_t^* and the foreign interest rate R_t^* are exogenous and each follow an AR(1) process given in log-linearized form as

$$x_t^* = \rho_{x^*} x_{t-1}^* + \epsilon_{x^*t} \tag{2.42}$$

where $x_t^* = \{P_t^*, Y_t^*, R_t^*\}$, ρ_{x^*} is an autoregressive coefficient vector and ϵ_{x^*t} is a vector of uncorrelated and normally distributed innovations each with zero mean and standard deviation σ_{x^*}.

2.4 Resource constraints

Production of the intermediate good firm is divided between consumption of domestic and foreign households and investment expeditures

$$Y_t = c_t^H + c_t^{H*} + i_t + f(\frac{i_t}{i_{t-1}})i_t \tag{2.43}$$

where $f(\frac{i_t}{i_{t-1}})i_t$ reflects physical adjustment costs.

2.5 Current account

Net foreign assets at the aggregate level evolve as

$$s_t B_{t+1}^* = p_t^H c_t^{H*} - s_t P_t^* c_t^F + s_t \Gamma_t R_{t-1}^* B_t^* \tag{2.44}$$

where B_{t+1}^* is the foreign net bond position, $p_t^H c_t^{H*}$ is total receipts from exports and $P_t^* c_t^F$ is total expense on imports (the retailer only pays the marginal cost for imported wholesale goods and keeps the profit) and $\Gamma_t R_t^*$ is the country premium-adjusted gross nominal interest rate. We assume balanced trade in the steady state and normalize the steady state real exchange rate to unity. Note that the net foreign asset position affects the endogenous country premium (see equation (2.6)).

2.6 Monetary policy

Monetary policy is conducted according to a Taylor-type rule with interest rate smoothing (expressed in log-linearized form)

$$\hat{R}_t = \rho^R \hat{R}_{t-1} + (1-\rho^R)(\varrho_\pi \hat{\pi}_t + \varrho_y \hat{y}_t + \varrho_s \hat{s}_t) + \hat{\epsilon}_{Rt} \tag{2.45}$$

The policy maker is assumed to adjust the nominal interest rate $\hat{R}_t$ in response to deviations from steady state of lagged interest rates $\hat{R}_{t-1}$, CPI inflation $\hat{\pi}_t$, output $\hat{y}_t$ and nominal exchange rate $\hat{s}_t$. $\hat{\epsilon}_{Rt}$ is an exogenous shock to monetary policy, normally distributed with zero mean and standard deviation σ_R. The smoothing parameter ρ^Rmeasures the rate of interest rate inertia and lies between zero and one. ϱ_π, ϱ_y, and ϱ_s are coefficients that measure the responses of monetary policy to deviations in inflation, output and nominal exchange rate.[5]

3 Calibration

Tables 1 and 2 in the Appendix report the calibrated parameters along with the implied steady state values of some key variables. The choice of parameter values reflects our aim to capture the key features of the Finnish economy during 1980–1998.

The discount factor is set at 0.99, which corresponds to an annual real rate in steady state of 4 per cent. The steady-state quarterly gross inflation rate is equal to 1.01, which matches the historical average over the period. We set at 1.5 the intratemporal elasticity of substitution for the consumption composite, ρ. The share of domestic goods in the consumption composite ω is 0.45. The share of home-produced consumption is fairly low, to capture the high import-output and export-output ratios. We choose the relative utility weight of labour η to fix the hours worked at one-third of the available time. The habit parameter b is set at 0.7.

The share of capital in the production function α is fixed at 0.45. We normalize the steady state utilization at unity, and the steady

[5]For the fixed exchange rate regime experiments in section 4, we assume a pure fixed exchange rate regime under which the central bank keeps the nominal exchange rate pegged at a predetermined level, ie $s_t = s$ for all t.

state quarterly depreciation $\delta(U_{ss})$ is set at 0.05. This relatively high rate of steady state depreciation is needed to capture the high investment-output ratio in the economy at the time. This is important, as the study focuses on explaining investment fluctuations. For the same reason, the share of capital in the production function is calibrated at a high level. The parameter ξ^u, which represents the elasticity of marginal depreciation with respect to the utilization rate, is set equal to 1, following Baxter and Farr (2001).

We set the price rigidity parameter (Calvo probability of not resetting optimally prices) ϕ so that prices are fixed on average for a year. The parameter θ, measuring the degree of monopoly power in the (domestic and import) retail sector, is set at 6, which implies a 20 per cent markup in the steady state.

The investment adjustment cost parameter χ is fixed at 4. The more costly it is to adjust investments, the more volatile the price of capital and therefore the more volatile the external finance premium, as the price of capital has a direct effect on firms' net worth.

With regard to the parameters of export demand, we set the price elasticity ζ to 1 and the share parameter τ at 0.25. This implies a relatively high degree of inertia in export demand. We fix the elasticity of the country borrowing premium with respect to net foreign indebtedness κ at 0.001, so that the evolution of net foreign assets does not affect the dynamics but does guarantee that the net foreign asset position is stabilized at zero in the long run.

The feedback coefficients in the monetary policy rule are calibrated as follows: the smoothing parameter ρ^R is given a value of 0.8, the coefficient on inflation ϱ_π 1.5, the coefficient on output gap ϱ_y 0.1 and the coefficient on nominal exchange rate ϱ_s is calibrated at 0.5.

