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Crises and capital controls in small open economies: a stock–flow consistent approach*

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This paper attempts to explain the role of capital inflows in creating economic booms and busts in a small open economy with sovereign currency. We develop a stock–flow consistent (SFC) model for a small open economy while relying on the experience of the Icelandic crisis. We demonstrate the destabilising effects of capital inflows on the economy by allowing for a sudden stop, and also discuss the role of capital controls as a policy response in the event of a crisis due to sudden stops. Finally, we discuss the policy implications of our results in order to tackle the destabilising effects associated with financial flows in a small economy.

Keywords: *post-Keynesian, stock–flow consistent, monetary policy, capital controls, sudden stops, financial crisis*

JEL codes: *E12, F32, F38, F41*

1 INTRODUCTION

Lifting restrictions on capital movements has proven to be a double-edged sword for many countries as expectations of greater prosperity have given way to financial turmoil and crisis. Iceland is a prime example where a short period of open capital markets gave rise to intensive domestic growth fuelled by exuberant capital inflows. This eventually turned into a nightmare scenario when access to capital markets dried up, dragging the economy into a recession in late 2008.

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While the Icelandic story is relatively well-known in general,¹ few attempts have been made to explicitly model the origins and channels of capital inflows to Iceland, which led to the build-up of external imbalances. A significant proportion of the capital inflows can be traced to bond issuance by the Icelandic banking sector held by international portfolio investors. This made fixed income securities one of the main sources of credit inflow in the first years of financial expansion. Another main source of the inflows into Iceland was the retail deposit accounts offered by the Icelandic banks during the last couple of years prior to the financial crisis. By offering significantly higher deposit rates, Icelandic banks were able to collect huge amounts of deposits, allowing them to reduce their capital market exposure while maintaining high growth momentum.

Capital inflows can induce financial sector growth, which in turn can have strong impacts on the real sector of the economy. Thus, explicitly modelling capital inflows alongside a financial and real sector enables us to understand the instability associated with capital inflows. The role of capital inflows in particular is crucial for understanding the balance of payments and exchange-rate dynamics in a small open economy with a sovereign currency such as Iceland.

Traditional models of exchange-rate determination tend to play down the role of capital flows, treating them as an independent source of exchange-rate movements. The main focus of these models has been centred on the trade flows, usually within an inter-temporal optimising set-up.² In such settings, movements on the capital account play a passive role relative to the current account while resting on the usual assumptions of purchasing-power parity and uncovered-interest parity. The Icelandic experience is somewhat at odds with the above view. Iceland was able to maintain a current-account deficit for a long time, suggesting that access to foreign financing was easily forthcoming despite obvious macroeconomic imbalances.

With the rise in cross-border flows, many models acknowledged the role of capital markets in explaining the balance-of-payments and exchange-rate dynamics. Most of these models, however, considered the balance of payments in isolation³ or ignored the special role played by the banks in attracting financial flows⁴ (Benes et al. 2014). Thus, the effects of capital inflows on the real economy remains largely unclear. Similarly, the role of capital controls, as described by Eichengreen (2004), is one of the most controversial and least understood issues in macroeconomics.

This paper attempts to explain the role of capital inflows in creating economic booms in a small open economy with sovereign currency. We develop a stock–flow consistent (SFC) model for a small open economy while relying on the experience of the Icelandic crisis. We demonstrate the destabilising effects of capital inflows on the economy by allowing for a sudden stop, and also discuss the role of capital controls in response to a crisis due to sudden stops.

The paper is organised as follows. Section 2 briefly discusses the history of economic instabilities occurring due to cross-border flows. Section 3 presents the structure of the model for a very small open economy with a floating currency, and also explains the results while introducing different regimes of capital flows. Section 4 concludes the paper.

1. For example, Matthiasson (2008); Benediktssdottir et al. (2011); Baldursson/Portes (2013); Gudmundsson (2016); Raza et al. (2016).
2. See Dornbusch (1975) for an explanation.
3. For example, Magud et al. (2011).
4. For example, Engel/Matsumoto (2006). While some progress has been made since the crisis, Benes et al. (2014) argue that substantial work is still required in order to examine the role of the financial sector from a balance-sheet perspective in particular.

2 FINANCIAL FLOWS AND INSTABILITIES

Since the late 1980s, many countries in pursuit of financial development abolished capital controls and refrained from interventions in the financial markets. Financial-account openness in an environment of innovative financial markets during this period greatly facilitated access to international capital. Less emphasis was placed on the risks associated with foreign borrowing. This allowed a sizeable expansion of the financial sector relative to the real sector in small economies, reaching levels never experienced before in the available statistics.⁵ This resulted in an extremely heavy reliance on finance-led growth. The expansion of the financial sector took place regardless of the prevailing currency regimes, for example, European peripheral countries (currency union), the Baltics (fixed exchange rate) and Iceland (floating regime).

With the eruption of the global financial crisis (GFC), small open economies that were heavily reliant on international credit experienced capital reversals, balance-of-payments crisis and recessions, all resulting in high unemployment, large fiscal costs and spending cuts on welfare. The crisis in 2007–2008 revealed two fundamental but interrelated weaknesses in small open economies. First, it revealed the lack of resilience of these economies to withstand the effects of global shocks. Second, it exposed the destabilising effects of financial flows in their systems, which had largely been ignored before the crisis. The latter can perhaps be linked to the psychology of policy-makers explained in Reinhart/Reinhart (2008), that persistent inflows can lead to the belief that the episode is a permanent phenomenon rather than a temporary one.

The surge in cross-border financial flows linked to economic integration and the subsequent decline generating economic instabilities is not unique to the recent episode of 2007–2008. The asset boom fuelled by capital inflows can be traced back to the Railway Mania in Britain in the 1840s, which ended with a banking crisis and a severe economic recession in 1847 (Bordo/Landon-Lane 2013). While past experiences of booms and busts share many similarities, they also have vital differences. These differences provide important lessons for policy-makers to design better policies and regulations.

In the past 140 years, the surges in global capital flows can broadly be divided into five major episodes.⁶

- The first episode, 1870–1913, was characterised by a boom in bond financing from advanced economies to the regions of recent settlement with abundant resources and scarce labour. The investors preferred fixed income debt instruments while foreign direct investment (FDI) share was small.
- The second episode, from post-World War I to the Great Depression, was marked by a large investment in government bonds. The governments heavily borrowed to finance public expenditures.⁷
- The third episode, 1973–1981, was driven by oil price shocks. The flows, however, were dominated by bank lending to finance the balance of payments in developing countries, while the share of debt instruments remained low.

5. The relationship between capital inflows and domestic credit growth is discussed in Lane/McQuade (2014).

6. See Bordo/Landon-Lane (2013) for a discussion on the historical perspective of asset prices, booms and busts. Also see Accominotti/Eichengreen (2016) on the history of capital inflows and reversals in Europe.

7. During these two episodes, credit was volatile but remained stable relative to the size of the economy in the long run. The only exception was the Great Depression of the 1930s, during which credit relative to the size of the economy collapsed (Schularick/Taylor 2009).

- The fourth episode, 1993–1997, marked the surge in capital flows to the private borrowers in emerging markets. The composition of capital flows in this episode greatly changed with the rise in FDI share along with investments in bonds and equities, while the share of bank lending was low. On the borrowing end, the share of private-sector debt dramatically increased.
- Fifth, the recent episode of the 2000s, with increased short-term inflows. Banks had cheap access to international credit, which amongst other things resulted in unprecedented levels of lending to the private sector in general.

