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Working Paper

Financial market disturbances as sources of business cycle fluctuations in Finland

Bank of Finland Research Discussion Papers, No. 5/2010

Provided in Cooperation with:

Bank of Finland, Helsinki

Suggested Citation: Freystätter, Hanna (2010) : Financial market disturbances as sources of business cycle fluctuations in Finland, Bank of Finland Research Discussion Papers, No. 5/2010, ISBN 978-952-462-577-7, Bank of Finland, Helsinki, <https://nbn-resolving.de/urn:nbn:fi:bof-20140807306>

This Version is available at:

<https://hdl.handle.net/10419/212162>

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Hanna Freystätter

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

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<http://www.bof.fi>

ISBN 978-952-462-576-0
ISSN 0785-3572
(print)

ISBN 978-952-462-577-7
ISSN 1456-6184
(online)

Helsinki 2010

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Bank of Finland Research
Discussion Papers 5/2010

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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 two domestic financial market shocks and financial frictions in the form of a BGG financial accelerator. 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.

Keywords: financial market disturbances, DSGE models, Bayesian estimation

JEL classification numbers: E32, E44, F41

Rahoitusmarkkinahäiriöiden vaikutus Suomen talouden suhdannevaihteluihin

Suomen Pankin keskustelualoitteita 5/2010

Hanna Freystätter
Rahapolitiikka- ja tutkimusosasto

Tiivistelmä

Tässä työssä tutkitaan, kuinka hyvin rahoitusmarkkinoilla syntyvät häiriöt selittävät investointien vaihteluita Suomessa vuosien 1995 ja 2008 välisenä aikana. Työssä rakennetaan ensin Suomen talouden analysointiin tarkoitettu moderni dynaaminen makromalli, joka työn empiirisessä osassa sitten estimoidaan tällaisten mallien estimoinnissa nykyään paljon käytetyllä bayesiläisellä suurimman uskottavuuden menetelmällä. Rahoitusmarkkinoiden epätäydellisyyksistä aiheutuvan rahoitusakseleraattorin lisäksi työssä käytetyn dynaamisen makromallin erityispiirteenä on pidettävä kahta rahoitusmarkkinahäiriötä, jotka aiheuttavat stokastista vaihtelua yritysten nettovarallisuudessa ja maakohtaisessa korkomarginaalissa. Tulosten mukaan estimoidut rahoitusmarkkinahäiriöt selittävät hyvin investointien historiallista vaihtelua Suomessa. Kotimaisten rahoitusmarkkinahäiriöt selittävät hyvin Suomen talouden suhdannedynamiikkaa silloinkin, kun lukuisat muut kotimaisen ja kansainvälisen talouden häiriölähteet on estimoinneissa otettu huomioon.

Avainsanat: rahoitusakseleraattori, korkomarginaali, investointitoiminta, suhdannevaihtelut

JEL-luokittelu: E32, E44, F41

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1 Introduction

The relevance of changes in financial conditions for real activity has become clear during the 2007–2008 financial crises. A key issue is understanding the 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 the 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 crises 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 the financial market disturbances in understanding macroeconomic dynamics.

This paper investigates empirically the strength of the financial accelerator mechanism 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 by 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 many other countries, Finland experienced a stock market boom and bust from late 1990s to early 2000s. Furthermore, the time period stretches to the financial market crises 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 misses 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

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 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 mechanism 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

¹Finland joined the euro area in the beginning of 1999. Since the euro area key policy rate depends on the 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 extra euro area countries (or not denominated in euros).

order to study the interaction between the exchange rate regime and financial crises. The strenght of the financial accelerator mechanism 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 on 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 into the creation of firms' net worth. The financial wealth shock exogenously destroys or creates the aggregate net worth of firms. This captures the effects stemming from exogenous movements in asset values to investment through the 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 of, for example, Dib, Mendicino and Zhang (2008). We follow Gilchrist, Ortiz and Zakrasek (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 the one 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 Zakrasek (2009) estimates a closed economy (Smets and Wouters) model that incorporates the same two domestic financial market shocks as 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 Zakrasek (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 Zakrasek (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 the model by investigating the match between the model outcome and financial market data.

Moreover, in empirical DSGE literature, investment-specific shock often turns out be the most important driving force of economic fluctuations. However, as Justiniano, Primiceri and Tambalotti (2008) argue, the 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 actually originate from the same source, we follow Gilchrist et al (2009) and omit the investment-specific technology shock from the analysis. This is different from, for example, Dib, Mendicino and Zhang (2008), who conclude that both financial and investment-specific shocks appear to be the main sources of Canadian cyclical fluctuations.

In our empirical work, we provide evidence of an operative financial accelerator mechanism in Finland. The parameter governing the strength of the financial accelerator mechanism is positive and close to values obtained in other estimated DSGE models with the financial accelerator. The presence of the financial accelerator mechanism 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 mechanism thus acts as an amplifying mechanism for many disturbances hitting the economy.

Our main result is that disturbances stemming from the financial market itself have contributed significantly to Finnish cyclical fluctuations between 1995 and 2008. We show that domestic financial market shocks hitting the 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 late 1990's and early 2000's and the subsequent early millennium slowdown and, more recently, the sudden reversal of investment activities in 2008 due to the global financial crises.

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

2 The model

The model builds on Christensen and Dib (2008) and Lopez, Prada and Rodriguez (2008) that 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 the fact 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 distinct from one another 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 operate more capital than their own resources can support. The two domestic financial market shocks are shocks hitting the entrepreneurs and their demand of capital. These shocks are explained in Section 2.2.