The choice of financial sector parameters is only meant to be suggestive. We calibrate at 0.05 the elasticity of the external finance premium to changes in net worth ψ, which is the key parameter governing the strength of the financial accelerator. This is a value often used for this parameter (eg BGG 1999) and is in line with some empirical work estimating the strength of the financial accelerator mechanism (eg Christensen and Dib, 2008, Freystätter, 2010). The steady state external finance premium G is set at 1.0075, corresponding to an annual risk spread of three hundred basis points. We fix the steady state spread to reflect the average spread between banks' lending rate and the base rate representing the riskless interest rate in the economy at the time. We employ a shorter sample to calculate the average, 1986–1995, as the spread seems to have

fluctuated and our aim is to capture the behaviour of the economy particularly at the time of the boom and bust. The ratio of capital to net worth is calibrated to 2.1, implying a firm leverage ratio (debt to asset) of 0.52.The choice of leverage ratio is a rough guess, as obtaining accurate data is very challenging. However, it is well known that Finnish firms were highly leveraged at the time. Therefore, our steady state leverage ratio may underestimate the actual leverage ratio at the time. The share of firm debt in foreign currency $(1-\omega^d)$ is set at 27%, the level to which the share of foreign currency loans in total lending had risen by 1991 (Honkapohja and Koskela, 1999). The steady state quarterly survival probability ν is set at 0.9728.

4 Boom and bust experiments

In this section, we present some quantitative experiments designed to illustrate how and under what conditions the model is able to capture certain key features of the Finnish boom-bust episode. We focus on three events that are claimed to have played a key role in the Finnish boom-bust episode and compare the model outcomes with actual Finnish data. Firstly, we use our model to assess the role of financial market deregulation in the 1980s boom that preceded the crisis. Secondly, we evaluate the negative impact of the collapse of Soviet-Finnish trade in the beginning of 1991. Thirdly, we investigate the effect of the collapse of the fixed exchange rate regime in September 1992.

In our experiments, we consider four types of aggregate shock: 1) a credit supply shock, 2) a financial wealth shock 3) a capital obsolescence shock, and 4) a country borrowing premium shock. The first three shocks are 'unconventional' in the sense that they hit the net worth of the entrepreneurial sector or the cost of external finance directly. The fourth shock stems from international financial markets and, although slightly more conventional, is greatly amplified by the existence of the financial accelerator mechanism and the presence of foreign currency denominated debt.

The first two shocks from domestic financial markets (credit suppply and financial wealth shocks) are used to represent the deregulation process of the Finnish financial markets in the 1980s. The third shock, the capital obsolescence shock, captures the collapse of Soviet-Finnish trade in the beginning of 1991, which rendered

useless the Soviet-oriented export-sector capital. The fourth shock, a country borrowing premium shock, captures the outflow of foreign capital and depreciation of the nominal exchange rate at the time of the collapse of the fixed exchange rate regime in September 1992.

Figure 1 shows the real-side behaviour of the Finnish economy in the late 1980s and early 1990s that we try to match with our model. As we see, investment boomed from mid-1988 until the end of 1989. The increase in investment was 20 per cent in 6 quarters. At the same time, GDP increased by 5 per cent. It is commonly argued that the overheating of the economy was due to the deregulation of financial markets in the 1980s and rapid credit expansion. In the beginning of 1991, trade with the Soviet Union virtually came to a halt. Consequently, investment fell by 20 per cent and GDP by 6 per cent within 6 quarters from the end-1990 level. The collapse of the fixed exchange rate regime followed in September 1992. Within a year, investment had contracted by another 9 per cent and GDP by 1–2 per cent. Our experiments in this section are designed to match particularly the behaviour of investment and output. We keep the calibration unchanged throughout the experiments and show that our model framework can explain both the boom and the bust.

The exchange rate regime is clearly essential in assessing the response of an economy to a shock. In this study, the experiments are conducted taking the effective exchange rate regime at the time of the event as given. Thus the first two experiments, the financial market deregulation and collapse of Soviet trade, are studied under a fixed exch rate regime.[6] The third experiment analyzes the response of the economy immediately after the collapse of the fixed exchange rate regime, ie under a flexible exchange rate regime. One could argue that the effects of financial market deregulation and the collapse of Soviet-Finnish trade would indeed have been different under a flexible exchange rate regime. For example, according to Gerltler, Gilchrist and Natalucci (2003), a crises will usually be worse if the nominal interest rate (and the nominal exchange rate) is not free to respond.

[6]For the fixed exchange rate regime we follow Gertler, Gilchrist and Natalucci (2003) and assume a pure fixed exchange rate regime under which the central bank keeps the nominal exchange rate pegged at a predetermined level, ie $s_t = s$ for all t. Here, the central bank sets the nominal interest rate to satisfy the uncovered interest parity condition given in equation 2.12.

4.1 Experiment 1: Financial market deregulation

In order to study financial market deregulation, we consider two financial market shocks: a credit supply shock that decreases the risk premium directly and a financial wealth shock that increases net wealth in the hands of entrepreneurs and leads to a decline in the external finance premium. These are both shocks to the demand for capital. Figure 2 plots the response of the economy to both shocks under a pure fixed exchange rate regime.

The credit supply shock is a shock to the external finance premium paid by firms to obtain finance. This shock captures the huge expansion of bank lending following financial market deregulation and the decrease in firms' borrowing costs. The second shock, a financial wealth shock, impacts the net worth of entrepreneurs. The financial wealth shock, on the other hand, captures the rapid appreciation of asset prices that is exogenous to the model, an asset price bubble. It can be argued that in the late 1980s there were signs of overoptimistic expectations of a lasting boom and that this contributed to an unsustainable increase in asset prices. As a consequence of this shock, the aggregate purchasing power of entrepreneurs as a group increased, which sustained the demand for capital and raised ts price. It is possible that both the credit supply shock and the financial wealth shock played a role in the boom phase, in driving up investment. However, as we show in our experiment, even separately, both of these shocks are able to trigger an economic expansion similar to that observed in Finland from mid-1988 until the end of 1989.