In all major episodes of capital booms, real output growth was accompanied by asset price booms and strong growth in international investment and trade. All episodes were eventually followed by a bust, causing currency crisis, financial instabilities and real output losses in the capital-borrowing economies. The impact of the crisis on the real economy in 2008 was the most severe since the Great Depression. The average output loss as a result of the recent crisis, reported by Laeven/Valencia (2010), is 25 per cent as compared to a historical average of 20 per cent estimated for past crises. In most country-specific cases, the underlying factor triggering the crisis has been an abrupt stop of inflows, beyond the control of the recipient economy.⁸

Despite a large literature on the economic volatility associated with inflows, restrictions on capital inflows are seen with scepticism. Ghosh/Qureshi (2016) discuss the long history of capital controls and explain how thinking around them has evolved over time. An interesting explanation of scepticism towards capital controls put forward by the authors is that people usually think that controls on inflows and outflows are linked, whereas the latter have been typically associated with autocratic and repressive regimes. The authors argue that controls on inflows as an economic policy to reduce volatility has not been specifically analysed from a historical perspective.

After the recent Great Recession, large financial flows relative to the size of the economy and their effects on growth and stability have become a topic of debate in macro-economics.⁹ Small economies benefited from globalisation and the resultant international capital flows, but this also posed a serious challenge to the policy-makers, essentially due to loss of monetary control, loss of competitiveness and vulnerability to external shocks.¹⁰ There seems to be an emerging consensus that a very large financial sector amplified by large financial inflows is potentially destabilising. For instance, Reinhart/Reinhart (2008) find that capital inflow bonanzas are associated with a higher likelihood of economic crisis. The emerging literature following the financial crisis suggests that capital controls may be justified when capital flows are strong and the economy fragile. In a recent paper published in the *IMF Economic Review*, Farhi/Werning (2014) find that in a New Keynesian model capital controls are desirable even when the exchange rate is flexible. Korinek/Sandri (2016) argue that capital controls are desirable in emerging economies because they stimulate domestic saving by favouring domestic intermediation. Zeev (2017) studies 33 emerging market economies and finds that output in economies with stricter capital inflow controls responds less to global credit supply shocks while capital outflow controls have no significant shock-absorbing capacity. A recent book by

8. The only exceptions highlighted in the literature are Chile (1990–1991) and Malaysia (1993–1994), where sudden stops were preceded by voluntary implementation of restrictions on short-term inflows (Calvo/Reinhart 1999).

9. See, for example, Obstfeld (2012); Krugman (2014).

10. The challenges posed to policy-makers by globalisation are well described in the political trilemma of world economy by Rodrik (2000).

Ghosh et al. (2017) studies the effectiveness of capital controls in a large number of countries, the tools used to implement capital controls and their pros and cons.

The experience of Iceland regarding capital inflows is somewhat similar to other crisis-hit economies, but nonetheless provides an excellent testing ground due to its exceptional financial sector growth, followed by a regime of strong capital controls, leading to a different post-crisis scenario than other countries'.¹¹ Using the Icelandic experience as a motivation, we now proceed to derive a theoretical model of capital inflows in the SFC tradition.

3 MODELLING CAPITAL INFLOWS IN A VERY SMALL OPEN ECONOMY

In general, modelling an open economy is a tough challenge due to cross-border capital flows originating from complex financial systems. However, the balance-sheet approach in the SFC framework conveniently allows one to incorporate the dynamics of international capital inflows by explicitly modelling the portfolio choices of domestic and international traders. In addition, SFC models are now well-known for their ability to link the real and financial sectors of the economy.¹² In the context of the recent financial crisis in Iceland, these features are central to our study. Therefore, the SFC approach provides a solid platform for studying the crisis.

Several authors have attempted to extend SFC analysis from closed to open economies. A very basic framework of an open economy with no cross-border financial movements is discussed in chapter 6 of Godley/Lavoie (2007). The analysis is then extended to a more advanced model in chapter 12 by introducing a number of realistic features such as flexible exchange rates, trading foreign assets and settling official imbalances through foreign currency denominated assets. Lavoie/Daigle (2011) further extended chapter 12 of Godley/Lavoie (2007) while mainly focusing on the issue of exchange-rate expectations. Duwicquet/Mazier (2010) developed a model for two countries of asymmetric size in a monetary union. They introduced three different shocks (loss of competitiveness, fall in consumption and a reduction in capital accumulation) to analyse macroeconomic adjustment and stabilisation in a monetary union. Kinsella/Khalil (2012) used a two-country SFC model to study a small economy experiencing debt deflation. They performed a series of simulations, including the impact of investment shock on debt deflation in a small economy under two different currency regimes (floating exchange rate and currency union). Greenwood-Nimmo (2014) examined the role of fiscal and monetary policy in an open-economy SFC model. A recent study by Burgess et al. (2016) developed an open-economy SFC model for the UK economy to address financial balances.

Open-economy models in the SFC tradition emphasise the importance of completeness and reciprocity in order to catch the dynamics of economic interconnections of countries trading with each other (see Lavoie/Daigle 2011, Mazier/Tiou-Tagba Aliti 2012, Greenwood-Nimmo 2014 and Caiani et al. 2018, amongst others). However, studies considering small open economies relax these conditions and treat developments within the rest of the world as given.¹³ In these models, the small open economy is treated as the one influenced by global factors, but not vice versa. A few recent examples of these are Meijers et al. (2015) and Byrialsen/Raza (2018).

11. Raza et al. (2018) empirically investigate the current-account adjustment in Iceland and compare it to that of Ireland and other eurozone countries.

12. For a comprehensive survey on the SFC approach to modelling, see Caverzasi/Godin (2015) and Nikiforos/Zezza (2017).

13. Note that this still involves modelling trade flows and portfolio allocation of international traders.

Built around the same general idea, our model also adopts the ‘small country assumption’ for Iceland, assuming the negligible impact of the Icelandic economy on the rest of the world. As a consequence, only model equations for the domestic economy need to be considered. Before explaining the structure of the model, we explain the balance sheets and transaction flows in our model.

3.1 Transaction flow and balance-sheet matrices

First, we present the interactions between the balance sheets of different sectors in the economy. A formal representation of assets and liabilities can be seen in the balance-sheet matrix in Table 1. The items reported with plus (+) signs represent assets, while minus (–) signs represent liabilities. As can be seen from the balance-sheet matrix, financial stocks in our model take the form of deposits, bills and loans. The banking sector has two branches: (i) a domestic branch, which holds domestic assets on its balance sheets; and (ii) a foreign branch, which attracts foreign deposit holders.

We now proceed to an explanation of the transactions in the economy. A complete presentation of the transactions flows matrix can be seen in Table A1 in Appendix 1. The matrix tracks all the flows between different sectors within the economy as well as the cross-border flows. A plus (+) sign in the matrix indicates that the flow has been received or that it can simply be considered as an income, while a minus (–) sign represents an outflow or simply an expenditure. For simplicity, aggregated transaction flows are graphically presented in Figure 1. There are three types of transactions taking place in the economy: (i) transactions associated with real economic activity; (ii) transactions associated with income from capital, which are interest rates in this case; and (iii) transactions occurring due to changes in financial assets and liabilities.¹⁴

The production in the economy takes place as described in the standard GDP identity. Trade and production of goods take place in the firm sector. Firms pay the wage bill to their workers (household) and taxes to the government. They acquire loans, which cover the discrepancy between investment expenditures and profits. They also pay interest on their loans to the financial sector.

Households finance their consumption by receiving income in the form of wages and interest payments on deposits and bills. They pay income taxes to the government sector.

The government sector receives income in the form of taxes from the firms and the households. It adjusts its expenditures according to its revenue, hence running a balanced budget.