2.1 Households

2.1.1 Preferences

Households live forever, 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

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

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

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

where γ denotes the constant elasticity of substitution between consumption and real balances and η is the weight on 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 is a money demand shock. These shocks follow first-order autoregressive processes given by

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

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

where ϵ_{et} and ϵ_{bt} are uncorrelated and normally distributed innovations with zero means 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

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

where c_t^H is 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 the 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

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

2.1.2 Budget constraint

The budget constraint of the representative household is as follows

$$c_t = \frac{W_t}{P_t} h_t + \frac{T_t}{P_t} + \frac{\Omega_t}{P_t} - \frac{M_t - M_{t-1}}{P_t} - \frac{B_{t+1} - R_t B_t}{P_t} - \frac{B_{t+1}^* - \Gamma_t R_t^* B_t^*}{P_t} \quad (2.7)$$

where c_t is real consumption, W_t/P_t is real wage, h_t is labour hours ($\frac{W_t}{P_t} h_t$ is the real earnings from work), $T_t = M_t - M_{t-1}$ is the newly created money transferred to the households as a lump-sum transfer and Ω_t represents the dividend payments from the 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 any 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 a simplifying assumption that both the foreign bonds B_t^* as well as the domestic bonds B_t are denominated in euros (hence, there is no need to multiply the foreign bond by the nominal exchange rate). 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^* 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 only one international bond, we make an assumption that international asset markets are incomplete. Incomplete market models of small open economies imply non-stationary equilibrium dynamics. The steady-state level of a choice variable, net foreign assets, is not pinned down by the model's optimality conditions. We need to choose a way to close the model that induces stationarity. Closing the model means finding a single stationary state equilibrium and then being able to find a log-linear approximation of the dynamic model around this 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, the reason for assuming such a friction is mainly technical: The country borrowing premium ensures that the model has a unique steady state and it induces 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

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

where $a_t \equiv B_t^*/P_t$ is the real net foreign indebtedness (in euros), \bar{a}_t is the steady state level of real foreign indebtedness and κ is the elasticity of the borrowing premium with respect to the net foreign indebtedness. κ is set close to zero so that it makes the real net foreign assets a_t revert to steady state following a shock but does not have a marked impact on the short run dynamics of the model.

2.1.3 First-order conditions

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

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

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

The money demand function is given by

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

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

$$\frac{\eta}{1 - h_t} = \lambda_t w_t \quad (2.11)$$

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

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

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

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

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

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

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. As opposed to the standard UIP, in the small open euro area case the nominal exchange rate is fixed with respect to intra-euro area countries and is independent of economic conditions in the small open euro area country. The nominal exchange rate movements that are exogenous from the small open euro area economy's point of view do, however, affect trade with countries outside euro area. The UIP condition in the small open euro area economy case states 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 at competitive markets for a price that equals 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

$$\min \frac{W_t}{P_t} h_t + z_t K_t \quad (2.15)$$

subject to a Cobb-Douglas production function

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

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

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

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

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

$$z_t = \xi_t\alpha\frac{Y_t}{K_t} \quad (2.19)$$

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

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

The model incorporates a version of the financial frictions proposed by Bernanke, Gertler and Gilchrist (1999), BGG from now on. 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 the entrepreneur (the borrower) and the financial intermediary (the lender), the lender charges the borrower a premium to cover the expected bankruptcy cost. For a detailed presentation of the financial arrangements between the entrepreneur and the lender, we refer the reader to Bernanke, Gertler and Gilchrist (1999) and Gertler, Gilchrist and Natalucci (2003).

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_{t+1}^f ²

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

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 we see the entrepreneur's net worth for period $t+1$. As in Christiano et al (2003), we assume that the 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 in the price level reallocates income between the households (lenders) and entrepreneurs (borrowers).³

²Without 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 the debt of the entrepreneurs.

³For simplicity, we impose 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 the foreign financial market.

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 the expected marginal financing cost $E_t f_{t+1}$. For an entrepreneur who is not fully self-financed, in equilibrium the expected return to capital will be equated to the marginal cost of external finance.

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

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 fluctuations in asset prices 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}

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

The external finance premium is the difference between the cost of external funds and the opportunity cost of internal funds (the 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 the aggregate financial condition of entrepreneurs, as measured by the ratio of net worth to the gross value of capital $\frac{n_{t+1}}{q_t K_{t+1}}$.

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

The financial accelerator mechanism thus relates the external finance premium negatively to the strength of entrepreneurs' balance sheets.⁴In this paper, the size of the external finance premium depends both on the leverage ratio and on 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 firm's external finance premium. We

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

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 the one warranted by current economic conditions.

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

$$\epsilon_{ft} = \rho_f \epsilon_{ft-1} + \epsilon_{fft} \quad (2.25)$$

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

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

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

We denote with 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 important to notice that fluctuations in the price of 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 equal to zero, the financial accelerator mechanism ceases to exist and there is no premium for the external finance of firms.

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 the entrepreneurial net worth, n_{t+1} , below.

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

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

In this expression, f_t is the ex-post real return on capital and $E_{t-1} f_t$ is the cost of borrowing implied by the loan contract signed in time $t - 1$. The sources of movements in net worth stem from unanticipated movements in returns (earnings effect) and borrowing costs (Fisher effect). On the asset side (returns), unforecastable changes in the asset price q_t provide the principle source of fluctuations in the return to capital. When it comes to the liability side (borrowing costs), as in Christiano et al (2003) we assume that entrepreneurs

⁵The 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.

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 decreases 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 (ie, asset prices) produces a fall in investment by reducing entrepreneurial net worth. Similarly, a shock that reduces 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 value of capital net of borrowing costs cuts into their ability to borrow by increasing the external finance premium. The increase in the external finance premium amplifies business cycles through an accelerator effect on investment, production and spending.

