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Financial frictions in Latvia

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Abstract This paper builds a dynamic stochastic general equilibrium (DSGE) model for Latvia that would be suitable for policy analysis and forecasting purposes at Bank of Latvia. For that purpose, I adapt the DSGE model with financial frictions of Christiano, Trabandt and Walentin (2011, "Introducing financial frictions and unemployment into a small open economy model" in Journal of Economic Dynamics and Control) to Latvia's data, estimate it, and study whether adding the financial frictions block to an otherwise identical ('baseline') model is an improvement with respect to several dimensions. The main findings are: i) the addition of the financial frictions block provides more appealing interpretation for the drivers of economic activity, and allows to reinterpret their role; ii) financial frictions played an important part in Latvia's 2008-recession; iii) the financial frictions model beats both the baseline model and the random walk model in forecasting both CPI inflation and GDP.

Keywords DSGE model · Financial frictions · Small open economy · Bayesian estimation · Currency union

JEL codes E0, E3, F0, F4, G0, G1

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1 Introduction

This paper builds a dynamic stochastic general equilibrium (DSGE) model for Latvia that would be suitable for policy analysis and forecasting purposes at Bank of Latvia, since the current main macroeconomic model lacks microfoundations. Also, the recent financial crisis has suggested that business cycle modeling should not abstract from financial factors, thus modeling financial frictions is deemed to be requisite.

Therefore, I take the model of Christiano, Trabandt and Walentin (2011) (henceforth, CTW) with financial frictions as a starting point. To assess the effect of having financial frictions mechanism in a DSGE model, I compare the output of the model throughout the paper with an otherwise identical model, called the 'baseline' model, but lacking the mechanism of financial frictions. The baseline model is a standard open economy model, and builds on Christiano, Eichenbaum and Evans (2005) and Adolfson, Laseen, Linde and Villani (2008). The financial frictions model adds the Bernanke, Gertler and Gilchrist (1999, henceforth BGG) financial accelerator mechanism to the baseline model.

I modify the CTW model with respect to monetary policy: since Latvia's currency has been pegged to euro since 2005 and became euro in 2014 when Latvia joined the euro area, I model the monetary policy as a currency union. The foreign economy is modeled as an identified structural vector autoregression (SVAR) in foreign output, inflation, nominal interest rate and technology growth, and corresponds to the euro area.

The main findings are as follows: i) the addition of financial frictions block provides more appealing interpretation for the drivers of economic activity, and allows to reinterpret their role; ii) financial frictions played an important part in Latvia's 2008-recession; iii) the financial frictions model beats both the baseline model and the random walk model in forecasting both CPI inflation and GDP.

This paper employs a model of financial frictions for firms but abstracts from frictions in financing households. Modeling frictions in both markets is beyond the scope of the current paper.

The paper is structured as follows. Section 2 overviews the model. Section 3 describes the estimation procedure, and Section 4 reports the results. Section 5 concludes. The online appendix contains more computational results and a detailed model's description.

2 The model in brief

Since the model is almost a replica of CTW, this section is a brief introduction to the model, whereas its formal description is relegated to the online appendix. The only noticeable difference between the CTW model and this one is in the behavior of monetary authority which is modeled as a currency union in this paper.

2.1 Baseline model

The baseline model builds on Christiano, Eichenbaum and Evans (2005) and Adolfson, Laseen, Linde and Villani (2008). The three final goods: consumption, investment and exports, are produced by combining the domestic homogeneous good with specific imported inputs for each type of final good. Specialized domestic importers purchase a homogeneous foreign good, which they turn into a specialized input and sell to domestic import retailers. There are three types of import retailers. One uses the specialized import goods to create a homogeneous good used as an input into the production of specialized exports. Another uses the specialized import goods to create an input used in the production of investment goods. The third type uses specialized imports to produce a homogeneous input used in the production of consumption goods. Exports involve a Dixit-Stiglitz (Dixit and Stiglitz, 1977) continuum of exporters, each of which is a monopolist that produces a specialized export good. Each monopolist produces its export good using a homogeneous domestically produced good and a homogeneous good derived from imports. The homogeneous domestic good is produced by a competitive, representative firm. The domestic good is allocated among the i) government consumption (which consists entirely of the domestic good) and the production of ii) consumption, iii) investment, and iv) export goods. A part of the domestic good is lost due to the real friction in the model economy due to investment adjustment and capital utilization costs.

Households maximize the expected utility from a discounted stream of consumption (subject to habit) and hours worked. In the baseline model, the households own the economy's stock of physical capital. They determine the rate at which the capital stock is accumulated and the rate at which it is utilized. The households also own the stock of net foreign assets and determine its rate of accumulation.

The monetary policy is conducted as a currency union[1]. The government expenditures grow exogenously. The taxes in the model economy are: capital tax, payroll tax, consumption tax, labor income tax, and a bond tax. Any difference between government expenditures and tax revenue is offset by lump-sum transfers. The foreign economy is modeled as an identified structural vector autoregression (SVAR) in foreign output, inflation, nominal interest rate and technology growth. The model economy has two sources of exogenous growth: neutral technology growth and investment-specific technology growth.

2.2 Financial frictions model

The details are relegated to the online appendix, while a brief summary follows. The financial frictions model adds the Bernanke, Gertler and Gilchrist (1999, henceforth BGG) financial frictions to the above baseline model. Financial frictions reflect that borrowers and lenders are different people, and that they have different information. Thus the model introduces 'entrepreneurs' - agents who have a special skill in the operation and management of capital. Their skill in operating capital is such that it is optimal for them to operate more capital than their own resources can support, by borrowing additional funds. There is financial friction because the management of capital is risky, i.e. entrepreneurs can go bankrupt, and only the entrepreneurs costlessly observe their own idiosyncratic productivity.

In this model, the households deposit money in banks. The interest rate that households receive is nominally non state-contingent.[2] The banks then lend funds to entrepreneurs using a standard nominal debt contract, which is optimal given the asymmetric information.[3] The amount that banks are willing to lend to an entrepreneur under the debt contract is a function of the entrepreneur's net worth. This is how balance sheet constraints enter the model. When a shock occurs that reduces the value of entrepreneurs' assets, this cuts into their ability to borrow. As a result, entrepreneurs acquire less capital and this translates into a reduction in investment and leads to a slowdown in the economy. Although individual entrepreneurs are risky, banks are not.

The financial frictions block brings two new endogenous variables, one related to the interest rate paid by entrepreneurs and the other - to their net worth. There are also two new shocks, one to idiosyncratic uncertainty and the other - to entrepreneurial wealth.

The explicit description of both the baseline and the financial frictions models is relegated to the online appendix.

3 Estimation

I estimate both the baseline and financial frictions models with Bayesian techniques. The equilibrium conditions of the model are reported in the online appendix.

3.1 Calibration

The time unit is a quarter. A subset of model's parameters is calibrated and the rest are estimated using the data for Latvia and the euro area. The calibrated values are displayed in Tables 1-2. These are the parameters that are typically calibrated in the literature and are related to "great ratios" and other observable quantities related to steady state values. The values of the parameters are selected such

[1] A generalized Taylor rule, including foreign interest rate and nominal exchange rate, was also studied but the results are skipped due to the space constraint. In short, the currency union fits the data better.

[2] These nominal contracts give rise to wealth effects of unexpected changes in the price level, as emphasized by Fisher (1933). E.g., when a shock occurs which drives the price level down, households receive a wealth transfer. This transfer is taken from entrepreneurs whose net worth is thereby reduced. With tightening of their balance sheets, the ability of entrepreneurs to invest is reduced, and this generates an economic slowdown.

[3] Namely, the equilibrium debt contract maximizes the expected entrepreneurial welfare, subject to the zero profit condition on banks and the specified return on household bank liabilities.

that they would be specific to the data at hand. Sample averages are used when available. The discount factor, β, and the tax rate on bonds, τ_b, are set to match roughly the sample average real interest rate for the euro area. The capital share, α, is set to 0.4.

Table 1: Calibrated parameters

Parameter	Value	Description
α	0.400	Capital share in production
β	0.995	Discount factor
δ	0.030	Depreciation rate of capital, quarterly
ω_c	0.450	Import share in consumption goods
ω_i	0.650	Import share in investment goods
ω_x	0.550	Import share in export goods
$\tilde{\phi}_a$	0.010	Elasticity of country risk to net asset position
η_g	0.202	Government expenditure share of GDP
τ_k	0.100	Capital tax rate
τ_w	0.330	Payroll tax rate
τ_c	0.180	Consumption tax rate
τ_y	0.300	Labor income tax rate
τ_b	0.000	Bond tax rate
μ_z	1.005	Steady state growth rate of neutral technology
μ_ψ	1	Steady state growth rate of investment technology
$\bar{\pi}$	1.005	Steady state inflation growth target
λ_w	1.500	Wage markup
$\lambda_{d;m,c;m,i}$	1.300	Price markup to the domestic, imp. for consump., imp. for investm. goods
$\lambda_{x;m,x}$	1.200	Price markup to exports and imports for export goods
ϑ_w	1.000	Wage indexation to real growth trend
$\varkappa^j$	$1-\kappa^j$	Indexation to inflation target for $j = d; x; m, c; m, i; m, x; w$
$\breve{\pi}$	1.005	Third indexing base
$\tilde{\phi}_S$	0	Country risk adjustment coefficient
		Financial frictions model
$F(\bar{\omega})$	0.020	Steady state bankruptcy rate
$100W_e/y$	0.100	Transfers to entrepreneurs

Import shares are set to reasonable values by consulting to the input-output tables and fellow economists - 45%, 65% and 55% for import share in consumption, investment and export, respectively.[4] The government expenditure share in the gross domestic product (henceforth GDP) is set to match the sample average, i.e. 20.2%. The steady state growth rates of neutral technology and inflation are set to two percent annually, and correspond to the euro area. The steady state growth rate of investment-specific technology is set to zero. The steady state quarterly bankruptcy rate is calibrated to two percent, up from one percent in the CTW model for the Swedish data. The values of the price markups are set to the typical values found in the literature, i.e., to 1.2 for exports and imports for exports, and 1.3 for the domestic, imports for consumption and imports for investment. Wage markup is set to 1.5 as in CTW.

There is full indexation of wages to the steady state real growth, $\vartheta_w = 1$. The other indexation parameters are set to get the full indexation and thereby avoid steady state price and wage dispersion, following CTW. Tax rates are calibrated such that those would represent implicit or effective rates. Three of these are calibrated using Eurostat data[5]: tax rate on capital income is set to 0.1, the value-added tax

[4] The import share in export might appear to be too high when consulting to the literature of international trade in value added. E.g. the results of Stehrer (2013) suggest, from the value-added perspective, that share about 30%. However, re-exports (with little or no value added) is an important phenomenon in Latvia's foreign trade and is the reason why the calibrated parameter is higher than the aforementioned 30%.