Table 1 The balance-sheet matrix

	Small economy			RoW		Net
	Household	Firms	Banks	Foreign branch	RoW	
Deposits	$+D_{ice}$	–		$-D_b$	$+D_{row}$	0
Loans	–	$-L_f$		$+L_b$	–	0
Fixed capital	–	$+K$		–	–	$+K$
Banks bills	$+B_{ice}$	–		$-B_b$	$+B_{row}$	0
RoW bills	$+B_{ice}^{row}$	–		–	$-B_{row}$	0

14. Note that the change in financial stock in the graph refers to the aggregation of financial assets and liabilities presented in Table 1.

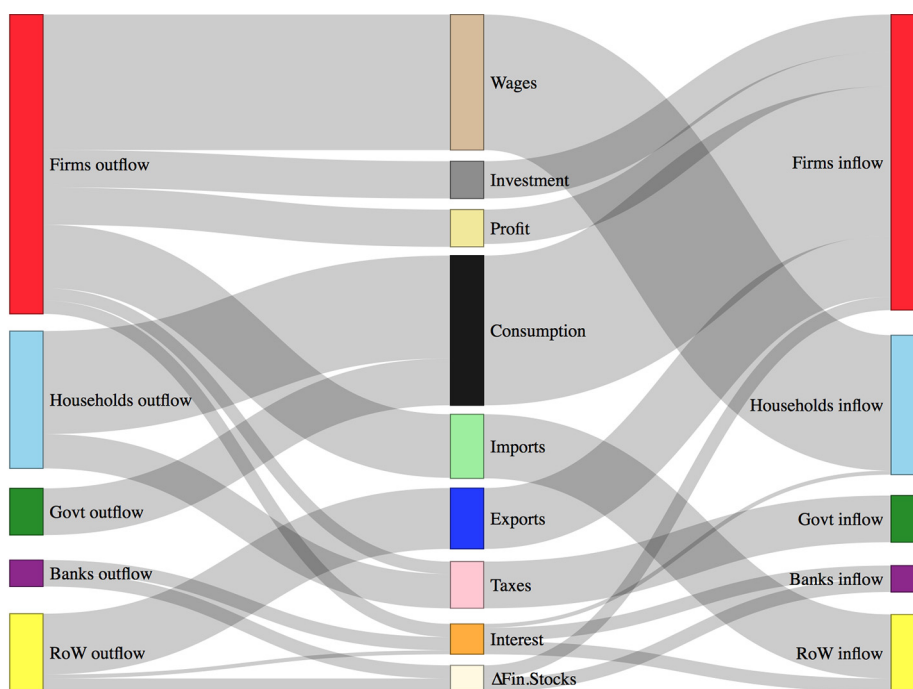


Figure 1 Transaction flows

The banking sector as a whole offers both the domestic currency denominated loans and the foreign currency denominated loans. The banking sector receives income in the form of interest on its lending. Banks also issue bills internationally to meet the demand for credit in the economy. They pay interest on their liabilities, which are deposits and bills. Finally, the rest of the world receives interest from Iceland on their bills and deposits, and engages in trade with Iceland.

In our model, the balance-of-payments dynamics are driven by the negative net position of the corporate sector. This setting is consistent with the sectoral balances of Iceland before the crisis. In Figure 2, it can be seen how the position of Iceland relative to the RoW sector (which is the balance-of-payments deficits and accumulation of external debt) is driven by the negative net position of the corporate sector. While the banks relatively maintain a net position somewhat closer to zero, they fulfil (as well as induce) the demand for credit in the economy by holding external debt on their balance sheets, which makes them vulnerable to a sudden stop.

3.2 Structure of the model

The structure of our model makes clear reference to the exceptional growth of the Icelandic financial sector. The institutional elements of the model relate to the specific social and economic conditions that evolved during the early 2000s, when Icelandic banks could attract huge amounts of portfolio capital seemingly without raising concerns about systemic sustainability. By implementing policies such as financial sector privatisation and deregulation of market activity, Iceland was seen as following a benign recipe for institutional

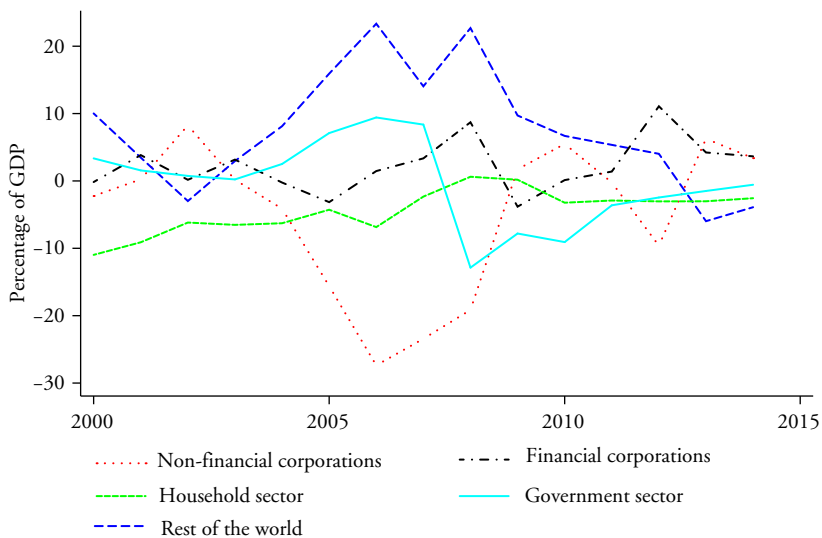


Figure 2 Sectoral balances of the Icelandic economy

improvement. Obviously some concerns were raised, and during the mini-crisis of early 2006, access to financial markets was temporarily restricted. However, confidence was restored as markets became convinced once again of the sustainability of the Icelandic financial model following protective measures by the Icelandic banks and assurances by the authorities that public support would be forthcoming if needed.

With the GFC, it became gradually more and more evident that the likelihood of systemic failure could not be excluded and investors’ confidence disappeared, resulting in a sudden stop. This fits well into the Harvey (2009) framework, explaining the role of psychological or behavioural factors, with regard to exchange-rate dynamics. The role of market psychology was perhaps even more important during the earlier stages when financial expansion took place in the early 2000s. The newly privatised Icelandic banks rushed into expansion mode, attracting large amounts of capital supporting further expansion. Bandwagon effects or Chartist investment strategies clearly seemed to be driving factors while economic fundamentals such as current-account imbalances were given less attention until the eruption of the crisis.

In order to capture the above aspects, the structure of the model is specified as shown below.¹⁵

3.2.1 Firms

Firms produce goods by employing workers (N) while paying them wages (W). Prices P^s are set as a mark-up (ϕ) over unit cost (equations (1)–(3)).

National income

$$y = c + g + i + x - m \tag{1}$$

15. Note that small letters indicate real (deflated) variables whereas capital letters represent nominal values. The full model can be seen in Appendix 1.

Wage bill

$$WB = W(N) \quad (2)$$

$$P^s = (1 + UC)\phi \quad (3)$$

Following the partial adjustment accelerator model, the level of real investment (i) in the model is determined by a partial adjustment of the existing stock of capital towards a desired stock of capital k^T , plus a level of depreciation (da) (equations (4)–(7)).