The aggregate entrepreneurial net worth evolves according to

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

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 away from 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 the 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 following form

$$\nu_t = \nu + \epsilon_{\nu t} \quad (2.29)$$

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

$$\epsilon_{\nu t} = \rho_{\nu} \epsilon_{\nu t-1} + \epsilon_{\nu \nu t} \quad (2.30)$$

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

When a shock drives the survival probability down, 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 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 good retailers and use them as material input to produce investment goods i_t . The aggregate capital stock evolves according to

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

where δ is the rate of depreciation. The investment goods i_t are combined with the 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's optimization problem, in real terms, consists of choosing the quantity of investment, i_t to maximize their profits, subject to quadratic adjustment costs

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

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

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

This is the standard Tobin's Q equation that relates the price of capital to the marginal adjustment costs. In the absence of capital adjustment costs, the price of capital is constant and equal to one. Capital adjustment costs slow down 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

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

It is a decreasing function of the relative price and an increasing function of foreign output, y_t^* . We assume that the export sector is pricing in 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 given 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.

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

The nominal exchange 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 foreign price level in euros 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 below

$$x_t = \rho_x x_{t-1} + \epsilon_{xt} \quad (2.36)$$

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

2.5 Retailers

There are two types of retailers in our open economy model: retailers of domestic and foreign goods. 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 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 preceding 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 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. For details, the retailer's optimization problem is presented in Christensen and Dib (2008).

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

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

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

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

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 the foreign good retailers is analogous to that of the domestic good retailers. The foreign good retailers transform a homogenous foreign good into a differentiated import good, which they sell to the domestic households. Similarly to domestic good retailers, foreign good retailers operate under Calvo-style price-setting. 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. 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.

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

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

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

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

$$Y_t = c_t^H + c_t^{H*} + i_t \quad (2.41)$$

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

The net foreign assets at the aggregate level evolve as follows

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

where B_{t+1}^* is the foreign net bond position, $p_t^H c_t^{H*}$ are the receipts from exports and $P_t^* c_t^F$ are the expenses 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. 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. Notice that the net foreign asset position affects the endogenous country premium (see equation (2.8)).

3 Empirical analysis

The empirical analysis aims at establishing the role of financial frictions and various shocks in the small open economy of Finland. Our goal is to answer what drives business cycle fluctuations in the Finnish economy. We estimate the model in log-linearized form using Bayesian Maximum Likelihood methods described eg in An and Schorfheide (2007). The method is based on maximization of the likelihood function. The likelihood function is estimated with the help of 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. below. The set of parameters that affect the dynamics are estimated using Bayesian methods. The estimated parameters include the ones that characterize the shock processes and frictions, namely the elasticity of external finance premium to firm leverage, price frictions, and capital adjustment costs. We discuss the priors of these parameters in the Section 3.1.3. below. 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 the Appendix A.

⁶We 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 before joining the European Monetary Union in 1999. However, we include data from 1995:1 to 1998:4 in order to have a slightly longer sample as it can be argued that the goal to join the Monetary Union practically limited the conduct of monetary policy in Finland already a couple of years before the actual start of the euro area.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 (the foreign demand and the foreign interest rate) as observables.⁸ We follow common practise 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. Then we use these results to fix those parameters in the estimation procedure of the whole system. As the foreign shocks are pre-estimated, this allows us to match the model to more variables than estimated shocks. This improves the estimation procedure as the foreign variables are informative about the parameters governing the propagation of foreign impulses to the domestic economy (see, for example, Adolfson et al, 2008).

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

The downside of dropping out the 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 the historical developments of the Finnish economy. Furthermore, this approach allows us to assess the performance of the model by investigating the match between the model outcome and financial market data. Similar analysis is done by, for instance, De Graewe (2008), who is able to reproduce external finance premium data for US with the model he estimates. The 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 series of investment, consumption and foreign output are measured as deviation from trend using a Hodrick-Prescott filter with a smoothing parameter of 1600 and data from 1980 to 2009:2 (until 2009:1 for foreign output). CPI inflation (expressed as quarterly rate), the real exchange rate

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

⁸The real exchange rate incorporates the foreign price level that is assumed exogenous in the model.

and the foreign interest rate are demeaned. Plots of the detrended data used in the estimation are presented in Figure 1. Detailed description of the data and the applied data transformations can be found in Appendix B.

3.1.2 Calibration

A number of parameters are kept fixed throughout the estimation procedure. Tables 2 and 3 report the calibrated parameters along with the implied steady state values of some key variables.

The discount factor is set to 0.993, implying annualized steady-state real interest rate of around 3 per cent. The steady state quarterly gross inflation rate is equal to 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 to 1.3166. The capital depreciation rate is 0.025, a value commonly used in the literature. The parameter measuring the degree of monopoly power in the retail (both domestic and import) sector is set to be equal to 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 to 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 to 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 to 0.9728 and the ratio of capital to net worth is calibrated to 2 implying a firm leverage ratio, defined as the ratio of debt to asset, 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 equal to 1 and the share parameter τ equal to 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 dynamics, while guaranteeing that the net foreign asset position is stabilized at zero in the long run.

3.1.3 Priors

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

⁹M1 divided by CPI.