[5] Source: `http://epp.eurostat.ec.europa.eu/cache/ITY_PUBLIC/2-29042013-CP/EN/2-29042013-CP-EN.PDF`, accessed in September 6, 2013

on consumption, τ^c, and the personal income tax rate that applies to labor, τ^y, are set to $\tau^c = 0.18$ and $\tau^y = 0.3$. Payroll tax rate is set to $\tau^w = 0.33$, down from the official 0.35 (0.24 by employer and 0.11 by employee). The elasticity of country risk to net asset position, $\tilde{\phi_a}$ is set to a small positive number and, in that region, its purpose is to induce a unique steady state for the net foreign asset position. Transfers to entrepreneurs parameter W_e/y is kept the same as in CTW. The country risk adjustment coefficient in the uncovered interest parity condition is set to zero in order to impose the nominal interest rate peg.

Table 2: Matched moments and corresponding parameters

	Parameter description	Posterior mean baseline	Posterior mean finfric	Moment	Moment value
$\tilde{\varphi}$	Real exchange rate	2.12	2.04	$SP^x X/(PY)$	0.462
A_L	Scaling of disutility of work	13.80	37.81	$L\varsigma$	0.270
γ	Entrepreneurial survival rate		0.96	$n/(p_{k'}k)$	0.600

Three observable ratios are chosen to be exactly matched throughout the estimation, and therefore three corresponding parameters are recalibrated for each parameter draw: the steady state real exchange rate, $\tilde{\varphi}$, to match the export share of GDP in the data, the scaling parameter for disutility of labor, A_L, to fix the fraction of their time that individuals spend working[6], and the entrepreneurial survival rate, γ, is set to match the net worth to assets ratio[7].

In the earlier steps of calibration, the depreciation rate of capital, δ, was also set to match the ratio of investment over output, but the realized value of depreciation rate turned out to be rather sensitive to initial values and slight changes in other calibrated parameters, therefore it was decided to fix the quarterly depreciation rate to a reasonable value of three percent.

3.2 Priors

There are 21 structural parameters, eight first-order autoregressive (henceforth, AR(1)) coefficients, 16 SVAR parameters for the foreign economy, and 16 shock standard deviations estimated with Bayesian techniques within Matlab/Dynare environment (Adjemian et al, 2011). The priors for the domestic block are displayed in Table 3, while those for the foreign SVAR are relegated to the online appendix. The priors are similar to CTW. Less agnostic priors are assigned for the foreign SVAR model since otherwise the foreign monetary policy appears to be weakly identified[8]. The prior means of the estimated standard deviations are set closer to their posteriors, and parameters and shock standard deviations are scaled to be of similar order of magnitude in order to facilitate optimization.

3.3 Data

The model is estimated using data for Latvia ('domestic' part) and the euro area ('foreign' part). The sample period is 1995Q1 - 2012Q4. I use 18 observable time series to estimate the financial frictions model and two less to estimate the baseline model. The variables used in levels are: nominal interest rate, GDP deflator inflation, consumer price index (henceforth CPI) inflation, investment price index

[6] The fraction of time spent working calibrated to 0.27 is somewhat arbitrary but checked against the marginal data density with respect to its neighboring values.

[7] The net worth to assets ratio for Latvia, if the definition of CTW is taken, yields about 0.15. However, the marginal data density favors a much larger number, 0.6, which is used in the final calibration. The latter number might be rationalized if the net worth was measured not only by the share price index but if it included also the real estate value.

[8] My unreported results show that this is true regardless of the sample span used in the estimation and whether or not the foreign block is estimated separately from the domestic block. Also, the use of foreign CPI inflation instead of the foreign GDP deflator's inflation (which is used by CTW) improves the identification of the foreign monetary policy only marginally. Therefore the results involving the foreign monetary policy should be interpreted with caution. The replacement of the foreign SVAR with a full-fledged foreign DSGE block thus might be an improvement but is not considered in this paper.

inflation, foreign CPI inflation, foreign nominal interest rate and the interest rate spread. The rest of the variables are in terms of the first differences of logs, and these are: real GDP, real consumption, real investment, real exports, real imports, real government expenditures, real wage, real exchange rate, real stock price index, total hours worked, and real foreign GDP. All the differenced variables are demeaned except for total hours worked. The domestic inflation rates and the real exchange rate are demeaned as well. All real quantities are in per capita terms. All foreign variables correspond to the euro area data.

3.4 Shocks and measurement errors

In total, there are 18 exogenous stochastic variables in the theoretic financial frictions model: four technology shocks - stationary neutral technology, ϵ, stationary marginal efficiency of investment, Υ, unit-root neutral technology, μ_z, and unit-root investment specific technology, μ_Ψ, - a shock to consumption preferences, ζ^c, and to disutility of labor supply, ζ^h, a shock to government expenditure, g, and a country risk premium shock that affects the relative riskiness of foreign assets compared to domestic assets, $\tilde{\phi}$. There are five markup shocks, one for each type of intermediate good, τ^d, τ^x, $\tau^{m,c}$, $\tau^{m,i}$, $\tau^{m,x}$ (d - domestic, x - exports, m,c - imports for consumption, m,i - imports for investment, m,x - imports for exports). The financial frictions model has two more shocks - one to idiosyncratic uncertainty, σ, and one to entrepreneurial wealth, γ. There are also shocks to each of the foreign observed variables - foreign GDP, y^*, foreign inflation, π^*, and foreign nominal interest rate, R^*.

The stochastic structure of the exogenous variables are the following: eight of these evolve according to AR(1) processes:

$$\epsilon_t, \Upsilon_t, \zeta_t^c, \zeta_t^h, g_t, \tilde{\phi}_t, \sigma_t, \gamma_t$$

Five shock processes are i.i.d.:

$$\tau_t^d, \tau_t^x, \tau_t^{m,c}, \tau_t^{m,i}, \tau_t^{m,x}$$

and five shock processes are assumed to follow a first-order SVAR:

$$y_t^*, \pi_t^*, R_t^*, \mu_{z,t}, \mu_{\Psi,t}.$$

As in CTW, two shocks are suspended in the estimation: the shock to unit-root investment specific technology, $\mu_{\Psi,t}$, and the idiosyncratic entrepreneur risk shock, σ_t. The first one should correspond to the foreign block but its identification is dubious in the particular SVAR model; the second has been found to have limited importance in CTW[9].

There are measurement errors except for domestic interest rate and the foreign variables. The variance of the measurement errors is calibrated to correspond to 10% of the variance of each data series.

4 Results

The domestic and foreign blocks are estimated separately since Latvia's economy has a minuscule effect on the euro area. The estimation results for the foreign SVAR model are obtained using a single Metropolis-Hastings chain with 100 000 draws after a burn-in of 900 000 draws. For the domestic block, the estimation results are obtained using two Metropolis-Hastings chains, each with 50 000 draws after a burn-in of 200 000 draws. Prior-posterior plots are relegated to the online appendix.

4.1 Posterior parameter values

The posterior parameter estimates for the domestic block are reported in Table 3, while those specific to the foreign SVAR are relegated to the online appendix. The priors were deliberately fixed to be the same across the two models for a more transparent comparison, and favor the baseline model. The estimated mode of the elasticity of substitution of investment goods parameter, η_i, is close to unity and thus the

[9] Christiano, Motto and Rostagno (2014) find (the anticipated part of) this shock important when loans are observable. My unpublished results show that fitting loans may require excessive amount of risk.

parameter is calibrated for the financial frictions model to 1.1, similar to the posterior mean in the baseline model, in order to avoid numerical issues.

The most notable difference between the estimated parameters across the models is in the investment adjustment costs parameter which is about 2.5 times lower for the financial frictions model compared to the baseline specification. They are statistically significantly different at a 5% significance level. The lower parameter indicates that the financial frictions model induces the gradual response that the investment adjustment mechanism was introduced to generate. Also, the estimated persistence parameter of the marginal efficiency of investment (henceforth MEI) shock is reduced (from 0.80 to 0.59) with the introduction of the financial frictions block. Regarding the estimated standard deviations of shocks, the financial frictions model assigns a smaller standard deviation to the marginal efficiency of investment shock, which, apparently, is 'crowded out' by the entrepreneurial wealth shock.

Comparing the overall fit of the models in terms of the marginal data density (based on a common set of observables and estimated parameters for both models), the posterior odds ratio is 1:3.5×10^{14} in favor of the financial frictions model (see Table 3).

4.2 Model moments and variance decomposition

4.2.1 Model moments

Table 4 presents the data and the model means and standard deviations for the observed time series. The table shows that there is a substantial variation of growth rates in the data, especially between the domestic and foreign variables, which is why real quantities, the domestic inflation rates and the real exchange rate are demeaned before matching the model to the data. The standard deviations are matched rather well but their over-estimation is evident for total hours, GDP, imports, as well as for the interest rate spread[10]. The introduction of the financial frictions block appears to slightly lessen this over-estimation issue.

Table 4: Data and (first-order approximated) model moments (in percent)

Variable	Explanation	Mean			Standard deviation		
		Data	Model baseline	Model finfric	Data	Model baseline	Model finfric
π	Domestic inflation	6.08	2.00	2.00	8.39	8.77	8.60
π^c	CPI inflation	5.62	2.00	2.00	6.29	8.78	8.71
π^i	Investment inflation	6.78	2.00	2.00	51.45	50.70	45.72
R	Nom. interest rate	7.06	6.04	6.04	5.86	5.75	6.37
Δh	Total hours growth	0.02	0.00	0.00	2.20	6.92	5.60
Δy	GDP growth	1.37	0.50	0.50	2.31	5.49	4.49
Δw	Real wage growth	1.06	0.50	0.50	2.35	2.95	2.91
Δc	Consumption growth	1.47	0.50	0.50	2.84	3.19	3.42
Δi	Investment growth	1.73	0.50	0.50	16.32	21.28	22.20
Δq	Real exch. rate growth	-0.88	0.00	0.00	2.51	2.28	2.27
Δg	Gov. expendit. growth	0.44	0.50	0.50	5.46	5.26	5.31
Δx	Export growth	2.19	0.50	0.50	3.41	3.70	3.61
Δm	Import growth	2.22	0.50	0.50	6.30	12.46	9.67
Δn	Stock market growth	1.32		0.50	10.38		14.78
$spread$	Interest rate spread	4.29		3.02	2.25		5.52
Δy^*	Foreign GDP growth	0.26	0.50	0.50	0.61	0.52	0.52
π^*	Foreign inflation	2.01	2.00	2.00	0.72	0.88	0.88
R^*	Foreign nom. int. rate	3.16	6.04	6.04	1.61	2.58	2.58

Note: 1) The model moments are theoretical, i.e. computed based on calibrated parameters or their posterior means. As such, the model moments are not subject to sampling uncertainty, as in the case of simulated moments.
2) The inflation and interest rates are annualized.