Real investment

$$i = \gamma(k^T - k_{t-1}) + da \quad (4)$$

Targeted stock of capital

$$k^T = \eta(y_{t-1}) \quad (5)$$

Depreciation of capital

$$da = \delta(k_{t-1}) \quad (6)$$

Change in stock of capital

$$\Delta k = i - da \quad (7)$$

Profit of firms

$$F^f = Y - WB - T^f \quad (8)$$

Profits (F^f) after paying taxes (T^f) are used to finance investment in every period. If the targeted investment is higher than the profits, which is the case in our model, investment is financed by directly borrowing from the banks (equation (9)). Firms can borrow both the domestic currency denominated loans ($L^{f,ice,d}$) and foreign currency denominated loans ($L^{f,row,d}$) as shown in equations (10)–(11). This feature is consistent with the experience of Icelandic firms, which borrowed both domestic and foreign currency denominated loans. In Iceland's particular case, two main motives for foreign-exchange (FX) denominated loans can be identified as follows: (i) a proportion of firms' revenue – coming from exports – was in the foreign currency; and (ii) interest rates charged on domestic denominated loans was higher than on the foreign currency denominated loans. Based on this argument, the demand for loans in our model has an inverse relationship with the associated interest rate, that is, if the interest rate on domestic currency borrowing ($r^{L,ice}$) increases as compared to the interest rate on FX denominated loans ($r^{L,row}$), the proportion of borrowing in the domestic currency will fall while the proportion of borrowing in FX denominated loans will increase.

Demand for loans

$$\mathfrak{L}^{f,d} = L_{t-1}^{f,d} + I - F^f + r_{t-1}^{L,ice}(L_{t-1}^{f,ice,d}) + r_{t-1}^{L,row}(L_{t-1}^{f,row,d}) \quad (9)$$

Demand for Icelandic króna (ISK) and foreign denominated loans¹⁶

$$L^{f,ice,d} = L^{f,d}(\psi_1 - \psi_2 r_{ice}^{L,ice} + \psi_3 r_{ice}^{L,row}) \quad (10)$$

$$L^{f,row,d} = L^{f,d}(\psi_4 + \psi_5 r_{ice}^{L,ice} - \psi_6 r_{ice}^{L,row}) \quad (11)$$

16. Note that the sum of the demand for domestic and FX loans equals total loans, that is, $\mathfrak{L}^{f,d} = L^{f,ice,d} + L^{f,row,d}$.

3.2.2 Households

Households’ consumption (c) is a function of disposable income (yd_{hs}) – adjusted for exchange-rate gains on foreign assets – and their past wealth, (v) as can be seen in equations (12)–(15).

Consumption function

$$c = \alpha_1(yd_{hs}) + \alpha_2(v_{t-1}) \tag{12}$$

Households’ disposable income

$$YD = WB + r_{ice(t-1)}^B (B_{ice(t-1)}^{ice,d}) + r_{row(t-1)}^B (B_{ice(t-1)}^{row,d}) + r_{ice(t-1)}^D (D_{ice(t-1)}^{h,ice,d}) - T^h \tag{13}$$

Haig–Simons disposable income

$$YD_{HS} = YD + (\Delta xr) B_{ice}^{row,s} \tag{14}$$

Wealth accumulation

$$V = V_{t-1} + YD_{HS} - C \tag{15}$$

The households allocate their wealth in financial assets and receive returns in the form of interest. The idea behind the portfolio allocation dates back to the work of James Tobin and his co-workers in the late 1960s in an effort to model basic relationships in a financial economy with several assets and their allocation among sectors (Brainard/Tobin 1968). However, our setting slightly differs from the standard practice of modelling financial assets. Following a more practical approach in Iceland’s case, the household sector in Iceland is faced with a decision of allocating its wealth in three financial assets, namely Icelandic bills ($B_{ice}^{h,ice,d}$), foreign bills ($B_{ice}^{h,row,d}$) and deposits in Icelandic banks ($D_{ice}^{h,ice,d}$) operating domestically (equation (16)).

Portfolio allocation of domestic households

$$\begin{bmatrix} D_{ice}^{h,ice,d} \\ B_{ice}^{h,ice,d} \\ B_{ice}^{h,row,d} \end{bmatrix} = \begin{bmatrix} \lambda_{10} \\ \lambda_{20} \\ \lambda_{30} \end{bmatrix} V + \begin{bmatrix} \lambda_{11} \lambda_{12} \lambda_{13} \\ \lambda_{21} \lambda_{22} \lambda_{23} \\ \lambda_{31} \lambda_{32} \lambda_{33} \end{bmatrix} \begin{bmatrix} r_{ice}^D \\ r_{ice}^B \\ r_{row}^B + dxre \end{bmatrix} \tag{16}$$

On the other hand, the rest of the world can allocate their wealth in four assets, that is, Icelandic bills ($B_{row}^{h,ice,d}$), RoW bills ($B_{row}^{h,row,d}$), deposits in the RoW banks ($B_{row}^{h,row,d}$), and deposits in the foreign branches of Icelandic banks, ($D_{row}^{h,ice,d}$) as shown in the portfolio matrix in equation (17).¹⁷ The portfolio allocation in our model is based on the fact that Icelandic households were not allowed to hold deposits in the foreign branches of Icelandic banks. Clearly this might seem to be at odds with the principle of free capital movements, but in practice this is precisely what happened when Icelandic banks were offering foreign depositors considerably higher rates than to depositors in Iceland.

17. Note that the two assets ($B_{row}^{h,row,d}$) and ($B_{row}^{h,ice,d}$) in the portfolio allocation are redundant and do not interact with our model, but are nonetheless included for completeness.

Portfolio allocation of foreign households

$$\begin{bmatrix} D_{row}^{b,row,d} \\ D_{row}^{b,ice,d} \\ B_{row}^{b,row,d} \\ B_{row}^{b,ice,d} \end{bmatrix} = \begin{bmatrix} \lambda_{50} \\ \lambda_{60} \\ \lambda_{70} \\ \lambda_{80} \end{bmatrix} V + \begin{bmatrix} \lambda_{51}\lambda_{52}\lambda_{53}\lambda_{54} \\ \lambda_{61}\lambda_{62}\lambda_{63}\lambda_{64} \\ \lambda_{71}\lambda_{72}\lambda_{73}\lambda_{74} \\ \lambda_{81}\lambda_{82}\lambda_{83}\lambda_{84} \end{bmatrix} \begin{bmatrix} r_{row}^D \\ r_{ice}^{D,row} \\ r_{row}^B \\ r_{ice}^B - dxre \end{bmatrix} \quad (17)$$

The international traders investing in Icelandic bills also consider their exposure to currency risks ($dxre$), that is, a rise in currency risk would lower the demand for Icelandic bills. However, the exchange-rate risk in our model does not affect the demand for deposits in the banks because these deposits are held in the foreign branches of the Icelandic banks. For example, a UK resident holding a deposit in an Icelandic bank that operates in the UK will not consider exchange-rate risks on his deposits as the bank account is in GBP.

3.2.3 Banks

The banking sector is the sole provider of credit in the economy. It fulfils the demand for loans and will only issue bills ($B_{ice}^{b,ice,s}$) if the demand for loans (L_{ice}^s) is greater than the available credit in the system (equation (19)). As can be seen, the first source of credit in the economy is provided by the available deposits (D_{ice}^d) in the banking sector. This, however, does not put a restriction on the process of credit creation, that is, if the demand for loans exceeds the available credit in the banking sector, the banks will issue bills to finance their operations and fulfil the demand for loans in the economy. As described earlier, these bills are held by households and the rest of the world, providing credit and willing to take a counterparty risk on Icelandic banks. Moreover, we do not put a restriction on the flow of credit between the domestic and foreign branches of the Icelandic banks. This implies that the deposits accumulated in the foreign branches can be used by the banks domestically without any direct risks involved. The deposits in the foreign branches of Icelandic banks are also considered as an inflow in the financial account even if these deposits are not transferred to the domestic banks.