The prior distributions for all the standard deviations of the shocks are inverted Gamma distributions with a mean of 1 and a degree of freedom of 10. This distribution guarantees a positive standard deviation with a rather large domain. Prior distributions of autoregressive parameters are assumed to follow Beta distributions with a mean of 0.75 and a standard error of 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). 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 of 0.4 and standard deviation of 0.05. Finally, the prior distribution for the capital adjustment cost parameter χ is set to follow a Gamma distribution with mean equal to 0.5 and standard deviation of 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 of 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. The plots of the prior and posterior densities are presented in Figure 2 which gives some indication of how informative the observed data are about the structural parameters. The prior and posterior densities differ clearly in most cases. As regards the autoregressive coefficient of the credit supply shock, its posterior is sharply peaked relative to our prior distribution and the variance of the posterior distribution is lower than the prior distribution, implying that the data is reasonably informative about the parameter. There are, however, some problems with the identification of the autoregressive coefficient of the financial wealth shock. Overall, it appears that the data are quite informative on the estimated parameters. Considering that we did not use any financial market data in the estimation, we are still able to identify reasonably well the financial market shocks and the elasticity of the external finance premium parameter.

The estimated value of the key parameter in the financial accelerator mechanism, 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 (for example, 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. This indicates that the financial accelerator is 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 mechanism ceases to exist. Entrepreneurs will then borrow but the cost associated with this source of financing will be given by the real riskless interest rate and will not be augmented by an endogenous risk premium depending on

firm balance sheets. Our results imply that there are financial frictions in the process of firms obtaining 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 the net worth of firms (through capital gains and losses) and therefore on the cost of external financing. 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 fluctuation in Finnish asset prices feed through to the real economy through the balance sheets of firms.

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. This implies an expected price duration of about 2 quarters.

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

We address the question of how well the model fits the data by comparing a set of statistics implied by the model to those measured in 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. Relative to output, the model matches investment and inflation variation 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 somewhat 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 fluctuations in investment.

Model validation can also be done by checking how accurately the model reproduces data that is not used as observable in the 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.¹⁰ The model tracks reasonably accurately the surge in the stock market and the subsequent collapse related to the high-tech boom-bust episode at the end of 1990's and beginning of 2000's. Furthermore, the model reproduces the rise in stock prices before the start of the recent financial market crises and the stock market bust in 2008. The volatility of the actual stock market data is, however, greater than 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

¹⁰Detrended real (deflated by CPI) stock market price index.

external financing cost of firms measured by business prime lending rate and the 3 months euribor.¹¹ Unfortunately, the data for 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 occurred when the financial crises 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 that are included in the model, we report the forecast-error-variance decompositions in Table 6. The contribution of each shock to the variance of key model variables is reported on 4 horizons. We can conclude by looking at the variance decompositions implied by the estimated model, that the financial shocks are important sources of business cycle fluctuations in Finland in all horizons. Adding the two financial shocks together, they account for major part of investment fluctuation both in the short and the 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 more importance in the long run. Furthermore, in contrast to a model 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, along with the technology shock, account for a substantial portion of inflation fluctuations both in the short and the long run. The foreign interest rate shock plays also 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 must 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 the 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

¹¹We use 3 months helibor as our reference interest rate instead of euribor before the start of the euro area in 1999.

of historical investment fluctuations. The figure suggests that financial factors contributed strongly to the boom-bust period from late 1990s to early 2000s. In the beginning of 2000's, 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 the subsequent economic downturn can largely be 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 activities in 2006. The shock to the external finance premium seems to also explain the peak in investment activities before the global financial crises resulted in a sudden reversal of investment in 2008. In the second half of 2008 there is 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 financial market crises in a way that accords well with the 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 the 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 may also study the relative importance of shocks stemming from the foreign economy. Interestingly, out of the open economy shocks only the foreign interest rate shock seems to play a role in explaining fluctuations in investment activity. The foreign interest rate shock, however, represents actually 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 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. As 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 (the 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 output as net worth propagates the shock long after the initial impact. The external finance premium decreases reflecting the 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 boosting output further. Once again, these results are obtained without nominal interest rate reaction due to lack of 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 model with financial accelerator (for example, Gilchrist, Ortiz and Zakrašek, 2009; and Christensen and Dib, 2008). We thus show that the financial accelerator mechanism is operative in Finland and there is a 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 have an impact on 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 output fluctuations both in the short and the long run.

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. A recent paper by Gilchrist et al (2009) obtains similar results for the US economy over the period 1973–2008. As opposed to Gilchrist et al (2009), our small open economy model incorporates also several open economy shocks and therefore allows us to examine the relative importance of shocks stemming both from foreign and domestic sources. We find that out of the foreign shocks only the foreign monetary policy shock, due to lack of independent monetary policy, has a significant impact on investment fluctuations. However, the presence of open economy shocks does not change the conclusion that domestic financial shocks are central to explaining investment developments in Finland over the time period of 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 the Finnish stock market data is reasonably well reproduced by the model. The model does slightly worse in matching the data on the external finance premium. However, there is uncertainty whether our data on the external finance premium measures the premium adequately.

It seems that the financial market shocks have taken over the role of an investment-specific shock which usually seems to account for a large share 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 late 1990's and early 2000's and the subsequent early millennium slowdown and, more recently, the sudden reversal of investment activities in 2008 due to the global financial crises. 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 hitting the entrepreneurs and their demand of 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 pull apart 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 should assess the role of financial factors in the early nineties recession that was particularly deep in Finland.