[10] CTW note that their use of 'endogenous prior' reduces the effect of over-estimated shock standard deviations. I'm not using such a prior.

4.2.2 Conditional variance decomposition

The conditional variance decomposition at eight quarters forecast horizon is reported in Table 5.

Table 5: Conditional variance decomposition (percent) given model parameter uncertainty at 8 quarters forecast horizon; posterior mean

	Description	model	R	π^c	GDP	C	I	$\frac{\text{NX}}{\text{GDP}}$	H	w	q	N	Spread
ϵ_t	Stationary technology	B	0.0	2.3	1.3	0.3	0.1	0.3	9.1	1.4	2.1		
		F	0.0	0.6	0.7	0.1	0.0	0.5	8.6	0.3	0.6	0.1	0.1
Υ_t	MEI	B	5.2	0.9	14.5	0.4	78.3	66.8	5.9	1.0	0.9		
		F	0.1	0.0	1.8	0.1	19.2	3.4	3.2	0.2	0.0	12.7	12.2
ζ_t^c	Consumption prefs	B	0.1	0.1	1.7	77.9	0.3	1.8	1.3	0.0	0.1		
		F	0.2	0.0	7.1	78.7	0.1	14.8	5.6	0.0	0.0	0.1	0.1
ζ_t^h	Labor prefs	B	0.1	14.1	5.6	3.5	1.1	0.8	5.5	41.4	12.7		
		F	0.1	10.1	5.8	4.0	1.0	6.6	8.0	51.7	9.3	2.0	0.6
τ_t^d	Markup, domestic	B	0.0	34.6	2.1	0.1	0.1	0.3	1.4	43.4	31.3		
		F	0.0	22.7	2.2	0.1	0.1	0.3	1.8	33.0	20.8	0.5	0.1
τ_t^x	Markup, exports	B	0.0	0.0	1.3	0.0	0.0	0.0	1.0	0.0	0.0		
		F	0.0	0.0	2.3	0.0	0.0	0.0	1.8	0.0	0.0	0.0	0.0
τ_t^{mc}	Markup, imp. for cons.	B	0.0	36.8	1.6	0.0	0.0	0.3	1.3	2.3	33.2		
		F	0.0	59.1	4.1	0.1	0.0	1.1	3.2	3.9	54.1	0.1	0.0
τ_t^{mi}	Markup, imp. for inv.	B	0.9	3.8	29.8	0.1	5.8	11.9	42.5	1.5	3.4		
		F	0.1	0.3	23.3	0.0	5.4	6.0	34.4	0.1	0.3	7.9	6.1
τ_t^{mx}	Markup, imp. for exp.	B	0.3	0.1	35.6	0.1	0.1	6.2	27.8	0.1	0.1		
		F	0.1	0.0	28.4	0.1	0.1	6.2	22.8	0.1	0.0	0.2	0.1
γ_t	Entrepreneurial wealth	B											
		F	0.7	0.6	10.1	0.2	58.1	38.9	1.1	0.6	0.5	62.4	77.3
$\tilde{\phi}_t$	Country risk premium	B	86.0	0.2	0.6	1.2	3.1	7.1	0.3	0.6	0.1		
		F	91.8	0.4	2.2	5.5	8.7	17.8	0.8	3.1	0.4	9.4	1.7
$\mu_{z,t}$	Unit-root technology	B	1.7	0.1	0.2	0.2	0.1	1.4	0.0	0.4	0.3		
		F	1.7	0.0	0.2	0.0	0.1	1.4	0.0	0.2	0.2	0.1	0.0
$\epsilon_{R^*,t}$	Foreign interest rate	B	1.8	0.1	0.0	0.1	0.3	0.8	0.0	0.0	0.0		
		F	1.6	0.1	0.1	0.3	0.3	0.7	0.0	0.1	0.0	0.2	0.0
$\epsilon_{y^*,t}$	Foreign output	B	3.7	0.2	0.0	0.3	0.5	2.3	0.0	0.1	0.2		
		F	3.6	0.1	0.0	0.8	0.2	2.1	0.0	0.3	0.2	0.0	0.0
$\epsilon_{\pi^*,t}$	Foreign inflation	B	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1		
		F	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
	5 foreign*	B	93.3	0.5	0.8	1.7	4.0	11.6	0.4	1.2	0.7		
		F	98.7	0.6	2.6	6.6	9.3	22.0	0.8	3.6	0.9	9.7	1.8
	All foreign**	B	94.5	41.2	69.1	1.9	9.9	30.0	73.0	5.1	37.5		
		F	98.9	60.1	60.7	6.8	14.9	35.3	63.1	7.8	55.3	17.9	8.0

Note: R - nominal interest rate, π^c - CPI inflation, C - real consumption, I - real investment, NX/GDP - net exports to GDP ratio, H - total hours, w - real wage, q - real exchange rate, N - real net worth.
$*$ '5 foreign' is the sum of the foreign stationary shocks, R_t^*, π_t^*, Y_t^*, the country risk premium shock, $\tilde{\phi}_t$, and the world-wide unit root neutral technology shock, $\mu_{z,t}$.
$**$ 'All foreign' includes the above five shocks as well as the markup shocks to imports and exports, i.e. τ_t^{mc}, τ_t^{mi}, τ_t^{mx} and τ_t^x. 'B' - baseline model, 'F' - financial frictions model.

Entrepreneurial wealth shock versus marginal efficiency of investment shock Table 5 shows that the entrepreneurial wealth shock, which is specific to the financial frictions model and absent from the baseline model, 'crowds out' the marginal efficiency of investment (MEI) shock by reducing its share of explaining the variance of investment from 78% (baseline) to 19% (financial frictions model), the variance of net exports to GDP ratio from 67% to 3%, and the variance of GDP from 15% to 2%.[11]

The entrepreneurial wealth shock explains 10% of the variance of GDP, 58% of the variance of investment, 39% of the net exports to GDP ratio, 62% of entrepreneurial net worth and 77% of the spread between the nominal interest rate paid by the entrepreneur and the risk-free one.

[11] As a reminder, MEI shock enters in the capital accumulation equation and affects how (efficiently) investment is transformed into capital. This is the shock whose importance is emphasized in Justiniano, Primiceri and Tambalotti (2011), where one of their interpretations of this shock being a proxy for the effectiveness with which the financial sector channels the flow of the household savings into a new productive capital.

CTW do not report the conditional variance decomposition for the baseline model, but with the financial frictions together with the search and matching frictions in labor market (without additional shock added) which are absent in my financial frictions model. Also, their model is estimated for Swedish data with inflation-targeting monetary policy. Nevertheless, it is instructive to compare the results of CTW with mine. The results of CTW suggest that, when financial frictions mechanism is present, MEI shock explains 10% of the variance of investment, 7% of the variance of net exports to GDP ratio, and 4% of the variance of GDP. Also, the entrepreneurial wealth shock explains 71% of the variance of investment, 23% of the variance of the net exports to GDP ratio, 25% of the variance of GDP, 64% of entrepreneurs' net worth, and 60% of the variance of the spread. CTW briefly mention, but do not report in tables, the effect of shutting down the financial shock in their model. In that case, MEI shock becomes more important in the variance decomposition: it explains 52% of the variance of investment and 6% of GDP. These results are broadly in line with mine except for the variance of investment which appears to be better explained by the entrepreneurial wealth shock than by MEI shock in Sweden compared to Latvia. The difference is likely due to the milder response of entrepreneurial net worth to the wealth shock in Latvia compared to Sweden, reflecting the fact that Swedish financial markets are more developed.

Country risk premium shock Table 5 also reports that the country risk premium shock is the major driving force of the domestic nominal interest rate and an important factor for Latvia's investment. This is more so in the financial frictions model compared to the baseline. So, for the given sample of 1995Q1-2012Q4, the country risk premium shock explains 92% of the variance of the domestic nominal interest rate (versus 86% in baseline), 9% of the variance of investment (versus 3% in baseline), 2% of the variance of GDP (versus 1% in baseline), 18% of the variance of net exports to GDP ratio (versus 7% in baseline) and 9% of the variance of the entrepreneurs' net worth.

Comparing to the results of CTW, there are big differences. For Sweden, this shock explains only 5% of the variance of nominal interest rate, 1% of the variance of investment, and 1% of the variance of net worth, while the variance of GDP is explained by about the same amount as in Latvia. The reason for the difference is that, during the specific historic sample, the domestic nominal interest rate in Latvia has been higher than in the euro area and given that, in the model, Latvia's currency is hard-pegged to the euro, the (huge historic) difference between the actual domestic and foreign interest rates is explained by the country risk premium. It is expected that, since Latvia's joining the euro area in 2014, the weight of the country risk premium shock on the domestic interest rate will diminish, giving more influence to the euro area-wide shocks.

Shocks in the foreign economy block The effect of the foreign interest rate, foreign output and foreign inflation shocks on the domestic economy is estimated to be rather limited, with the greatest influence being to the domestic nominal interest rate. The unit-root technology shock also has been estimated to have little influence on the domestic economy during the particular historic period.

These results are broadly close to the results of CTW who also find negligible role of the shock to foreign interest rate, foreign output and foreign inflation to Swedish economy. Though, their estimated effect of the unit-root technology shock is more influential, explaining 4.1% of the variance of Swedish GDP compared to 0.2% for Latvia's GDP. The latter result might be explained by the fact that, during the particular historic episode, Latvia's economy has been on its more or less idiosyncratic catching-up boom-bust cycle, while the more developed Swedish economy has been more reliant on the world-wide technology growth. Also, CTW estimate this shock based on the trade-weighted foreign variables, while I use the euro area variables, thus the link (the common technology) between the domestic and foreign variables is looser in my case.

Stationary neutral technology shock While touching upon technology shocks, another difference between CTW results for Sweden and mine for Latvia is in the effect of the stationary neutral technology shock affecting the intermediate goods producers' production function. This shock is estimated to have minor influence on Latvia's economy except for total hours worked (9% of the variance explained by this shock).