Profit of the banks

$$F^b = r_{ice}^{L,ice} (L^f,ice,d) + r_{ice}^{L,row} (L^f,row,d) - r_{ice}^{D,row} (D_{row}^{b,ice,d}) - r_{ice}^D (D_{ice}^{b,ice,d}) - r_{ice}^B (B_{ice}^{b,s}) \quad (18)$$

Bills issued by the Icelandic banks

$$\begin{aligned} \Delta B_{ice}^{b,ice,s} &= z_2 (\Delta L_{ice}^s - (\Delta D_{ice}^d + F^b)) \\ z_2 &= 1, \text{ if } L_{ice}^s > (\Delta D_{ice}^d + F^b), \text{ otherwise } 0 \end{aligned} \quad (19)$$

Icelandic bills issued in the FX market

$$B_{row}^{eb,s} = \underbrace{B_{ice}^{b,ice,s}}_{\text{bills issued}} - \underbrace{B_{ice}^{b,ice,d} - B_{row}^{b,ice,d} (xr) - B_{ice}^{b,ice,d}}_{\text{bills demanded}} \quad (20)$$

It is worth mentioning that traditional models designed for conventional monetary policy, especially before the crisis, ignored the special role played by the banks in creating credit from a balance-sheet perspective as discussed above. In general, the banking sector in these models in itself is not a source of shock and vulnerabilities (Benes et al. 2014).

In contrast, based on the balance-sheet approach, the banking sector in our framework can be a source of vulnerability and shocks by fulfilling all demand for credit due to their optimistic expectations concerning growth prospects. This feature of the financial sector is widely acknowledged by several authors (see Jakab/Kumhof 2015).

3.2.4 Government

For completeness, we include a simple government sector in the model which finances its expenditures through taxes. The expenditure of the government is simply determined by its tax revenue (equations (21)–(22)), hence running a balanced budget. This is a strong assumption but our setting here is based on the Icelandic experience, where the government sector has a relatively minor or non-existent role in the accumulation of external debt. Icelandic firms and banks are generally held responsible for creating economic instability as they accumulated a large volume of external debt.

Tax revenue

$$T = T^f + T^h \tag{21}$$

Government budget balance

$$G = T \tag{22}$$

3.2.5 Balance of payments and exchange-rate setting

The current-account balance is presented in equation (23), taking into account net exports and factor payments in both directions. The determination of trade flows in our model is based on the standard demand theory. The volumes of exports and imports are presented in log-linear form (equations (24)–(27)) in order to estimate elasticities. Exports and imports in the model are determined by the level of price competitiveness as well as by the income of the domestic economy (y) and that of the trading partners (y_{row}^*). Exports are modelled as partly exogenous, reflecting Iceland’s natural resource export base and partly dependent on the real exchange rate, reflecting price-sensitive service exports such as tourism. The level of the nominal exchange rate affects tradeables through its effects on prices. Equations (28) and (29) explain the prices of tradeables from the perspective of Iceland in the model. Export prices (P^x) are determined by domestic prices (P^y), foreign prices (P_{row}^y) and the exchange rate (xr). Import prices which are exogenous are expressed in nominal currency by simply adjusting the export prices of trading partners for the nominal exchange rate.

Current-account balance

$$CAB = X - M + r_{row(t-1)}^B (B_{ice(t-1)}^{h,row,d}) - r_{ice(t-1)}^B (B_{row(t-1)}^{h,ice,d})xr - r_{ice(t-1)}^{D,row} (D_{row(t-1)}^{h,ice,d})xr - r_{ice(t-1)}^B (B_{row(t-1)}^{eb,d})xr \tag{23}$$

Real imports

$$\log(m) = \mu_0 - \mu_1 \log\left(\frac{P^m}{P^y}\right) + \mu_2 \log(y) \tag{24}$$

Real exports: tourism

$$\log(x_1) = \epsilon_0 - \epsilon_1 \log\left(\frac{P^x}{P_{row}^y}\right) + \epsilon_2 \log(y_{row}^*) \tag{25}$$

Exports based on natural resources

$$\log(x_2) = \epsilon_0 + \epsilon_2 \log(y_{row}^*) \quad (26)$$

Total exports

$$x = \alpha_3(x_2) + 1 - \alpha_3(x_1) \quad (27)$$

Import prices

$$P^m = P_{row}^x(xr) \quad (28)$$

Export prices

$$\log(P^x) = \nu_{x_0} + \nu_{x_1} \log(P_{row}^y) + (1 - \nu_{x_1}) \log(P^y) + \nu_{x_1} \log(xr) \quad (29)$$

The nominal exchange rate (equation (30)), based on the portfolio balance approach, is determined by the ratio of bills issued and demanded in the FX market. During normal times, the traders consider a fundamental currency risk by taking into account the exchange-rate misalignment, that is, the deviation of the exchange rate from its long-run path (equation (32)). This particular measure of risk is based on the model of Lavoie/Daigle (2011), however those authors consider two types of agents in the FX market, speculators and fundamentalists, with fixed weights. Our setting of exchange-rate risks and expectations differs from those authors. We allow for regime shift where investors during a sudden stop change their expectations as they anticipate a currency crisis. This will be discussed in more detail when we introduce a sudden stop in the model.

Exchange-rate setting: ISK per foreign currency

$$xr = \left(\frac{B_{ice}^{b,row,d}}{B_{row}^{b,ice,d}} \right) \quad (30)$$

Real exchange rate

$$rxr = xr \left(\frac{P_{row}^y}{P^y} \right) \quad (31)$$

Exchange-rate expectations

$$dxre = \frac{\Omega(xr^* - xr)}{xr} \quad (32)$$

We do not allow deposits in the foreign branches of the banks to affect the exchange-rate dynamics in the model. Deposits held in foreign branches do not directly affect the currency system unless converted into local currency. This, however, is an internal operation of the banking system and is not entirely clear from the literature or existing studies. Finally, the real exchange rate in our model reflects price competitiveness vis-à-vis foreign countries measured in common currency.

3.3 Simulations

To understand the dynamics of the real and financial sector in general and the role of capital flows in particular, we numerically solve the model to achieve a baseline scenario. In obtaining a numerical solution, we use a combination of estimation and calibration with

the aim of replicating certain key features of the Icelandic economy.¹⁸ We then introduce two shocks in different time periods to see the response of the economy.

The shocks generated in the model are explained as follows.

3.3.1 Shock 1: increase in real investment

First, we introduce a real investment (gross fixed capital formation) shock where we increase the real investment by increasing the η from 1 to 1.10 after ten iterations. This increases the share of real investment in total output, making it a major driver of output. The increase in investment, however, requires financing through credit, therefore the economic growth in this sense is finance-led. This scenario is based on the Icelandic experience of investment boom in the years leading to the crisis. In particular, investment to GDP increased from 19 per cent in 2002 to 35 per cent in 2006.

3.3.2 Shock 2: increase in interest-rate differentials

In response to the investment boom generated by rapid credit creation, the Icelandic central bank raised interest rates, which then created profit opportunities for the carry trade. The carry trade consisted of foreign currency speculators taking positions in the Icelandic króna, as well as local businesses and also households borrowing in foreign currency and hence taking an unhedged position in the currency market. Using this as a motivation, we introduce an interest-rate differentials shock after 30 iterations by increasing the Icelandic interest rates while keeping the effect of the investment shock (shock 1) in the system.¹⁹ We adjust all the interest rates so that the interest rates in Iceland are higher than the interest rates abroad. In particular, we increase the return on Icelandic bills from 2 per cent to 3.5 per cent and also increase the interest rate on loans linked to domestic currency from 4 per cent to 4.5 per cent.