We fix the sizes of the shocks so that the boom in investment is of a similar magnitude to the boom at the end of 1980s and set the autoregressive coefficient at 0.7 in both cases. In our experiment, both the credit supply shock and the financial wealth shock are able to produce an economic expansion similar to that observed in Finland. Both financial market shocks lower the external finance premium, which leads to a long-lasting increase in investment and output, and an appreciation of asset prices.The increase in asset prices raises net worth and thus further lowers the cost of creadit. Inflation picks up and, in our open economy model, the real exchange rate appreciates, resulting in a decline in net trade (dampening the increase in output). The model is thus able to mimic most of the basic features of the 1980s boom in Finland. The only exception is consumption, which

instead of increasing falls slightly initially. However, the initial fall in consumption is very modest and, after a delay, consumption also picks up. Due to the initial fall in consumption, the increase in output (ca 4–5 per cent) is slightly smaller than the observed 6 per cent increase. However, the timing of the boom is fairly accurately reproduced by the model, with investment and output peaking after 6 quarters (as in the data) and starting to decline afterwards.

The difference between the two financial market disturbances is that the boom is slighly more persistent in the case of a positive financial wealth shock. Net worth propagates the financial wealth shock longer and keeps the external finance premium below the steady state for a longer period. In the case of the credit supply shock, the initial fall in the external finance premium needed to produce the boom is clearly greater than in the case of the financial wealth shock, which hits the wealth of the entrepreneurial sector directly.

4.2 Experiment 2: The collapse of Soviet-Finnish trade

In this section, we illustrate the consequences of the collapse of Soviet-Finnish trade in the beginning of 1991. The initiating shock is a five per cent capital obsolescence shock. The shock follows an AR(1) process with persistence parameter 0.85. This shock captures the fact that part of the capital stock became useless as trade with the Soviet Union practically stopped in the beginning of 1991.We fix the size of the shock simply to mimic the roughly 20 per cent decline in investment observed between the beginning of 1991 and September 1992 (within 6 quarters). Figure 3 plots the responses of the model to this shock under a pure fixed exchange rate regime. We compare the results obtained with and without financial frictions.

In the model without financial frictions, the loss of capital produces only a modest downturn. This is due to a pick-up in investment after an initial drop. The decline in capital below its steady state induces an increase in investment due to high returns to capital. Without financial frictions, the cost of external finance does not increase as a result of the negative disturbance, which supports the economy in the case of a sudden loss of economically valuable capital.

With financial frictions, however, the sharp fall in entrepreneurs' net worth, due to the capital obsolescence shock destroying economically valuable capital on firms' balance sheets, increases the external finance premium. The increase in the cost of external finance is a drag on the real economy so long it takes for entrepreneurs' net worth to climb back to trend (a deleveraging process). Output decline at the through in this case is more than twice as large as in the frictionless case. The magnified effect is due to an enhanced and persistent decline in investment. With entrepreneurs balance sheet constrained, the negative impact of the loss of economically valuable capital is greatly amplified via firm balance sheets. The amplification is due not only to the shock itself but also to falling asset prices leading to further decreases in entrepreneurial net worth and higher credit costs, which induces a magnified drop in investment.

Comparing the model outcome with the data shows that the model is able to reproduce a persistent 6 quarter fall in investment, roughly of the same magnitude (about 20 per cent) as that observed between the beginning of 1991 and the collapse of the fixed exchange rate regime in September 1992. Furthermore, the model is able to reproduce a decline in output: The data show a 6 per cent drop in output within the 6 quarters, while the fall produced by the model is slightly faster and stronger. The response of consumption produced by the model is slighly slower than that observed in the data but the magnitude is in line with the evidence.

In our open economy model, the recovery of output back to trend is slowed by gradually declining net trade.This is due to an increase in inflation and an appreciation of the real exchange rate resulting from the capital obsolescence shock. However, in Finland the fall in net trade did not materialize before the next big shock hit the economy, namely the collapse of the fixed exchange rate regime in August 1992.

4.3 Experiment 3: The collapse of the fixed exchange rate regime

In this section, we illustrate the role played by financial factors after the collapse of the fixed exchange rate regime. Our focus in this paper is on the effects of the collapse, we do not explore the causes. We model the shock as a sudden 4 percentage point increase in the country borrowing premium (with an autoregressive coefficient

of 0.6). An increase in the country borrowing premium is a way to model sudden capital outflows along with a depreciation of the nominal exhange rate. In the Finnish data, the drop in investment following the collapse of the fixed exchange rate regime was 9 per cent in about 4 quarters. At the same time, GDP fell by 1–2 per cent. As previously, the size of the shock is chosen to match the magnitude of contraction in investment. We illustrate the role played by the financial accelerator and foreign currency denominated debt in reproducing the impact of the collapse of the fixed exchange rate regime. Figures 4–6 plot the responses of the model to the country borrowing premium shock under a flexible exchange rate regime.[7]

In this experiment, the initial shock originates in the international financial markets. An increase in the country borrowing premium raises the effective foreign interest rate. According to the UIP condition, the nominal exchange rate depreciates. The positive effect of a nominal and real exchange rate depreciation is an increase in net trade. Without the financial accelerator, investment and consumption fall, but this is nearly offset by an increase in exports. As a result output falls, but the outcome is only a mild recession.

With the financial accelerator, the fall in investment is clearly stronger and more protracted. Investment falls by 7 per cent within 4–5 quarters and recovers only slowly. This is mainly due to falling asset prices, which results in a decline in net worth and an increase in the external finance premium. Based on our model, about half of the overall 10 per cent fall in investment is explained by an operative financial accelerator mechanism.