CTW estimation shows that this shock explains about the same portion of the variance of hours worked but also 11% of the variance of consumption (0.1% for Latvia), 9% of the variance of GDP (0.7% for Latvia), 6% of CPI inflation (0.6% for Latvia) and 8% of the domestic nominal interest rate (0.0% for Latvia). Apparently, other domestic shocks have compensated the lack of influence of the stationary technology shock on Latvia's economy.

Household preference shocks Noticeable, the *consumption* preference shock explains 79% of the variation of consumption in Latvia, whereas 'only' 45% in Sweden. This difference might be explained by the strong consumption-driven boom that Latvia experienced starting around 2004 (see the historic shock decomposition below).

The *labor* preference shock is estimated to have similar effect on both countries with respect to wages; this shock is estimated to explain 52% and 39% of the variance of real wages in Latvia and Sweden, respectively. The effect on total hours worked differ, but this is probably due to the different structure of labor market modeling block in the models.

Domestic markup shock The domestic markup shock, affecting marginal cost of producing the domestic intermediate good, is estimated to explain 23% of Latvia's CPI inflation (45% in Sweden) and 33% of the variance in real wage (31% in Sweden). This completes the similarities of this shock across the countries, since, given Latvia's peg regime, this shock explains 21% of the variance of Latvia's real exchange rate (0.2% in Sweden), while in Sweden, it affects, through Taylor rule, the nominal interest rate, and parts of real economy stronger than in Latvia; e.g. it explains 7% of the variance of Swedish GDP and 3% of the variance of Swedish investment, while these figures are 2% and 0.1% for Latvia.

Export goods markup shock Table 5 shows that the markup shock to export goods is estimated to have little effects on Latvia's economy; the only noticeable ones are the 2% (up from 1% in baseline) of the variance of GDP and hours worked, while in Sweden these figures are 8% and 10%, respectively. Again, given the model differences, it is hard to point exact source of the discrepancy. A small part of the difference[12] is due to the higher calibrated imported goods share in exports for Latvia (55%) than for Sweden (35%), resulting in a smaller effect of the exports markup on Latvia's GDP and hence hours worked, since the markup to imports for exports is subject to a separate shock.

Imports markup shocks The *imports for exports* markup shock, indeed, has more weight on Latvia's economy than on Swedish: it is estimated to explain 28% of the variance of Latvia's GDP (16% for Sweden) and 23% of the variance of total hours worked in Latvia (14% in Sweden).[13]

Regarding the rest of the imports goods markup shocks, the *imports for consumption* markup shock explains the majority, 59% of the variance of the the domestic CPI inflation (up from 37% in baseline and 34% in Sweden), and hence is the major shock affecting the real exchange rate - it explains 54% (up from 33% in baseline) of the variance of Latvia's real exchange rate, while in Sweden, this shock explains, through Taylor rule, 17% of the variance of the nominal interest rate but less so the real exchange rate. In contrast to the domestic markup shock, the imports for consumption markup shock is estimated to have a non-negligible effect on Latvia's GDP - it explains 4% of the variance of Latvia's GDP, while only 0.2% of Swedish GDP. The importance of this effect, again, can be explained by the strong consumption-driven boom Latvia's economy experienced during the considered sample span.

Finally, the *imports for investment* markup shock explains 5% of the variance of investment, 23% of the variance of GDP, and 34% (down from 43% in baseline) of the variance of total hours worked. Quite differently, this shock is estimated to have negligible effect on Swedish economy. The explanations for the difference might be i) the higher calibrated import share in investment goods for Latvia (65%) than in Sweden (43%), ii) the differences in the structure of the labor market block, and iii) the noise in Latvian investment inflation data.

Foreign shocks combined Overall, if the foreign shocks are defined as the three foreign (interest rate, output, inflation) stationary shocks, the country risk premium shock, the world-wide unit root neutral technology shock, the markup shocks to imports (imports for exports, consumption, investment) and exports - in total, nine shocks - see the bottom row of Table 5, then they explain 99% of the variance in the domestic nominal interest rate (up from 28% in Sweden), the overwhelming part explained by the country risk premium shock. Also, 60% and 61% of the variations of CPI inflation and GDP, respectively, (versus 40% and 32% in Sweden) at two year forecast horizon are explained by the foreign shocks, the

[12] I have checked this claim by recalibrating the model.

[13] My unpublished results show that when data measurement errors are estimated, the imports for exports markup shock is almost eliminated. The true source of this shock is yet to be determined.

overwhelming portion coming from markup shocks to imports for consumption and domestic goods (for CPI inflation) and to imports for exports and imports for investment (for GDP).

Since, in the literature, the sources of business cycles are largely related to fluctuations in investment, the major source of the variance of investment in Latvia is estimated to be the entrepreneurial wealth shock. Given the evidence from Sweden, the influence of this shock is to be expected to grow as Latvia's firms become more financially integrated.

4.3 Impulse response functions

Since Table 5 shows that the entrepreneurial wealth shock is the main driver of the variance of investment in the financial frictions model and that it 'crowds out' MEI shock from the baseline model, it is instructive to compare the impulse response functions (henceforth IRF) of these two shocks.

Entrepreneurial wealth shock The IRF to the entrepreneurial wealth shock are plotted in Figure 1, which shows that a positive temporary entrepreneurial wealth shock, γ_t, drives up the net worth, reduces the expected bankruptcy rate and thus the interest rate spread, and increases the investment (by about the same percentage change as in net worth); GDP goes up accordingly, and so do the real wage and total hours worked. Both exports and imports increase but the latter increases more due to the demand for investment goods, thus net exports to GDP ratio decreases slightly. As a consequence, the net foreign assets to GDP ratio worsens, driving up a slight risk premium on the domestic nominal interest rate. The shock causes the cost of investment to decrease, and consumption to pick up only steadily. Therefore, CPI inflation decreases, though by a small amount, and thus the real exchange rate depreciates.

The response of net worth to this and other shocks is quite muted, i.e. its dynamics appear to die out in a few periods. This observation together with the autocorrelated measurement error of net worth suggest that the stock market price index might be a weak proxy for net worth in Latvia, and thus other potential measures, such as the house price index, could be investigated. Such an option is left for future research.

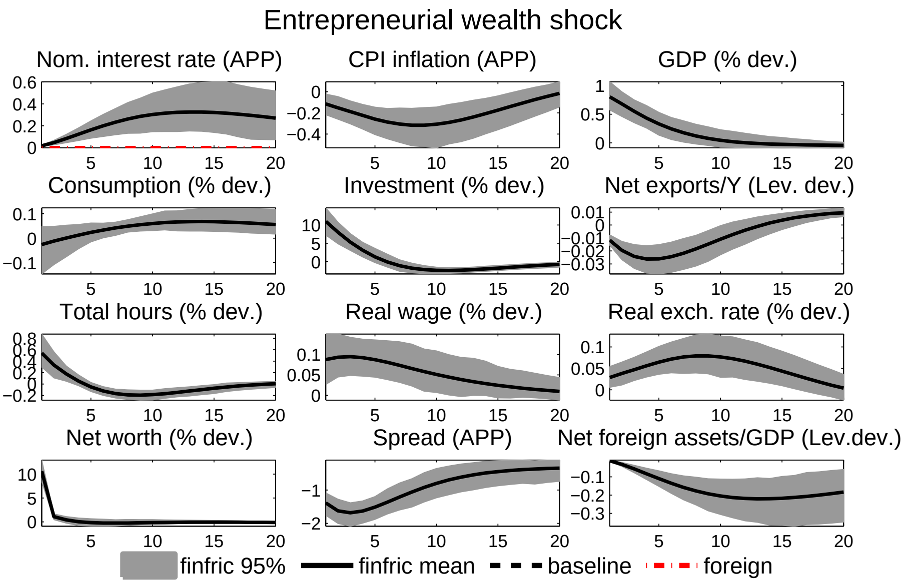

Fig. 1: Impulse responses to the entrepreneurial wealth shock, γ_t.

Note: The units on the y-axis are either in terms of percentage deviation (% dev.) from the steady state, annual percentage points (APP), or level deviation (Lev. dev.).

MEI shock Comparing the wealth shock to a temporary MEI shock, Figure 2 shows that the effect of MEI shock in the baseline model is qualitatively similar to the effect of the wealth shock in the financial frictions model (except for the effect on consumption which decreases initially), but the introduction of financial frictions dampens the effect of MEI shock on all plotted variables (and consumption now slightly increases). The changes in IRF are statistically significant at a 5% significance level. The effect of these shocks on net worth and the spread is opposite; this is how the two shocks are distinguished in the financial frictions model.

MEI shock increases the amount of capital per investment and thus the price of capital decreases. Consumption barely moves, thus MEI shock has a downward pressure on prices.

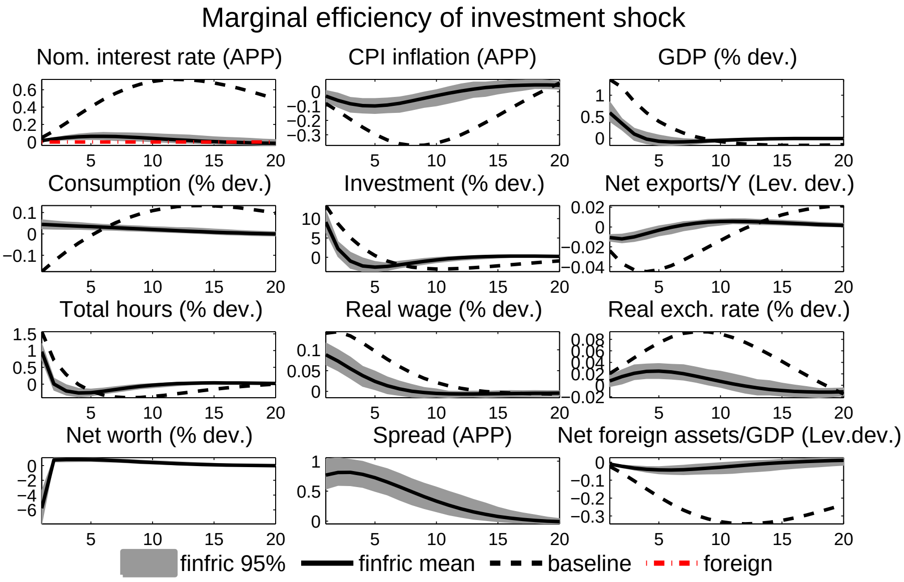

Fig. 2: Impulse responses to the marginal efficiency of investment shock, Υ_t.

Note: The units on the y-axis are either in terms of percentage deviation (% dev.) from the steady state, annual percentage points (APP), or level deviation (Lev. dev.).