3.4 Discussion

Figure 3 shows the dynamics of the current-account balance and the financial-account balance for three different scenarios: (i) the baseline scenario; (ii) the scenario after investment shock; and (iii) the scenario in which investment shock is followed by an interest differentials shock in the system.

The small open economy in our model is a net borrower and is running a small current-account deficit and a financial-account surplus in the baseline scenario. In effect the economy is operating very close to a current-account balance. The economy interacts with the rest of the world through trade and financial assets. The financial sector issues bills and holds deposits internationally to fulfil the demand for credit in the economy. An increase in investment (gross fixed capital formation) will induce credit inflow into the economy while pushing the current account into further deficit. This scenario reflects a simple stylised fact: if the demand for loans by firms is not fulfilled by domestic credit, banks borrow

18. We include the real sector of the rest of the world in order to determine the dynamics of wealth and prices. However, we do not explicitly model the financing decisions of the firms and the banking sector within the rest of the world and treat these variables as exogenous.

19. The increases in interest rates – shown in bold type – can be seen in Table A2 in Appendix 1.

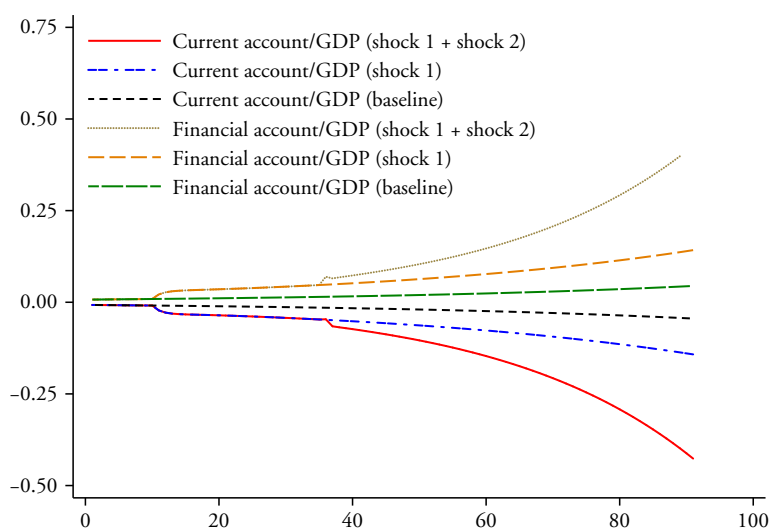


Figure 3 Balance of payments

internationally to fulfil the demand for loans in the economy. Increased international borrowing generates a financial-account surplus and a current-account deficit.

If the investment shock is followed by a rise in interest-rate differentials, the current-account deficit deteriorates further. A rise in interest rate differentials creates an opportunity for carry trade. The international traders, despite considering exchange-rate misalignment (that is, the deviation of the exchange rate from its long-run path), allocate their wealth into Icelandic assets, triggering inflow of credit into the economy. The introduction of shock 2 in the model allows a speculative attack on the currency.

The deteriorating balance-of-payments position, apart from a speculative attack, is due to an increase in the cost of borrowing in the economy, which in turn results in even higher demand for credit. The burden of a higher interest rate in our model is directly borne by the firms.

We now turn to the real economic indicators in the model. Overall, capital inflows have a strong positive effect on output, as the fall in trade balance (see Figure 5) is offset by a rise in domestic demand. Thus, capital inflows are expansionary in nature. In particular, Figure 9 shows that an increase in real investment boosts real output, as expected. A rise in investment followed by a rise in the interest-rate differential further increases real output, as shown in Figure 4. The transmission channel can be explained as follows: a rise in the interest-rate differential in Iceland (with good sovereign rating) makes Icelandic assets look more attractive than foreign assets. Thus, households allocate their wealth in assets with higher returns which in turn increases their wealth as shown in Figure 6. Thus, the interest-rate differential increases real output through a wealth effect, that is, an increase in wealth due to higher returns feeds back into output via the consumption channel in the model, as shown in Figure 8.

Focusing on the dynamics of the exchange rate, Figure 7 shows that a rise in interest-rate differentials results in the deviation (appreciation in this case) of the exchange rate from its baseline, which has negative effects on the trade balance. An investment shock alone (with no direct speculative attack on the currency) has small effects on the