In the presence of foreign currency denominated debt, the decline in investment is even stronger. The additional negative impact depends on the extent to which firm debt is expressed in foreign currency. In the case of Finland, about 27 per cent of firm debt was denominated in foreign currency in 1991 (Honkapohja and Koskela, 1999). Our experiment shows that the presence of foreign currency denominated debt magnifies the contraction in investment

[7]As reported in section 3, we assign a small weight to the nominal exchange rate, to approximate the behaviour of the central bank after the collapse of the fixed exchange rate regime in Finland. According to Korhonen (2010) the central bank aimed at an internationally credible interest rate and dampening the depreciation of the currency. Our modeling choice thus attempts to mimic monetary policy reactions after the collapse of the fixed exchange rate regime in a plausible fashion and aims at producing a model outcome that reproduces Finnish data. In further work, we should estimate exchange rate regime-specific policy rules to have a sense of the best fitting rule.

from 7 per cent to 10 per cent. The drop in output is also clearly magnified. Based on our model, about a quarter of the overall fall in investment and output is explained by foreign currency denominated debt. Furthermore, the recovery of investment and output is postponed further.With part of firm debt denominated in foreign currency, the depreciation of the nominal exchange rate hits the entrepreneurs' net worth directly by increasing the real indebtedness of the entrepreneurial sector. Net worth falls and the risk premium increases more than in the case of only domestic currency denominated debt. The further increase in the risk premium magnifies the drop in investment and output. Overall, our model illustrates how the positive effect of an increase in net trade is offset by a dramatically stronger and more persistent decline in investment.

Furthermore, financial factors contribute to the slow recovery of the economy back to trend. To reduce the spread between the cost of external finance and the riskless rate, net worth must increase. The recovery of entrepreneurial net worth back to trend takes time. Throughout the deleveraging process, the risk premium remains above its steady state value and drags the economy down.

We conclude that our model is able to produce a persistent fall in investment, consumption and output, and an increase in net trade roughly in line with the actual response of the Finnish economy after the collapse of the exchange rate regime. Thus, our model with the financial accelerator seems to capture the key financial factors contributing to the severity of the Finnish crises and to the slow recovery. The indebtedness of the entrepreneurial sector and the fact that a significant part of loans were foreign currency denominated are at the core of the explanation. Even though abandonment of the fixed exchange rate regime frees the hands of the central bank and allows the economy to recover faster than under a fixed exchange rate regime, as shown by Gertler, Gilchrist and Natalucci (2003), financial factors were dragging the Finnish economy down and contributing to the slow recovery of the economy despite improved competitiveness and the pickup in net trade.

5 Conclusions

This paper studies the boom-bust episode in Finland the late 1980s and early 1990s, focusing on the role of financial frictions and investment behaviour. The boom-bust cycle manifested itself in the strong and persistent movement in investment, first above and later below its trend. We show in this paper how financial factors combined with the shocks that hit the Finnish economy produced a boom that was followed by a severe depression.

We construct a DSGE model with balance sheet constrained firms and an unconventional shock structure that captures the key events of the episode. In this framework, we show how financial factors, either boosting or depressing economic activity, contributed first to the boom and later to the severity of the crises and to the slow recovery of the Finnish economy from the crises. We argue that the financial accelerator mechanism is a key amplifying mechanism that helps the model match, in particular, the large and persistent swings of investment first above and later below its trend.

This paper focuses on three shocks that hit the Finnish economy commonly claimed to have either initiated the boom or produced the severe depression. These three key events are the financial market deregulation in the 1980s, the collapse of the Soviet-Finnish trade in the beginning of 1991 and the collapse of the fixed exchange rate regime in 1992. Our model framework allows us to study whether and under which conditions these events, combined with financial constraints, are able to induce a boom and a bust similar to the Finnish experience.We argue that the shocks that hit Finland were powerful sources of strong economic fluctuations, as they impacted the balance sheets of leveraged and credit-constrained firms.

In this paper, we produce a similar boom to that experienced in Finland late 1980s by modeling the financial market deregulation in the 1980s as shocks from the financial market lowering the cost of credit. The boom is induced in our model by two alternative financial disturbances: a credit supply shock that lowers the cost of credit directly and a financial wealth shock that increases the net worth in the hands of the entrepreneurs, leading tolower credit costs. We argue that both of these shocks combined with balance sheet constrained firms are able to produce a boom that mimics some basic features of the Finnish expansion. Both shocks lower the cost of credit, which leads to a long-lasting increase in investment and output, an appreciation of asset prices and thus a further increase in

net worth; as well as a pickup in inflation, an appreciation of the real exchange rate and a fall in net trade.

The collapse of Soviet-Finnish trade hit the Finnish economy in the beginning of 1991, when the boom already showing signs of weakening. We argue that the collapse of Soviet-Finnish trade is better understood as a capital obsolescence shock as opposed to a conventional trade shock. The severe impact of the collapse of Soviet-Finnish trade was due to the shock that destroyed part of the economically valuable capital and thus led to a sharp decline in the net worth of entrepreneurs. Due to the presence of balance sheet constrained firms, the contraction of net worth increased the cost of finance and dragged investment down. We illustrate that the severity of the impact depends on the strength of the financial accelerator mechanism. Without balance sheet constrained firms, the result would merely have been a mild recession: investment activities would have picked up soon to replace the obsolete capital. In contrast, an operative financial accelerator mechnism explains the stong and persistent fall in investment and output after the collapse of Soviet-Finnish trade. We argue that a traditional trade shock does not capture the direct damage to the capital stock and firms' balance sheets, which are key to capturing the magnitude and persistence of the impact observed in the data.