Country risk premium shock Figure 3 shows the IRF to a temporary country risk premium shock. As Table 5 shows, this shock is the major cause of the variance of the domestic nominal interest rate. The effects are qualitatively similar across the models but the financial frictions mechanism somewhat amplifies them. The shock increases the domestic nominal interest rate which decays towards its steady state with persistence. This is followed by a decrease in consumption and entrepreneurial net worth, an increase in the spread and the bankruptcy rate (both reverse the sign after a year), and a decrease in investment (initially, about twice as much with financial frictions mechanism compared to the baseline), GDP, real wage, and total hours worked. Imports decrease more than exports, resulting in a negligible increase in net exports to GDP ratio. CPI inflation decreases for about two years. The real exchange rate thus depreciates for the first two years after the shock.

Foreign nominal interest rate shock Table 5 shows that the foreign nominal interest rate shock has little influence on the domestic economy during the particular historic period; nevertheless, policy-makers are usually interested in what happens when the policy rate changes, and it is the European Central Bank's policy rate that matters for Latvia after it joined the euro area in 2014. Figure 4 shows that a positive temporary foreign nominal interest shock increases both the foreign and the domestic nominal interest rate by the same amount, and both decay towards their steady state slowly. Consumption, investment and entrepreneurial net worth decrease, bankruptcy rate increases (for the first year) and, as a result, so does the spread. GDP decreases, so do real wage and total hours worked. There is a negligible increase in net exports to GDP ratio due to a decrease in imports. Thus, the net foreign assets to GDP ratio

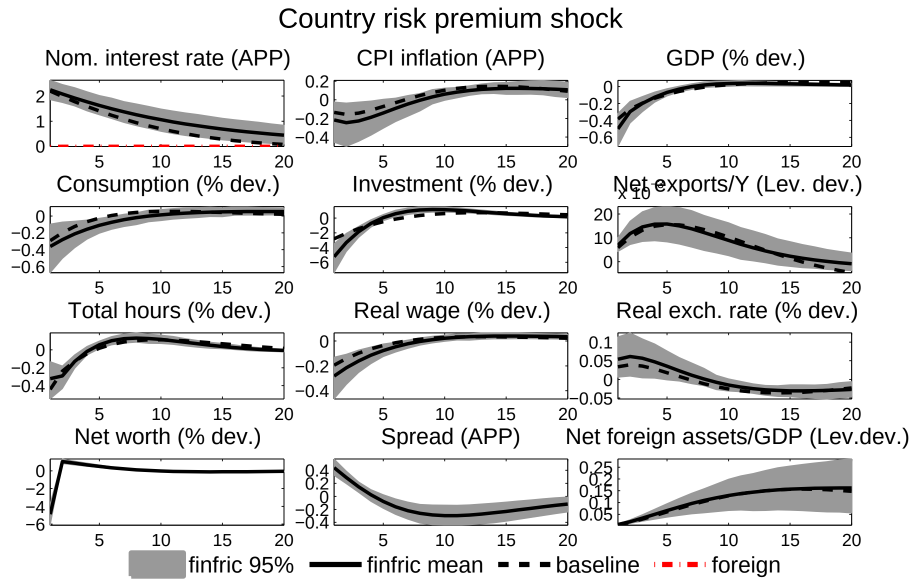

Fig. 3: Impulse responses to the country risk premium shock, $\tilde{\phi}_t$.

Note: The units on the y-axis are either in terms of percentage deviation (% dev.) from the steady state, annual percentage points (APP), or level deviation (Lev. dev.).

increases slightly, fostering a decrease of the domestic country risk premium, and therefore, also of the domestic nominal interest rate. CPI inflation decreases due to the slower domestic activity. The domestic inflation decreases by a larger amount than the foreign inflation, resulting in the initial depreciation of the real exchange rate. The effect is similar across the models except for the more persistent dynamics of the nominal interest rate under the financial frictions mechanism.

The impulse response functions are similar between the country risk premium and the foreign nominal interest rate shocks, thus signaling the potential identification issues of these two shocks. The particular procedure of estimating the foreign SVAR separately from the domestic block mitigates the identification problem somewhat. The replacement of the foreign SVAR with a full-blown foreign DSGE block could be a cure since it would identify the foreign monetary policy better but at the cost of model complexity.

The rest of the IRF are plotted in the online appendix.

4.4 Historical shock decomposition

Figures 5 to 10 show the historic shock decomposition of GDP, CPI inflation and the interest rate spread.

GDP Concentrating on the most sizable shocks, Figure 5 shows that the model identifies the shock to household consumption preferences as the most important driving force of the 2004-boom. During the period of 2004-2007, the values of this shock were persistently above the sample average (see smoothed shock figures in the online appendix), signifying that households were especially keen on spending on consumption goods during that period. The shock ceased during the second half of 2007, probably due to the rising costs of living and thus the decreasing consumer confidence (the latter claim is backed by the ECFIN consumer survey data). At that time several other shocks became adverse, including the stationary and unit-root neutral technology shocks, and the risk premium shock. Starting from 2008 and up to 2011, a series of negative entrepreneurial wealth shocks is identified to have significantly affected GDP growth. In fact, this shock has become the major source determining the GDP level during the post-recession episode. In the model, the dynamics of the entrepreneurial wealth is observable and measured by the NASDAQ OMX Riga share price index, which plummeted during the recession. In practice, it is likely that the variable captures also a part of the dynamics in the real estate prices (otherwise, the real estate sector is not present in the model), which also fell sharply during the recession as a result of the burst of the housing bubble.

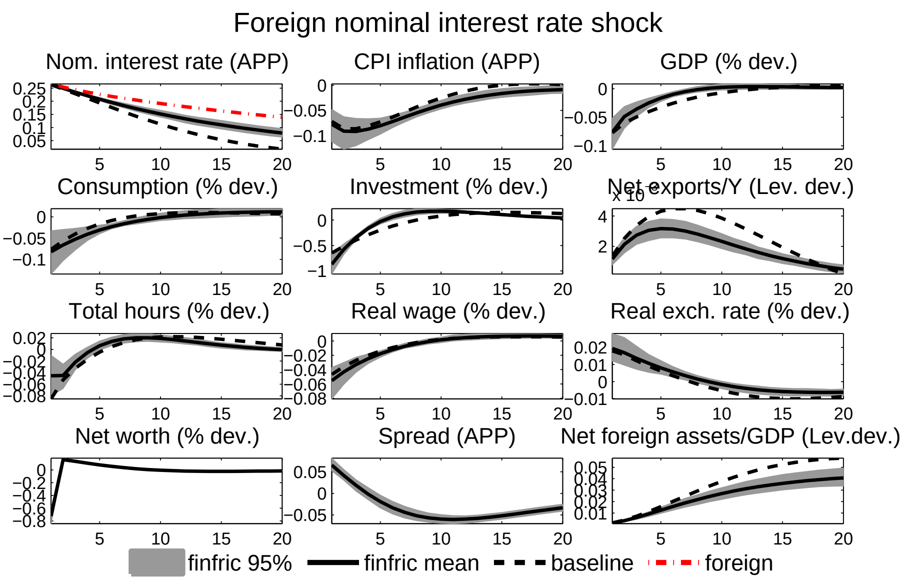

Fig. 4: Impulse responses to the foreign nominal interest rate shock, $\epsilon_{R^*,t}$.

Note: The units on the y-axis are either in terms of percentage deviation (% dev.) from the steady state, annual percentage points (APP), or level deviation (Lev. dev.).

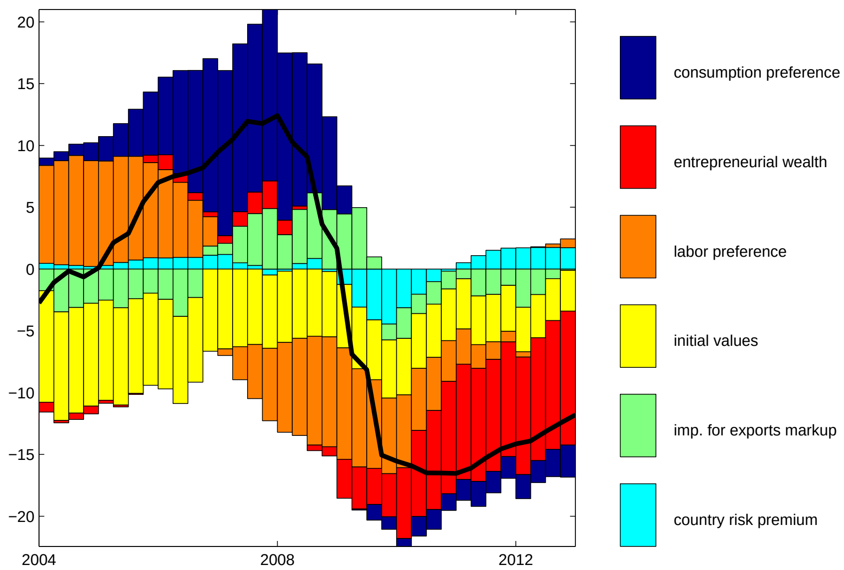

Fig. 5: Decomposition of GDP less its measurement error (log-levels; deviation from a steady state), 2004Q1-2012Q4.

Note: Financial frictions model. Only the six shocks with the greatest influence shown.

For comparison, Figure 6 shows the growth decomposition delivered by the baseline model. The baseline model identifies MEI shock as one of the most important shocks driving the 2004-boom and the subsequent recession. According to the baseline model, MEI shock has contributed negatively over the whole post-recession period, which is not easy to interpret.

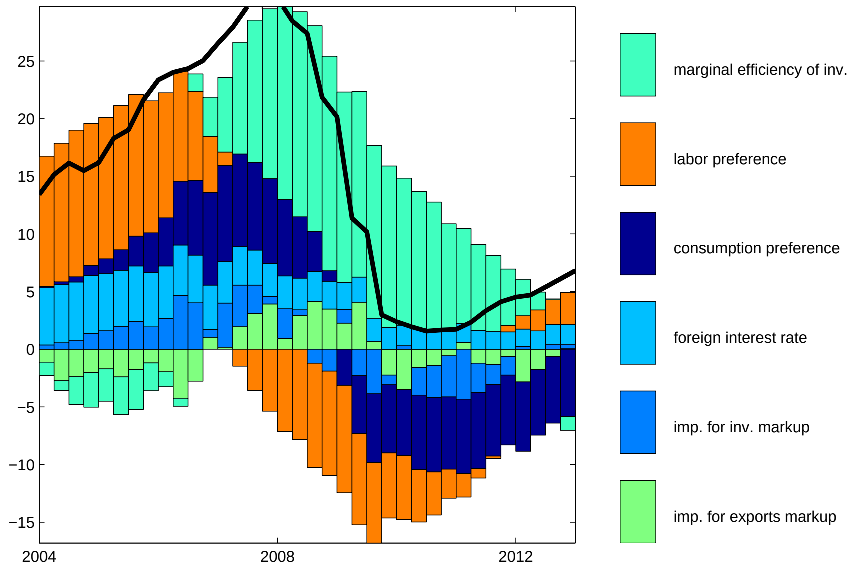

Fig. 6: Decomposition of GDP less its measurement error (log-levels; deviation from a steady state), 2004Q1-2012Q4, baseline model.