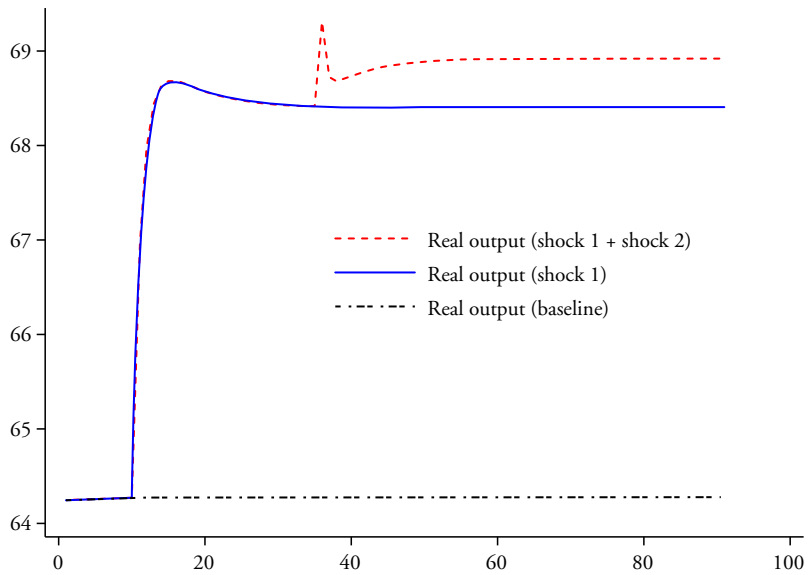


Figure 4 Real GDP

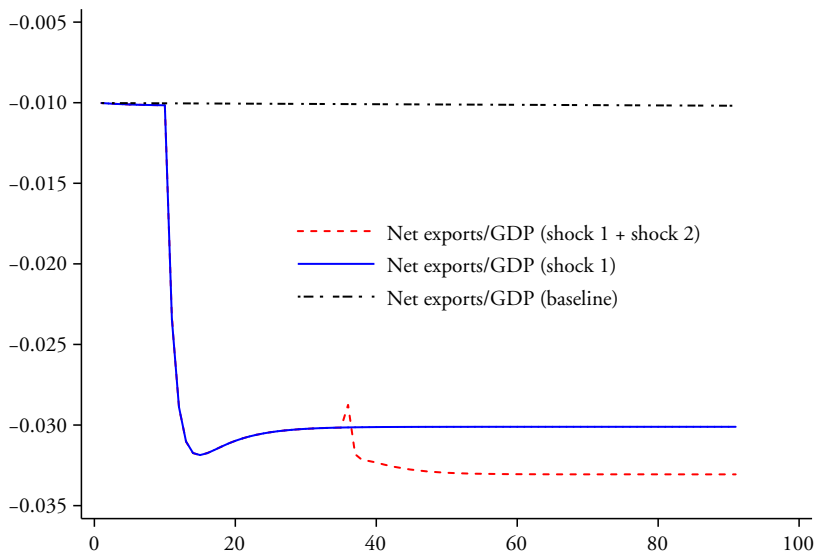


Figure 5 Net exports

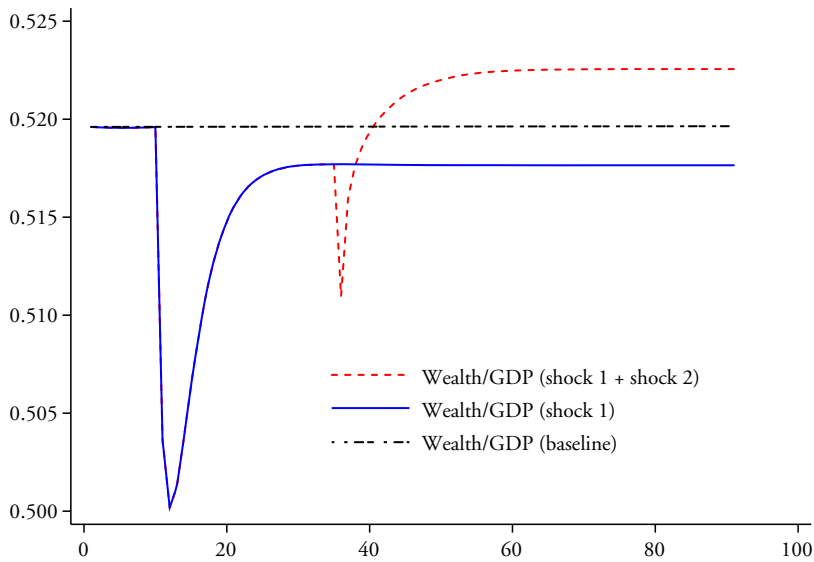


Figure 6 Wealth

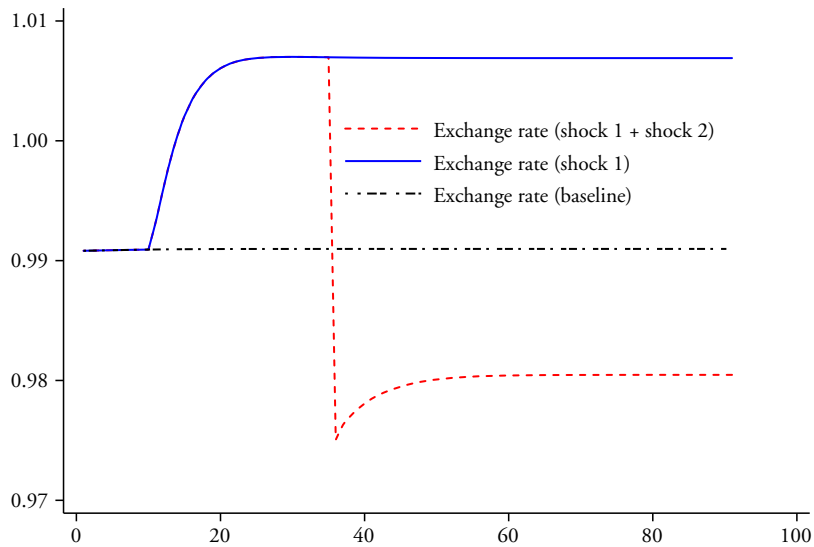


Figure 7 Exchange rate

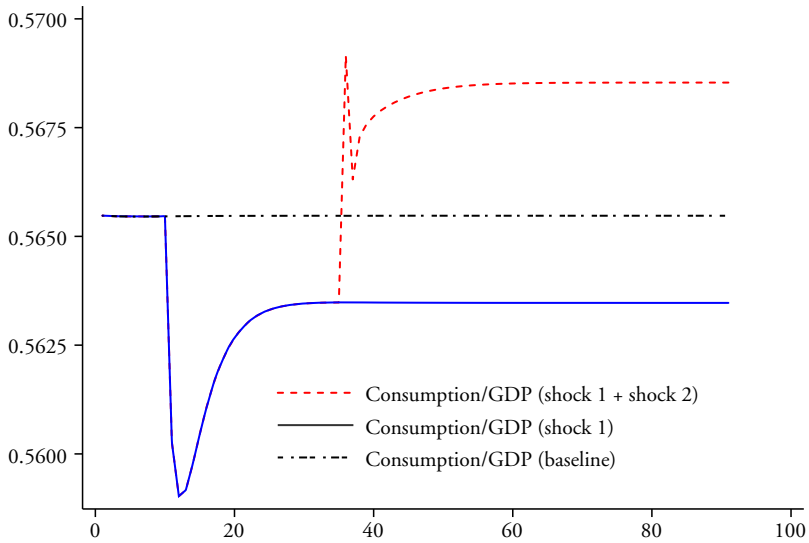


Figure 8 Consumption

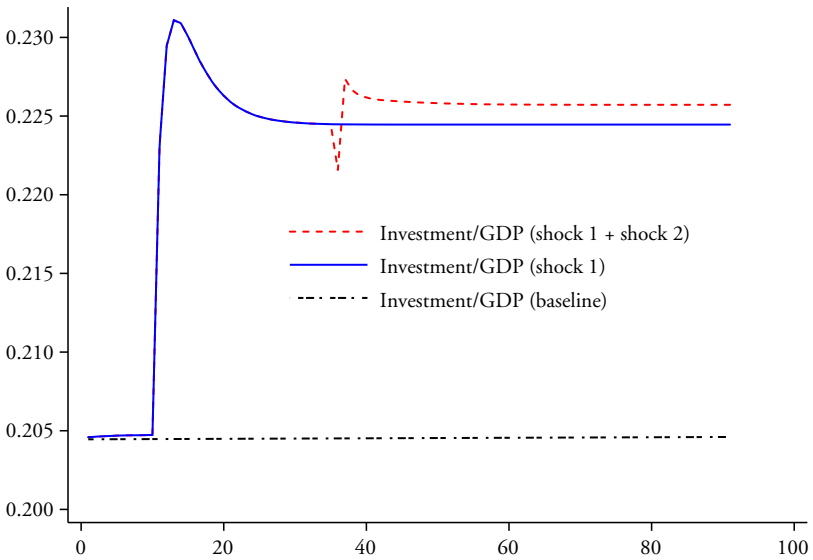


Figure 9 Investment

exchange rate. The asset traders do not change their wealth allocation if the investment returns on Icelandic and foreign assets are uniform. The mild depreciation in this case is the result of an increased wealth effect in the model. An increase in Icelandic wealth as compared to its trading partners will increase the holding of foreign assets by the Icelandic households as they become richer.

Exchange-rate dynamics in the model also affect the domestic price of goods, that is, a currency appreciation (depreciation) results in lower (higher) import prices, which decreases (increases) the domestic price of goods.