The collapse of Soviet-Finnish trade was followed by the collapse of the fixed exchange rate regime in September 1992. Despite the depreciation of the real exchange rate and a pickup in net trade, investment contracted further and output remained depressed for several years. This study attributes the slow recovery of the Finnish economy to the persistent weakness in investment activities due to financial factors.With balance sheet constrained firms, the fall in output and asset prices after the collapse of the fixed exchange rate regime led to increased firm indebtedness (ie lower net worth) and thus an increase in the cost of finance that depressed economic activities significantly more than would occurred without an operative financial accelerator.We assess that an operative financial accelerator accounts for about half of the weakness of investment actitivies after the collapse of the fixed exchange rate regime.

Furthermore, the Finnish crisis was exacerbated due to about 30 per cent of firm debt being denominated in foreign currency at the time of the collapse.Therefore, the depreciation of the nominal exchange rate increased firms' debt burden, raising the cost of external finance further. We argue that roughly one-fourth of the overall fall

in investment and in output resulted from the additional adverse effect due to the presence of foreign currency denominated debt. Furthermore, our model illustrates how increased firm indebtedness and the deleveraging process slowed the recovery of the Finnish economy. After the shock, firms' net worth recovered only slowly and the cost of external finance remained elevated until firms had reduced their indebtedness and rebuilt their net worth. In other words, it was the deleveraging process of firms that led to the persistent weakness in investment activities.

We conclude that our model is able to tell the story of the Finnish boom-bust cycle in a DSGE framework where balance sheet constrained firms play a key role. Our model is particularly successful in explaining the role of financial factors and in reproducing quantitatively the behaviour of investment activities and output during the boom-bust cycle. However, several questions are left for future research. For example, more work is needed to capture more accurately the behaviour of private consumption during both the boom and bust phases. This may involve assessing the role of downward wage rigidities that are known to have been a key feature of the Finnish economy at the time. Several important questions remain about the role of economic policies at the time. For example, one could ask whether the boom-bust cycle could have been mitigated by appropriate economic policies. The decline of the real economy was followed by a large-scale banking crisis that deepened 1992 and contributed to the severity of the crisis. The additional negative impact of the banking crisis should also be assessed. In this paper, we calibrate the degree of financial frictions necessary to explain the dynamics of the boom-bust cycle in Finland. Further work could thus include estimating the model to study the strength of the financial accelerator mechanism at the time and the role of the various shocks.

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Appendix

Table 1. Calibrated parameter values for Finnish economy

Symbol	Definition	Value
β	discount factor	0.99
θ	final goods elasticity of substitution	6
δ	capital depreciation rate	0.05
η	weight of leisure in utility function	4.2
α	share of capital in production function	0.45
ψ	elasticity of external finance premium with respect to firm leverage	0.05
ν	survival rate of entrepreneurs	0.9728
G	steady state external finance premium	1.0075
k/n	steady state ratio of capital to net worth	2.1
Π	steady state gross inflation rate	1.01
b	habit persistence parameter	0.7
χ	investment adjustment cost parameter	4
ρ	intratemporal elasticity of substitution between consumption of domestic and foreign goods	1.5
ω	share of domestic goods in consumption composite	0.45
ω^d	share of firm debt in domestic currency	0.73
ϕ	sticky price parameter/probability of keeping prices fixed	0.75
ζ	price elasticity of export demand	1
τ	share parameter of export demand	0.25
κ	elasticity of country borrowing premium with respect to net foreign indebtedness	0.001
ξ^u	elasticity of marginal depreciation with respect to utilization rate	1
ϱ_π	Taylor rule coefficient on inflation	1.5
ϱ_y	Taylor rule coefficient on ouput gap	0.1
ϱ_s	Taylor rule coefficient on nominal exchange rate	0.5
ρ^R	Monetary policy smoothing parameter	0.8

Table 2. Implied steady state relationships

	Data (1980:1–1998:4)	model
$\frac{k}{y}$	4.6	5.5
$\frac{i}{y}$	0.28	0.28
$\frac{c}{y}$	0.79	0.72
$\frac{c^F}{y}$	0.36	0.35
$\frac{c^{H*}}{y}$	0.34	0.35
$\frac{c^H}{y}$	0.38	0.37
$\frac{wh}{y}$	0.54	0.46