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Appendix

A. Euro area open economy model

Households

$$\begin{aligned} \frac{e_t c_t^{-\frac{1}{\gamma}}}{c_t^{\frac{\gamma-1}{\gamma}} + b_t^{1/\gamma} \left(\frac{M_t}{P_t}\right)^{\frac{\gamma-1}{\gamma}}} &= \lambda_t \\ \frac{e_t b_t^{\frac{1}{\gamma}} \left(\frac{M_t}{P_t}\right)^{-\frac{1}{\gamma}}}{c_t^{\frac{\gamma-1}{\gamma}} + b_t^{1/\gamma} \left(\frac{M_t}{P_t}\right)^{\frac{\gamma-1}{\gamma}}} &= \lambda_t - \beta E_t \left(\frac{\lambda_{t+1}}{\pi_{t+1}} \right) \\ \frac{\eta}{1-h_t} &= \lambda_t w_t \\ \frac{\lambda_t}{R_t} &= \beta E_t \left(\frac{\lambda_{t+1}}{\pi_{t+1}} \right) \\ \frac{c_t^H}{c_t^F} &= \frac{\omega}{1-\omega} \left(\frac{p_t^H}{p_t^F} \right)^{-\rho} \\ E_t \left\{ \frac{\lambda_{t+1}}{\pi_{t+1}} [R_t - \Gamma_t R_t^*] \right\} &= 0 \end{aligned}$$

Country borrowing premium

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

Entrepreneurs

$$\begin{aligned} Y_t &= K_t^\alpha (A_t h_t)^{(1-\alpha)} \\ \frac{W_t}{P_t} &= \xi_t (1-\alpha) \frac{Y_t}{h_t} \\ z_t &= \xi_t \alpha \frac{Y_t}{K_t} \\ E_t f_{t+1} &= E_t \left[\frac{z_{t+1} + (1-\delta)q_{t+1}}{q_t} \right] \end{aligned}$$

Financial accelerator

$$\begin{aligned} E_t f_{t+1} &= E_t \left[S \left(\frac{n_{t+1}}{q_t K_{t+1}} \right) \frac{R_t}{\pi_{t+1}} \epsilon_{ft} \right] \\ E_t n_{t+1} &= \nu_t [f_t q_{t-1} K_t - E_{t-1} f_t (q_{t-1} K_t - n_t)] + (1-\nu_t) g_t \end{aligned}$$

Capital producers

$$\begin{aligned} q_t - 1 - \chi \left(\frac{i_t}{K_t} - \delta \right) &= 0 \\ K_{t+1} &= i_t + (1-\delta)K_t \end{aligned}$$

Domestic retailers

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

Foreign good retailers

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

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

$$\pi_t^F = \frac{P_t^F}{P_{t-1}^F}$$

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 of home retail consumption good

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

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

Figures

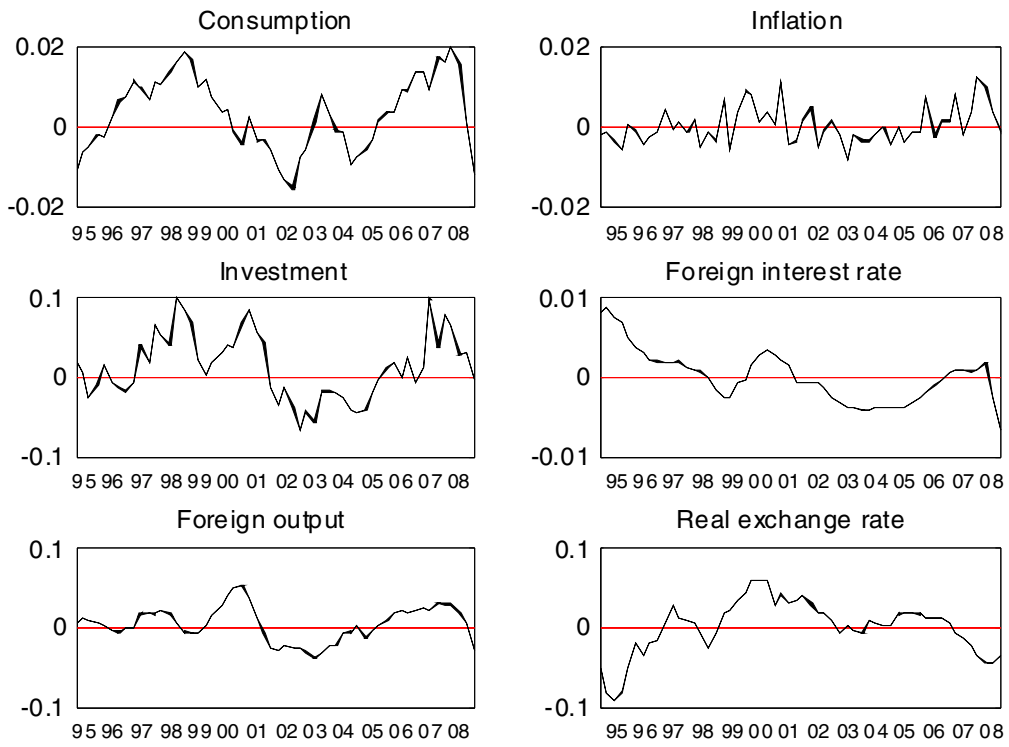


Figure 1.