Note: Only the six shocks with the greatest influence shown.

Therefore, having the financial frictions block in the model both clarifies and changes the story. First, the entrepreneurial wealth shock behaves differently than MEI shock, since the former has played little role during the boom period. Thus, consumption preferences are left as the single most important factor creating the 2004-boom. Second, the entrepreneurial wealth shock is more easily understandable force that has deepened the recession but ceased to be active during the post-recession episode. On the contrary, in the baseline model, the ever-active MEI shock during the post-recession period is harder to explicate.

The results of the financial frictions model are supported by a model-free decomposition of GDP annual growth into its expenditure components, which shows that the GDP 2004-boom was driven mainly by private consumption, and the 2008-bust resulted in a sharp decline in both private consumption and gross fixed capital formation (Figure 7).

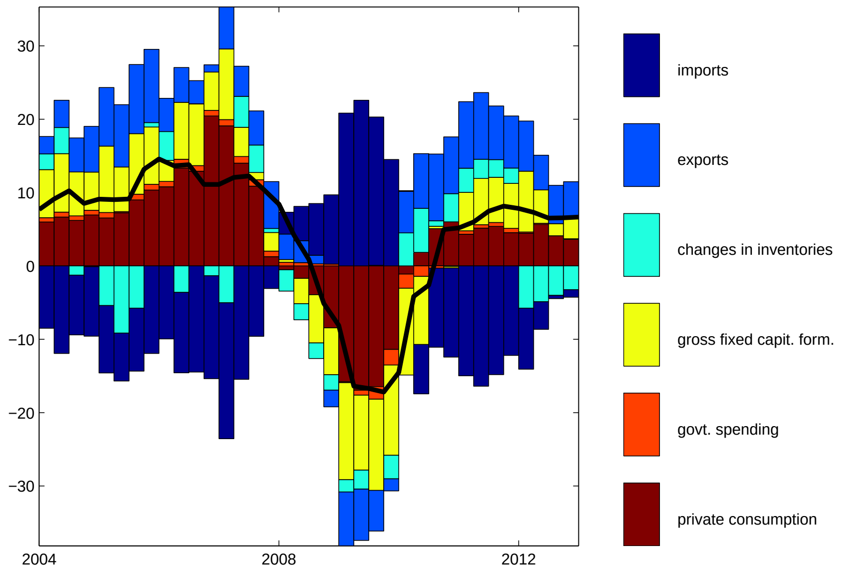

Fig. 7: Model-free decomposition of GDP (undemeaned annual growth rates) into its expenditure components, 2004Q1-2012Q4.

Note: Seasonally adjusted series are used, thus the sum of the contributions of components do not exactly match the GDP growth rates.

CPI inflation Figure 8 shows that the model identifies the shock to household labor preferences as the major driving force of Latvia's CPI inflation up in the 2004-boom, coupled with the imports for consumption markup shock in 2007-2008, and these same shocks together with the domestic markup shock drew CPI inflation down in 2009.

The labor preference shock reflects the household willingness to work[14]. The model identifies that, during the period of 2005-2007 households in Latvia were keen to work less (and to consume more), relative to the sample average. The disutility from work arose probably due to the rapidly growing economy and thus the relatively easy money available for spending. Tight labor market drove wages up to compensate for the household disutility from work; and that in turn, pushed the price of consumption goods up. Beginning in late 2008 and continuing until the sample ends in 2012Q4, the labor preference shock is identified to have downward pressure on CPI inflation, which could be explained by the increased necessity to earn a living due to lower wages and fewer job opportunities.

The markup shock to imports for consumption goods raises the price of imports for consumption goods. The model identifies that the level of this shock was persistently above its sample average during the year 2008, the time at which the consumption preference shock had already become flat or even negative, and coinciding with the period of the above average foreign inflation shock (unaffected by the domestic block, since estimated separately) and the peak in both crude oil and natural gas prices. It is likely that the imports for consumption markup shock captures the increase in the cost of energy, since the price of energy is not present in the model but through foreign inflation. Apparently, the foreign inflation variable is not able to fully represent the dynamics of imported costs, thus the rest is absorbed by the markup shock. For example, the price of natural gas affects the heating bills. It was a matter of fact that heating bills rose during the year 2008, constituting up to three percentage points of the annual inflation at that time. Overall, the model suggests that the imports for consumption markup shock constituted about a half of the annual CPI inflation during the year 2008.

The domestic markup shock affects the marginal cost of domestic production before it is affected by the foreign markup shocks. The model identifies a series of negative domestic markup shock during

[14] The labor preference shock reflects the supply side in the labor market, and thus it can be affected by 'long-run' factors such as demographics and labor force participation rate. Indeed, the latter increased during the boom years in 2006-2007 and decreased during the recession in 2009-2010. Therefore, the participation rate has dampened the cyclical fluctuations of the labor preference shock. See Christiano, Trabandt and Walentin (2010) for a model with endogenous participation rate.

2009 (probably due to the easing in labor market, the reforms in the public sector, postponed investment projects or dividend payments by firms), and partly rebalancing during late 2010-2011, which pushed CPI inflation upwards.

The presence of the financial frictions block in the model reduces the role of MEI shock and stationary technology shock on CPI inflation, see Figure 9.

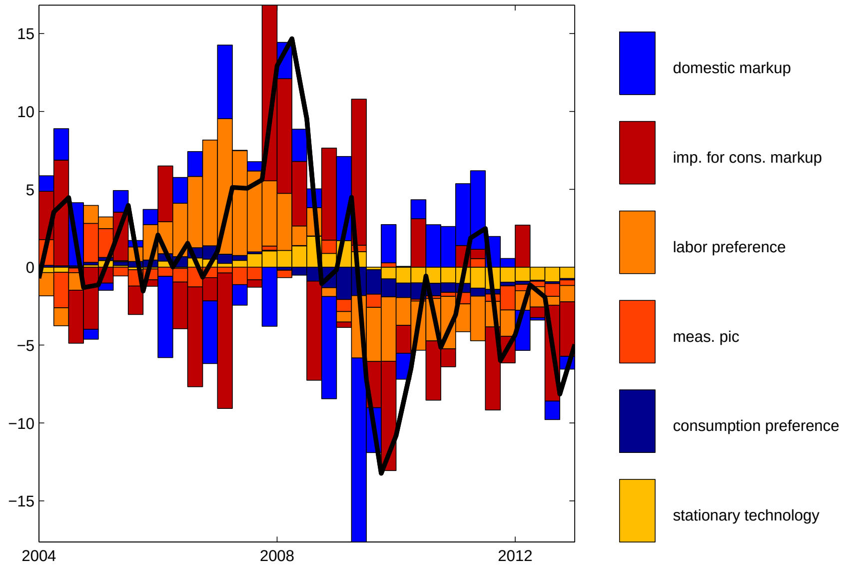

Fig. 8: Decomposition of CPI, 2004Q1-2012Q4.

Note: Financial frictions model. Only the six shocks with the greatest influence shown.

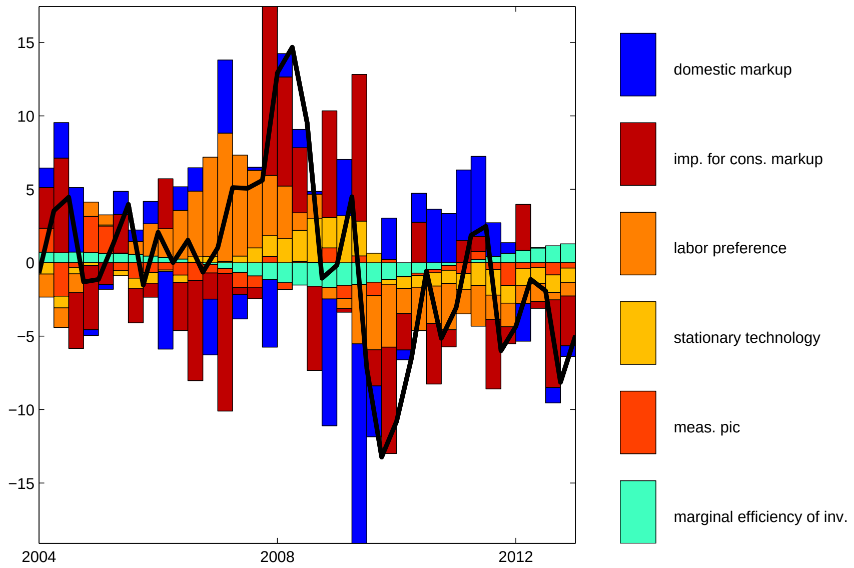

Fig. 9: Decomposition of CPI, 2004Q1-2012Q4, baseline model.

Note: Only the six shocks with the greatest influence shown.

Interest rate spread Figure 10 shows that the entrepreneurial wealth shock is the main driving force behind the interest rate spread. The increased spread in the 2008-recession is explained mainly by a negative temporary wealth shock. MEI shock has also contributed to affect the spread but its role has been different from the wealth shock: MEI shock's contribution has been mild during the recession episode. Rather, it has contributed to reduce the spread during the boom period (as the wealth shock but to a greater extent) and during the years 2011-2012 (counteracting the wealth shock). Again, as MEI shock is ad hoc, it is not easy to interpret it.

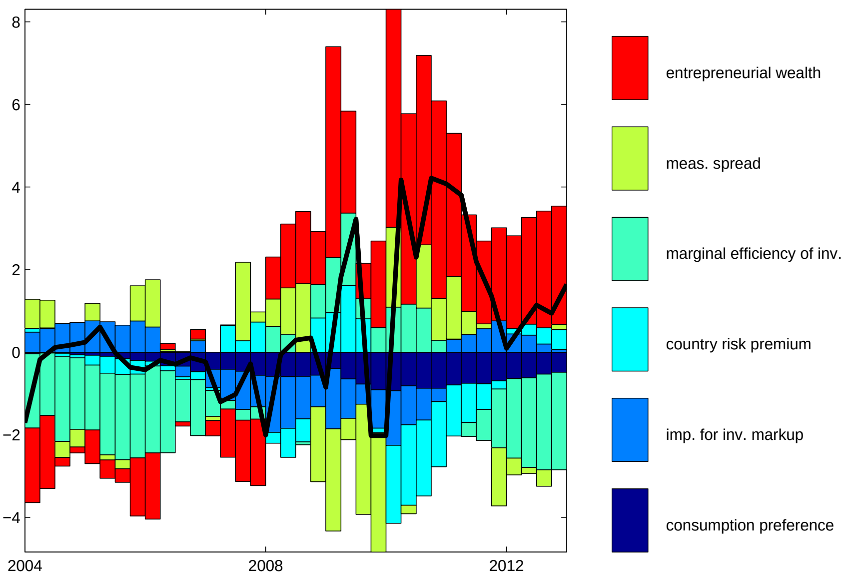

Fig. 10: Decomposition of interest rate spread, 2004Q1-2012Q4.