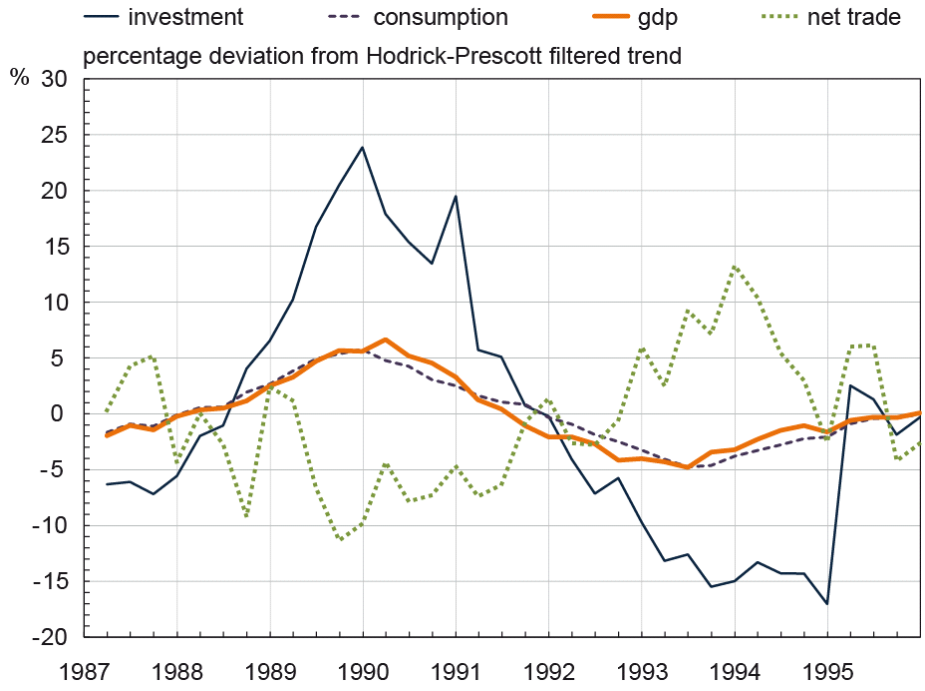

Figure 1: Data on the boom-bust episode

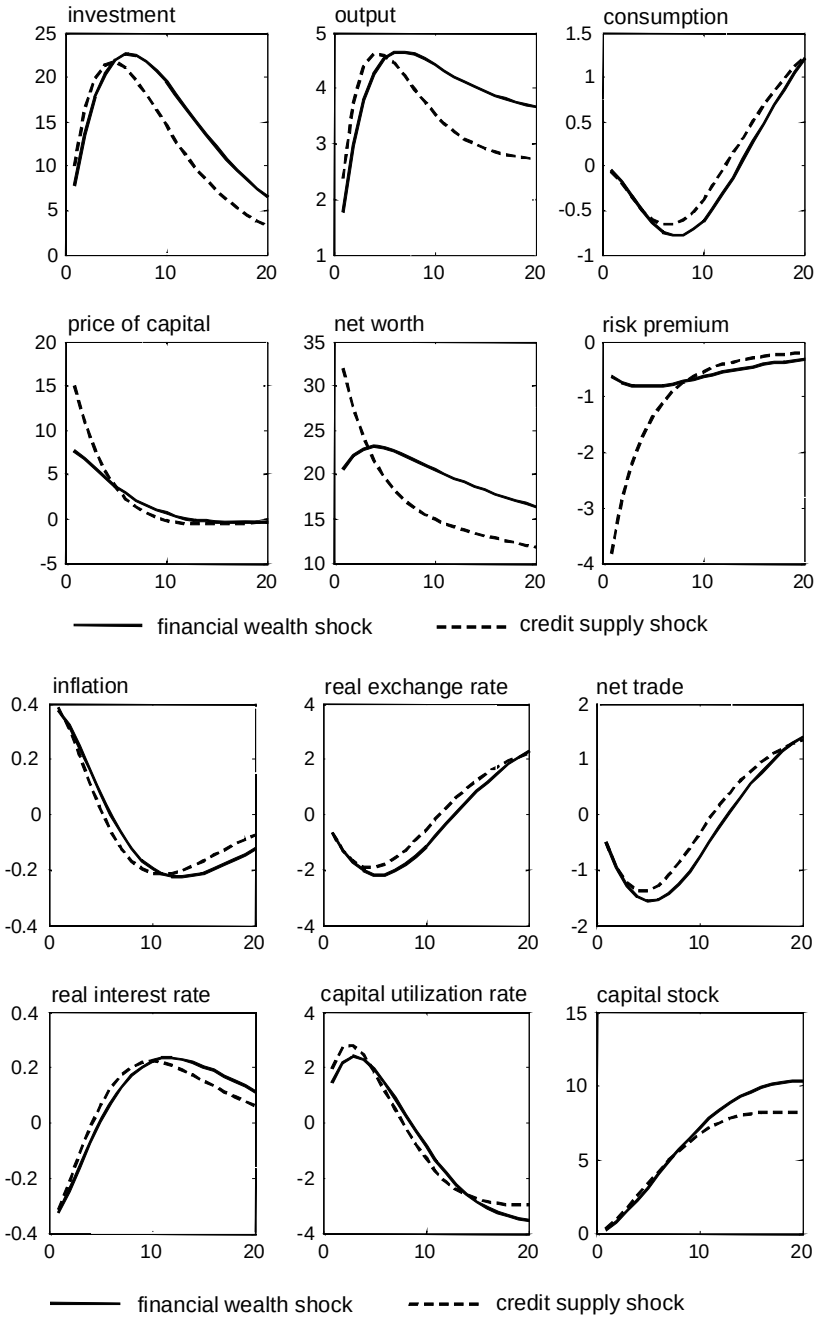

Figure 2: Boom: financial market deregulation (credit supply (dashed line) vs financial wealth (solid line) shock)