The data

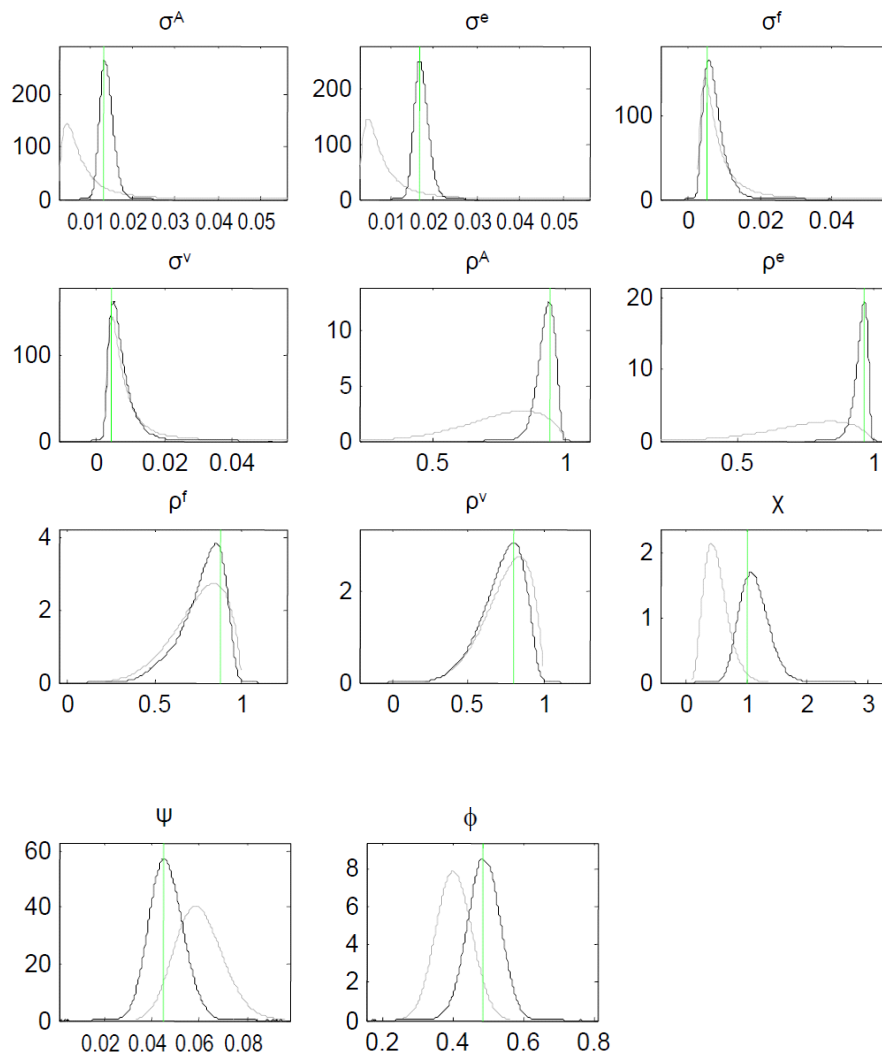


Figure 2. **Prior and posterior distributions of the structural parameters**

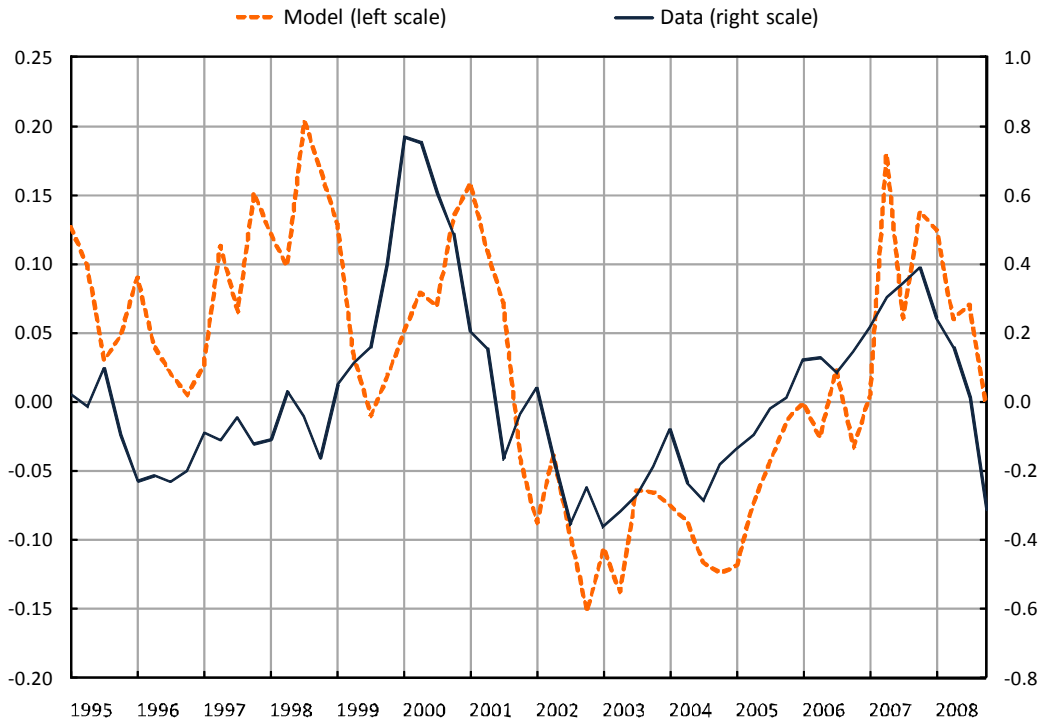


Figure 3. **The model implied new worth and data on net worth**

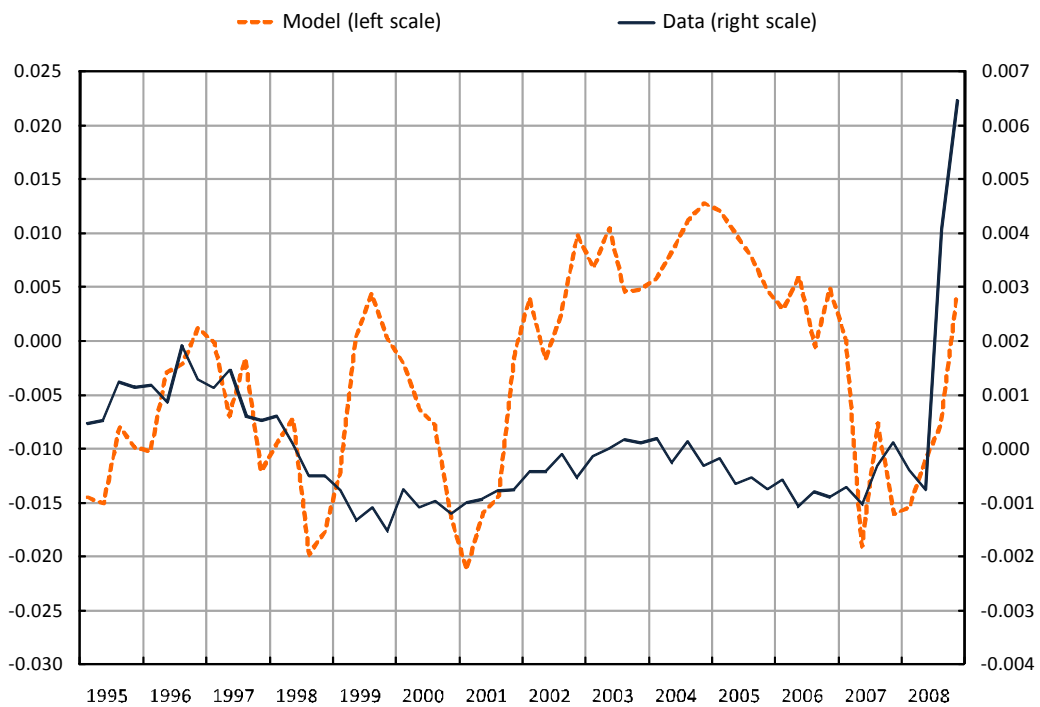


Figure 4. **Model implied external finance premium and data on external finance premium**