Note: Financial frictions model. Only the six shocks with the greatest influence shown.

4.5 Forecasting performance

Figures 11 to 13 show one-step ahead forecasts of the baseline and the financial frictions models for all the observables. These are not true out-of-sample forecasts because the model is calibrated/estimated on the whole sample period 1995Q1-2012Q4. Nevertheless, these figures indicate approximate forecasting performance of the models. Particularly, it is informative to see whether the models tend to yield unbiased forecasts. The results show that the models forecast relatively well. No crucial biases are evident, except for the CPI inflation which appears to be slightly upward biased. The total hours worked forecasts are rather volatile, inducing this volatility in the GDP series.

Table 6 reports the forecasting performance of the baseline and financial frictions models relative to a random walk model (in terms of quarterly growth rates) with respect to predicting CPI inflation and GDP growth for horizons: one, four, eight and 12 quarters. I also report the forecasting performance of a Bayesian SVAR on three domestic variables: GDP, CPI and nominal interest rate (with the same structure as the foreign SVAR, and with similar priors), since it is often taken as a benchmark in the literature[15]. Table 6 shows that both models forecast both variables at least as precisely as the random walk model at all horizons considered. Both models outperform the random walk by about 30% in forecasting both variables for horizons two to three years, and deliver about the same precision at a one quarter horizon. Moreover, the financial frictions model tends to deliver somewhat more precise forecasts than the baseline model of both CPI inflation and GDP growth, with the forecast differences being statistically significant at shorter horizons in terms of Diebold-Mariano test statistic. Table 6 also indicates that the DSGE model does not lose much to the SVAR model in terms of forecasting precision.

Thus, the model can be used not only for policy studies but also for forecasting purposes. The results from our forecasting exercise are similar to those of CTW who also find that the financial frictions model tends to outperform the baseline model.

[15] The particular SVAR has some economically implausible estimated parameters, since Latvian GDP, CPI inflation and nominal interest rate data do not possess a stable and economically plausible relationship over the particular sample span.

Model	Distance measure	1Q π^c	1Q Δy	4Q π^c	4Q Δy	8Q π^c	8Q Δy	12Q π^c	12Q Δy
Baseline	RMSE	1.04	1.01	0.82	0.74	0.67	0.64	0.71	0.64
	MAE	0.99	1.25	0.86	0.78	0.74	0.63	0.71	0.66
Financial frictions	RMSE	1.00	0.96	0.78	0.70	0.65	0.64	0.68	0.64
	DM p-val	0.492	0.319	0.113	0.059	0.101	0.071	0.080	0.091
	MAE	0.93	1.15	0.80	0.69	0.70	0.57	0.66	0.60
	DM p-val	0.279	0.900	0.125	0.025	0.117	0.058	0.070	0.104
SVAR	RMSE	0.86	0.72	0.71	0.81	0.62	0.68	0.63	0.66
	MAE	0.89	0.71	0.70	0.77	0.62	0.62	0.58	0.61
Finfric vs Baseline	DM p-val (RMSE)	0.006	0.005	0.018	0.111	0.162	0.451	0.136	0.516
	DM p-val (MAE)	0.001	0.000	0.011	0.053	0.069	0.125	0.089	0.090

Table 6: Root mean squared forecast error (RMSE) and mean absolute forecast error (MAE) compared to the random walk model.

Note: 1) For RMSE and MAE, a number less than unity indicates that the model makes more precise forecasts compared to the random walk model.
2) DM p-val is a one-sided p-value of the Diebold-Mariano (Diebold and Mariano, 1995) test for equal forecast accuracy between two models. Its value below 0.05 implies that the precision of a model's forecasts is better than the alternative's at a 5% significance level. The last row of the table compares the financial frictions model versus baseline model.
3) SVAR is estimated on three domestic variables: GDP, CPI and nominal interest rate, and is of the same structure and with similar priors as the foreign SVAR.
4) Note that this is not a true out-of-sample forecasting performance since the models have been estimated on the whole sample period 1995Q1-2012Q4.