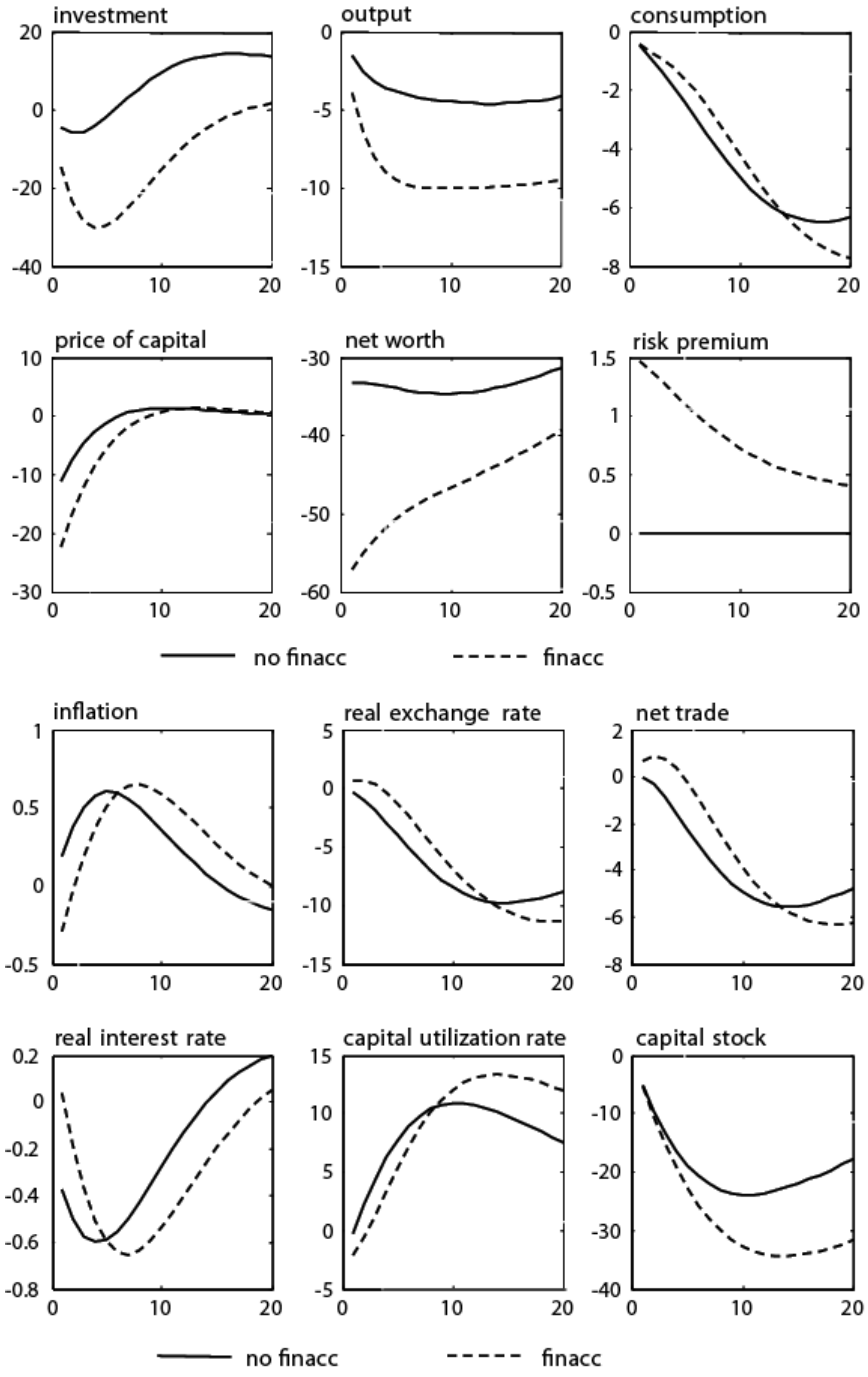

Figure 3: Bust: Collapse of Soviet trade (capital obsolescence shock with (dashed line) and without (solid line) financial accelerator)

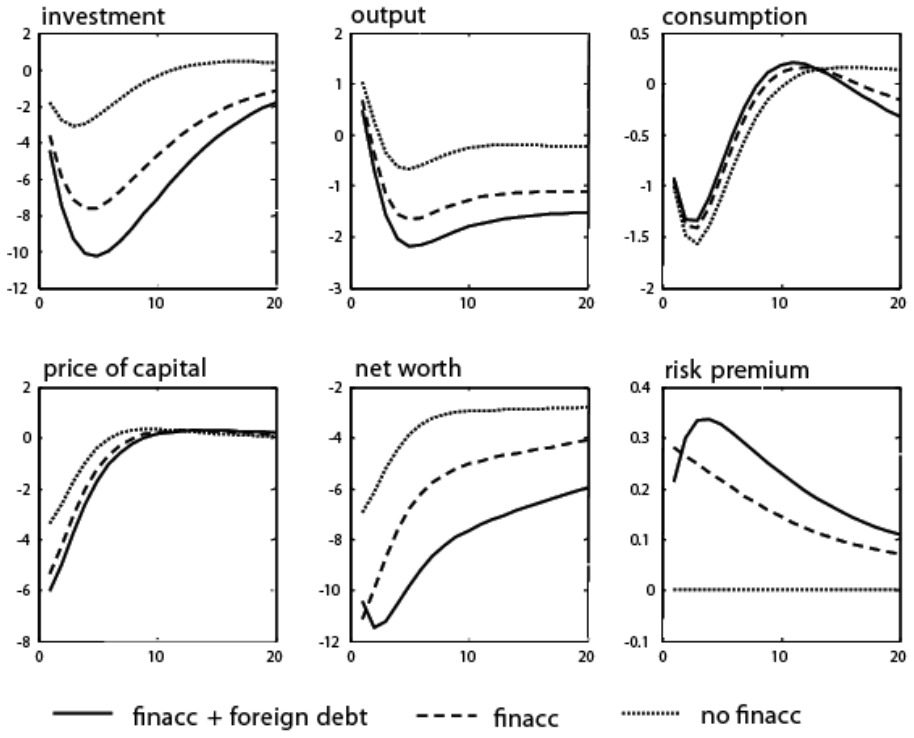

Figure 4: Bust: Collapse of fixed exchange rate regime (A country borrowing premium shock without financial accelerator (dotted line), with financial accelerator but only domestic debt (dashed line), with financial accelerator and 27% foreign debt (solid line))