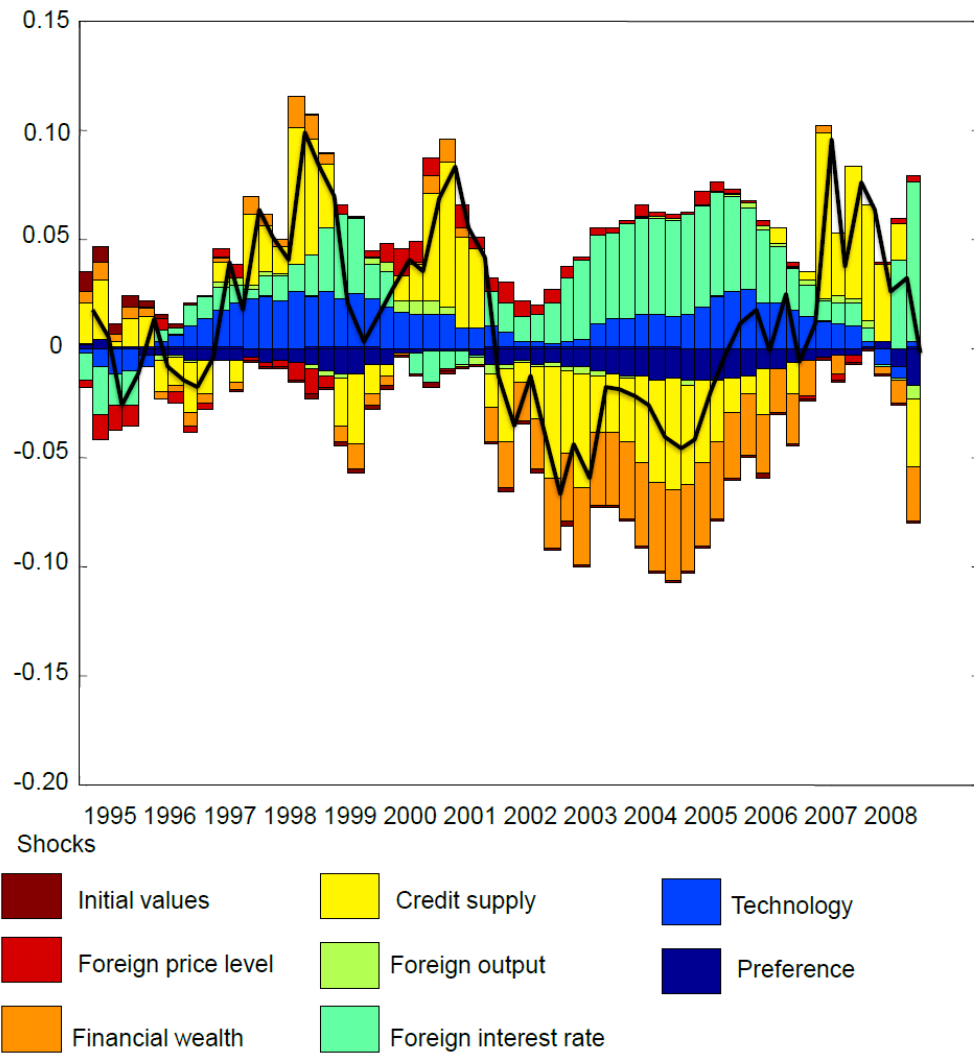


Figure 5. **The historical variance decomposition of investment**

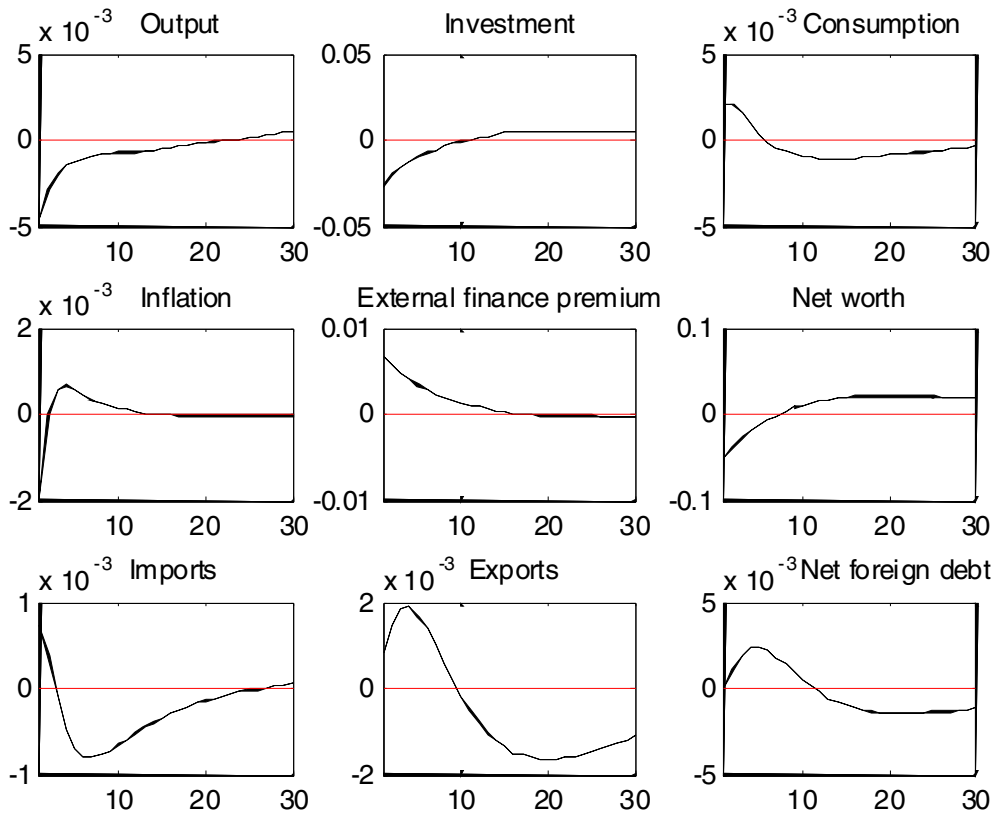


Figure 6. Adverse credit supply shock

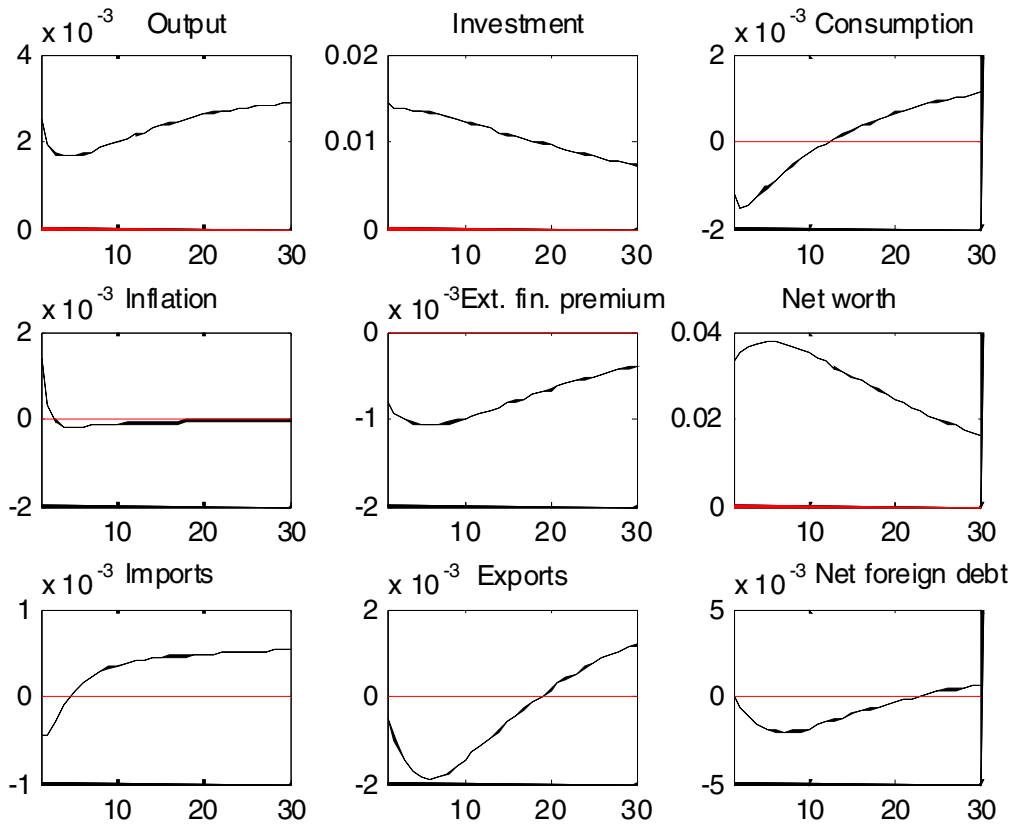


Figure 7. Positive financial wealth shock

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 the utility function	1.3166
α	the share of capital in production function	0.4
v	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	intra-temporal elasticity of substitution between consumption of domestic and foreign goods	1
ω	the share of domestic goods in the consumption composite	0.35
ω^E	the share of intra-euro area trade	0.4
$(1-\omega^E)$	the share of extra-euro area trade	0.6
ζ	the price elasticity of export demand	1
τ	the share parameter of export demand	0.25
κ	the 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
the 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, in per cent)						
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, in per cent)						
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, in per cent)						
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, in per cent)						
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

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