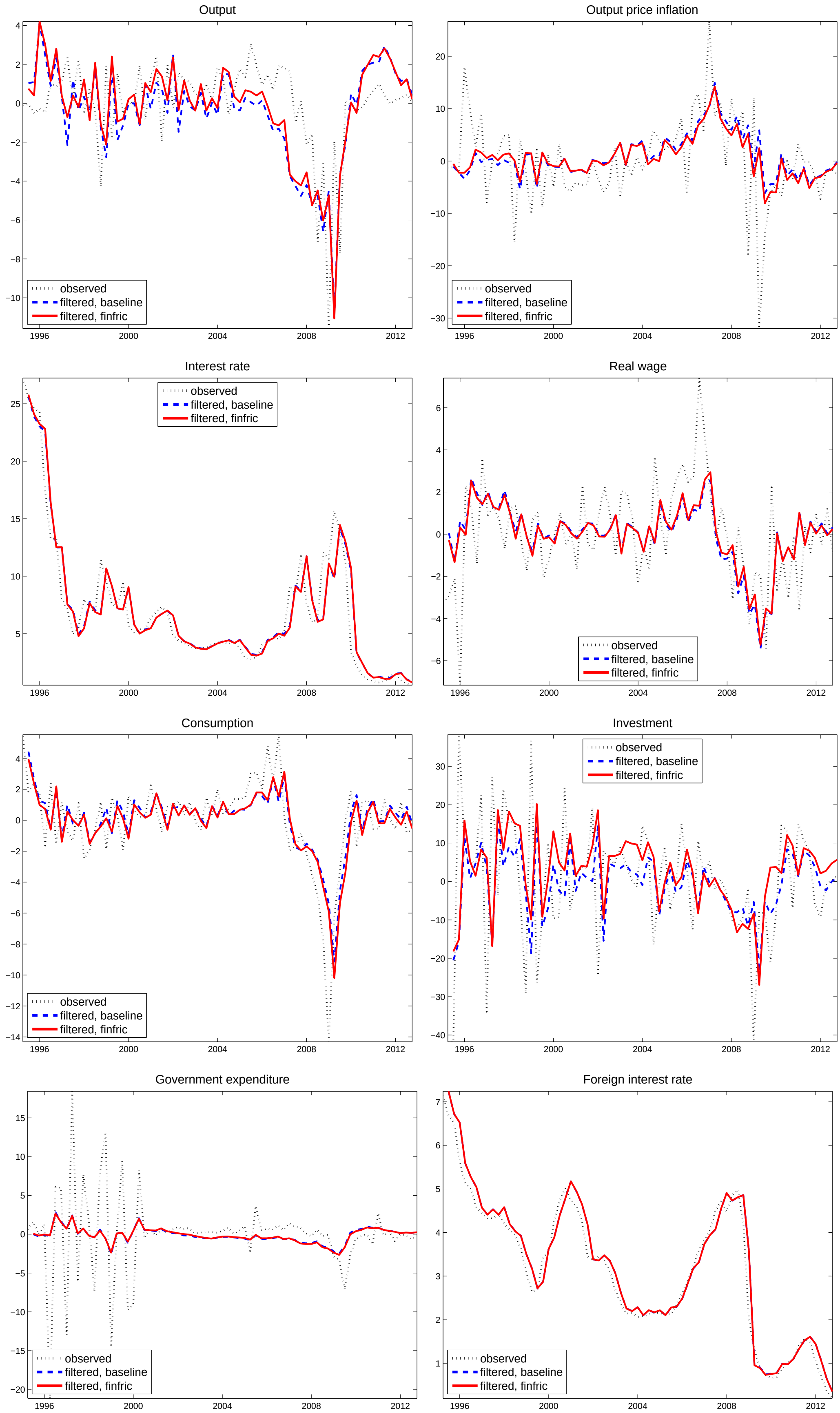

Fig. 11: One-step ahead forecasts

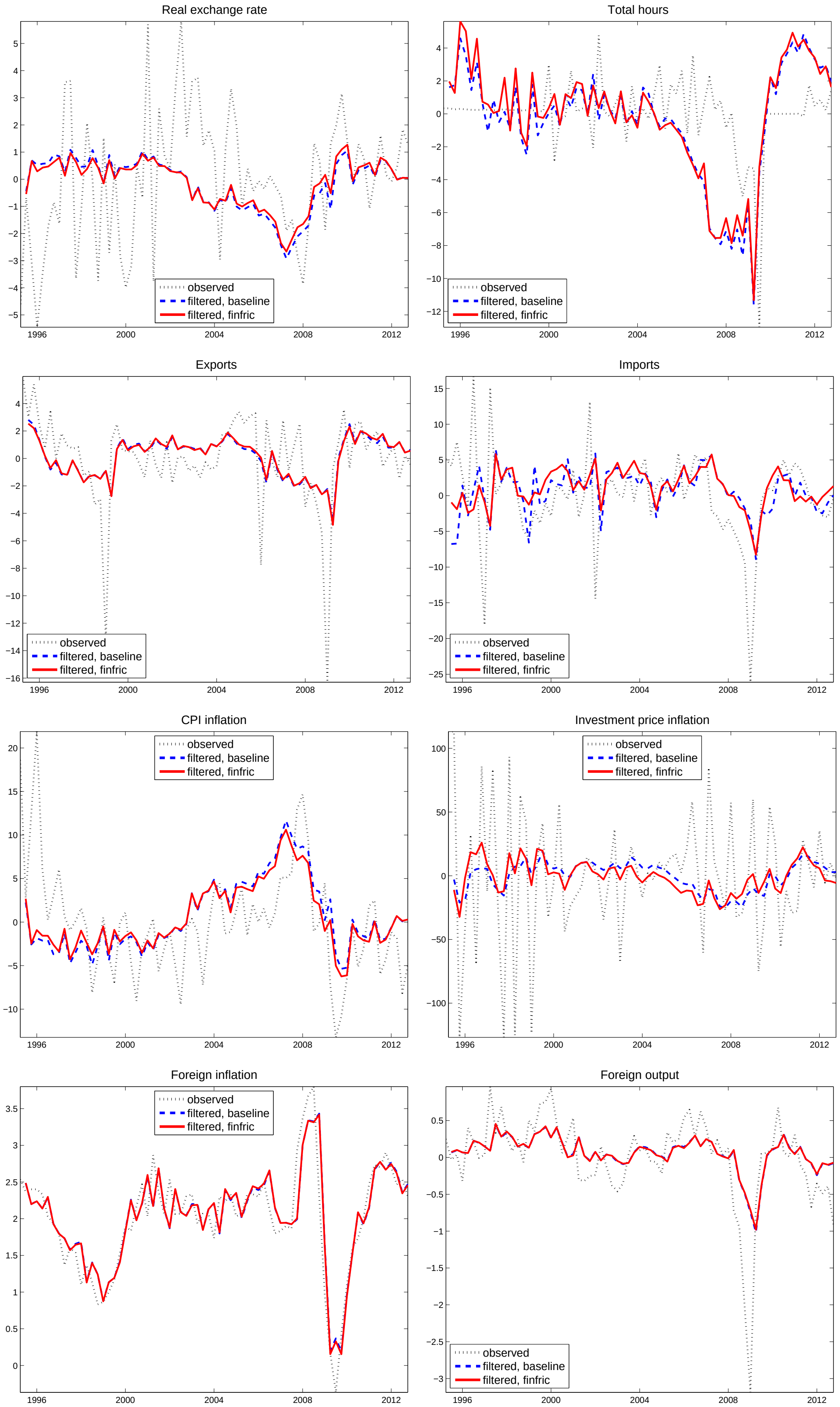

Fig. 12: One-step ahead forecasts (continued)

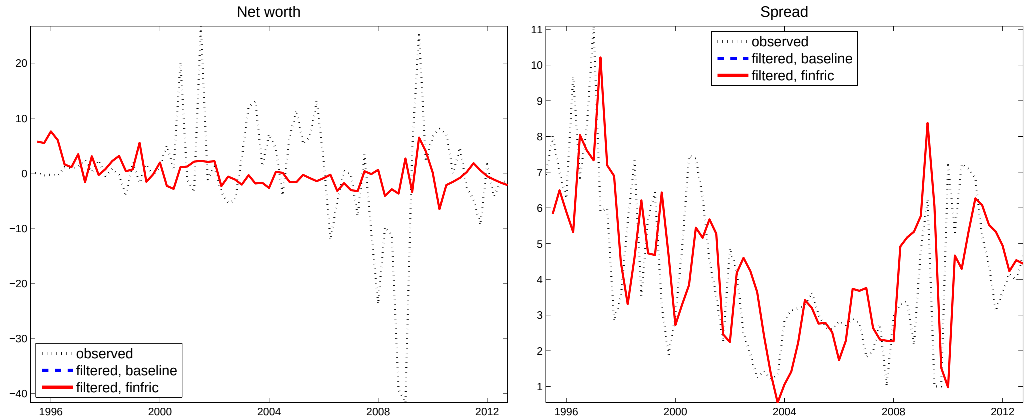

Fig. 13: One-step ahead forecasts (continued)

5 Summary and conclusions

This paper builds a DSGE model for Latvia that would be suitable to replace the traditional macroeconometric model currently employed as the main macroeconomic model at Bank of Latvia. For that purpose, I adapt the Christiano, Trabandt and Walentin (2011, henceforth CTW) financial frictions model to Latvia's data. The monetary policy is modeled as a currency union. I study whether adding the financial frictions block to an otherwise identical ('baseline') model is an improvement with respect to several dimensions.

The main findings are as follows. The addition of financial frictions block provides more appealing interpretation for the drivers of economic activity, and allows to reinterpret their role. Financial frictions played an important part in Latvia's 2008-recession. The financial frictions model beats both the baseline model and the random walk model in forecasting both CPI inflation and GDP, and does not lose much to a SVAR.

Overall, the results suggest that the financial frictions model is suitable for both policy analysis and forecasting exercises, and is an improvement over the model without the financial frictions block.

This paper employs a model of financial frictions for firms but abstracts from frictions in financing households. In the future work, it would be beneficial to separate frictions in the two markets.

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Table 3: Estimated domestic block parameters

	Description	Distr.	Prior Mean	Prior st.d.	Posterior Mean base	Posterior Mean finfric	Posterior st.d. base	Posterior st.d. finfric	HPD int. 5% finfric	HPD int. 95% finfric
ξ_d	Calvo, domestic	β	0.75	0.075	0.800	0.804	0.025	0.023	0.756	0.860
ξ_x	Calvo, exports	β	0.75	0.075	0.848	0.860	0.034	0.031	0.806	0.910
ξ_{mc}	Calvo, imports for consumpt.	β	0.75	0.075	0.774	0.779	0.042	0.049	0.676	0.898
ξ_{mi}	Calvo, imports for investment	β	0.65	0.075	0.556	0.408	0.062	0.042	0.306	0.525
ξ_{mx}	Calvo, imports for exports	β	0.65	0.10	0.546	0.589	0.082	0.091	0.452	0.731
κ_d	Indexation, domestic	β	0.40	0.15	0.196	0.162	0.066	0.075	0.037	0.303
κ_x	Indexation, exports	β	0.40	0.15	0.308	0.301	0.086	0.107	0.108	0.506
κ_{mc}	Indexation, imports for cons.	β	0.40	0.15	0.357	0.366	0.114	0.106	0.156	0.610
κ_{mi}	Indexation, imports for inv.	β	0.40	0.15	0.286	0.249	0.115	0.100	0.052	0.461
κ_{mx}	Indexation, imports for exp.	β	0.40	0.15	0.299	0.317	0.095	0.115	0.094	0.534
κ_w	Indexation, wages	β	0.40	0.15	0.258	0.241	0.091	0.079	0.062	0.447
ν^j	Working capital share	β	0.50	0.25	0.381	0.456	0.253	0.179	0.017	0.882
$0.1\sigma_L$	Inverse Frisch elasticity	Γ	0.30	0.15	0.199	0.287	0.094	0.106	0.083	0.541
b	Habit in consumption	β	0.65	0.15	0.854	0.898	0.043	0.030	0.839	0.954
$0.1S''$	Investment adjustment costs	Γ	0.50	0.15	0.414	0.168	0.077	0.030	0.094	0.254
σ_a	Variable capital utilization	Γ	0.20	0.075	0.375	0.567	0.091	0.093	0.291	0.855
η_x	Elasticity of subst., exports	Γ_{tr}	1.50	0.25	1.681	1.535	0.162	0.143	1.098	1.959
η_c	Elasticity of subst., cons.	Γ_{tr}	1.50	0.25	1.444	1.333	0.163	0.164	1.023	1.678
η_i	Elasticity of subst., invest.	Γ_{tr}	1.50	0.25	1.122	1.1*	0.067			
η_f	Elasticity of subst., foreign	Γ_{tr}	1.50	0.25	1.544	1.540	0.206	0.159	1.085	2.036
μ	Monitoring cost	β	0.30	0.075		0.273		0.040	0.188	0.352
ρ_ϵ	Persistence, stationary tech.	β	0.85	0.075	0.883	0.847	0.038	0.041	0.724	0.953
ρ_Υ	Persistence, MEI	β	0.85	0.075	0.803	0.588	0.059	0.106	0.340	0.851
ρ_{ζ^c}	Persist., consumption prefs	β	0.85	0.075	0.852	0.851	0.053	0.038	0.733	0.945
ρ_{ζ^h}	Persistence, labor prefs	β	0.85	0.075	0.801	0.817	0.083	0.048	0.694	0.935
$\rho_{\tilde{\phi}}$	Persist., country risk prem.	β	0.85	0.075	0.912	0.934	0.024	0.025	0.884	0.976
ρ_g	Persist., gov. expenditures	β	0.85	0.075	0.762	0.777	0.051	0.083	0.627	0.930
ρ_γ	Persistence, entrepren. wealth	β	0.85	0.075		0.796		0.059	0.634	0.951
	Standard deviations of shocks									
$10\sigma_\epsilon$	Stationary technology	Inv-Γ	0.15	inf	0.139	0.126	0.015	0.014	0.098	0.155
σ_Υ	Marginal efficiency of invest.	Inv-Γ	0.15	inf	0.236	0.157	0.038	0.027	0.066	0.255
σ_{ζ^c}	Consumption prefs	Inv-Γ	0.15	inf	0.152	0.236	0.049	0.056	0.123	0.373
σ_{ζ^h}	Labor prefs	Inv-Γ	0.50	inf	0.708	0.895	0.415	0.283	0.269	1.740
$100\sigma_{\tilde{\phi}}$	Country risk premium	Inv-Γ	0.50	inf	0.544	0.552	0.044	0.045	0.460	0.652
$10\sigma_g$	Government expenditures	Inv-Γ	0.50	inf	0.465	0.471	0.046	0.041	0.380	0.565
σ_{τ^d}	Markup, domestic	Inv-Γ	0.50	inf	0.368	0.373	0.107	0.089	0.183	0.625
σ_{τ^x}	Markup, exports	Inv-Γ	0.50	inf	0.852	0.992	0.332	0.391	0.428	1.670
$\sigma_{\tau^{m,c}}$	Markup, imports for cons.	Inv-Γ	0.50	inf	0.878	0.863	0.334	0.329	0.192	1.915
$\sigma_{\tau^{m,i}}$	Markup, imports for invest.	Inv-Γ	0.50	inf	0.911	0.433	0.319	0.078	0.263	0.622
$\sigma_{\tau^{m,x}}$	Markup, imports for exports	Inv-Γ	0.50	inf	1.306	1.383	0.501	0.643	0.540	2.385
$10\sigma_\gamma$	Entrepreneurial wealth	Inv-Γ	0.50	inf		0.295		0.042	0.215	0.381

Model fit items

	base	finfric
Log marginal likelihood**	-2959.4	-2925.9
Posterior odds ratio base : finfric**	1 : 3.5e14	

Note: Based on two Metropolis-Hastings chains, each with 50 000 draws after a burn-in period of 200 000 draws. Truncated priors, denoted by Γ_{tr}, with no mass below 1.01 have been used for the elasticity parameters η_j, $j = \{x, c, i, f\}$.
* Calibrated in order to avoid numerical issues.
** To compare marginal likelihood across the models, a common set of observables and estimated parameters are used. Specifically, the interest rate spread and the stock market growth data are excluded from the observables in the financial frictions model, and the otherwise estimated parameters particular to the financial accelerator block are calibrated to their posterior mean values.