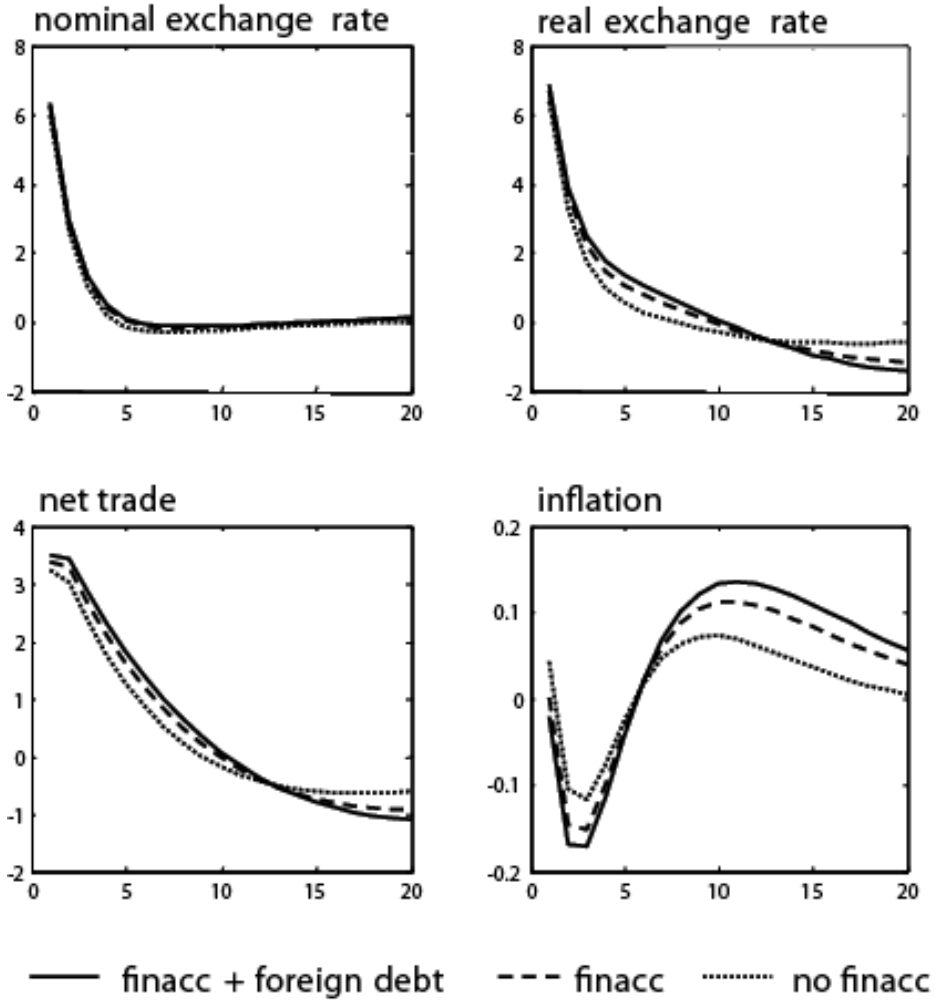

Figure 5: Bust: Collapse of fixed exchange rate regime (A country borrowing premium shock without financial accelerator (dotted line), with financial accelerator but only domestic debt (dashed line), with financial accelerator and 27% foreign debt (solid line))

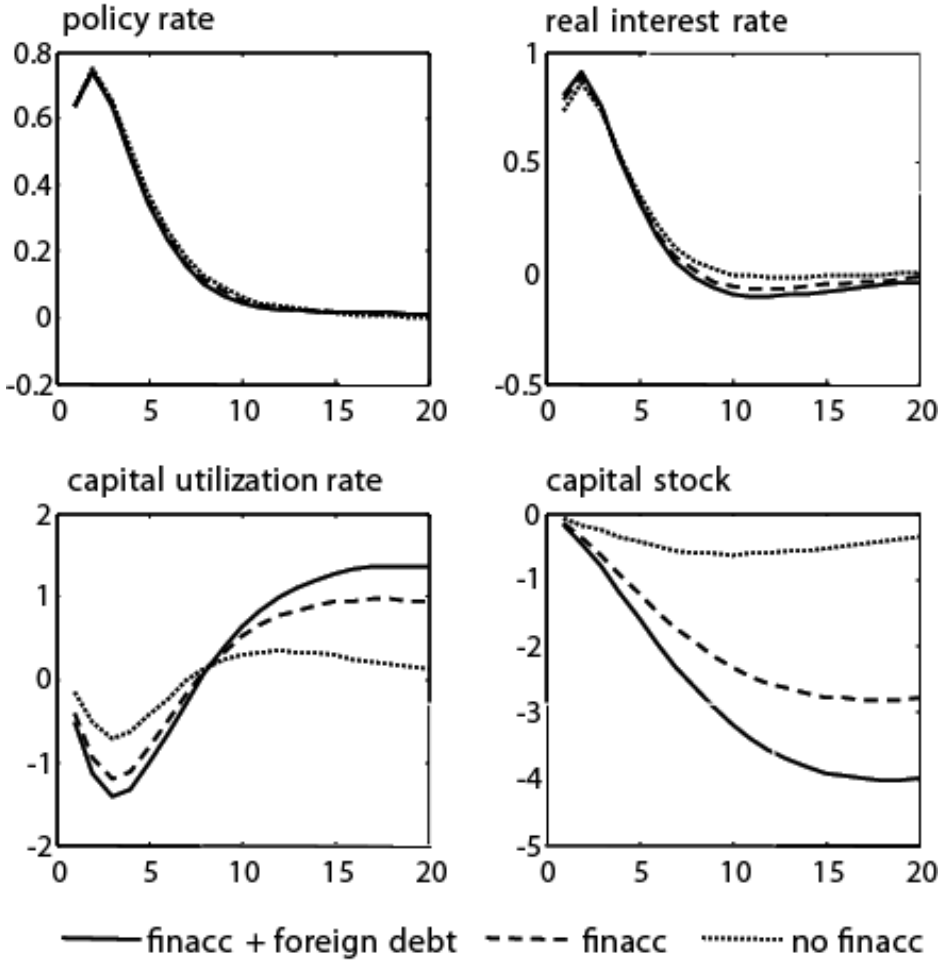

Figure 6: Bust: Collapse of fixed exchange rate regime (A country borrowing premium shock without financial accelerator (dotted line), with financial accelerator but only domestic debt (dashed line), with financial accelerator and 27% foreign debt (solid line))

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