Figure 10 and 11 show two important financial indicators in the economy. The effects of both shocks in the model are clearly reflected in the rising external debt to GDP and

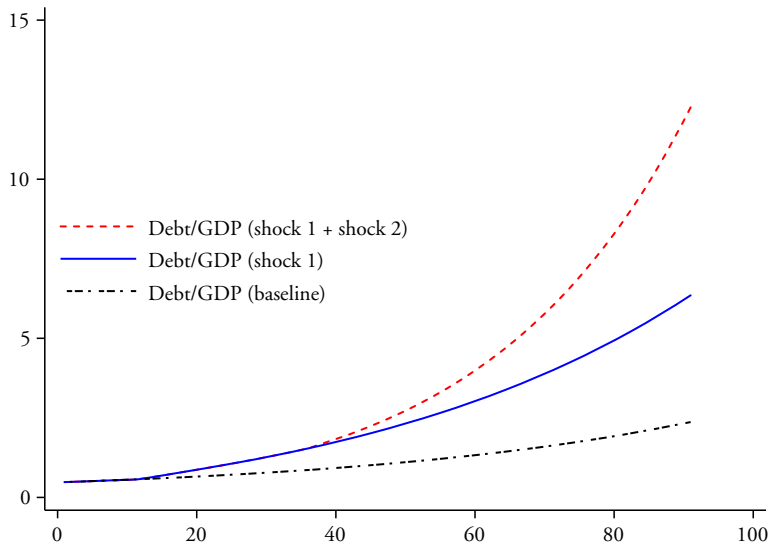


Figure 10 Debt to GDP

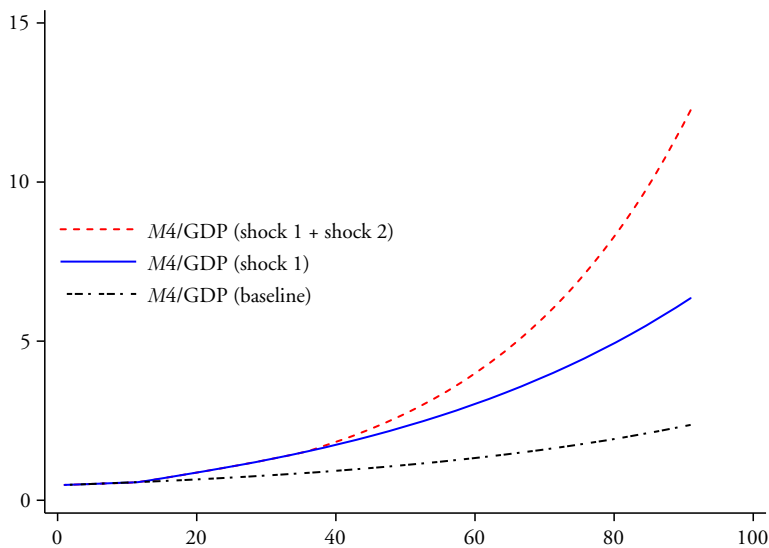


Figure 11 M4 to GDP

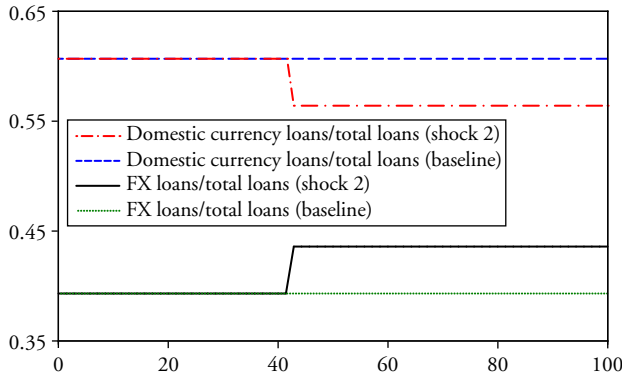


Figure 12 Loans breakdown

increased $M4$ (money supply) to GDP. The dynamics of these stock–flow norms following an increasing trend are consistent with the actual data of Iceland, where the main financial indicators relative to GDP follow an upward trend before the crisis. The increased trend in these financial indicators implies that the growth of the financial sector is faster than the real growth of the economy.

Figure 12 shows the demand for ISK and foreign-denominated loans by firms. An increase in the interest-rate differentials will trigger borrowing in foreign-denominated loans. It can therefore be argued that when the channel of borrowing in foreign currency is open, as was the case in Iceland, the increase in interest rate is not very effective in controlling domestic demand. Apart from lower interest rates on FX loans, the rise in demand for FX borrowing could also be the result of currency appreciation as domestic sectors, such as firms and households, are encouraged to speculate and benefit from exchange-rate movements.

In the section above, we demonstrated how international financial flows can fuel a credit boom, which in turn can create an economic boom. This, however, comes at the cost of persistent current-account deficits and growing external debt as discussed above. Such scenarios prevailed in many small open economies in the years preceding the crisis. The situation, however, changed dramatically when a wave of international bankruptcies affected many small open economies. The sudden stop of capital inflows revealed the fragility and inability of small open economies to deal with the crisis.

3.4.1 Crises and sudden stops

In order to capture the destabilising role of international credit in small economies, we create a scenario where shock 1 and shock 2 are followed by a sudden stop. We allow the external debt to GDP to reach six times the size of the economy. Such a high level of external debt relative to the economy raises concerns and the international creditors stop lending to the economy. We impose the following restriction on Equation (20):

Change in Icelandic bills issued in the international market and held by the foreign bank

$$\Delta B_{row}^{e,b,s} = 0, \text{ if } \underbrace{\left(\frac{B_{ice}^s}{Y} \geq 6 \right)}_{\text{debt to GDP}} \quad (20a)$$

The foreign banks stop holding Icelandic bills and the flow of credit comes to a halt.²⁰ The firms are unable to finance their investments, resulting in the collapse of real investments.

After sudden stops, the credit rating of the debt issuers fall, and the international traders readjust their strategy in the financial markets. The interest-rate differentials, which in normal times with good credit ratings are seen as an opportunity to make profit, are seen during the crises as a measure of risk premia. During such circumstances, an increase in the interest-rate differentials induces capital reversals. Equation (32) can be augmented as follows:

Changes in expectations during the crisis

$$dxre = \frac{\Omega(xr^* - xr)}{xr} + (r_{ice}^B - r_{row}^B) \quad (32a)$$

Hence, any further increase in interest-rate differentials would further increase the expectations of a currency crisis. The anticipation of a currency crisis is exactly what causes a currency crisis, when international traders start selling their Icelandic assets.

During a sudden stop, the sectors with higher debt are the first ones to go bankrupt as they fail to pay their liabilities. Bankruptcy from one sector quickly spreads to the other sectors of the economy. In our model, firms cannot remain solvent even if the level of investment is significantly reduced and no new borrowing takes place. The reason is that firms have to pay a higher interest rate on the large pile of existing debt trapped in the economy. This triggers the balance-of-payments crisis as shown in Figure 13, leaving no option other than to impose capital controls. The crisis makes the financial sector unable to repay its debt along with the interest payments on the current account as it goes bankrupt.

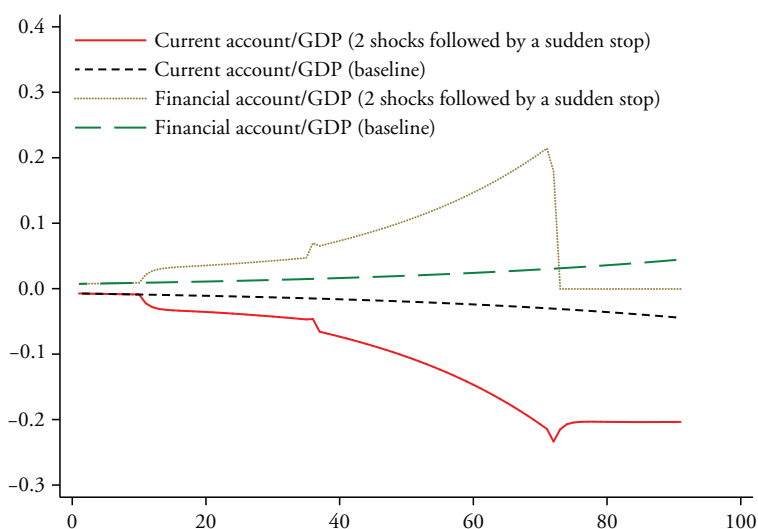


Figure 13 Balance of payments

20. It should be noted here that the flow of credit (inflows) goes to zero which means the stock of debt will remain constant. The stock of debt will only reduce when an outflow of credit takes place.

The anticipated currency crisis in the model results in the foreign households selling their assets in Iceland, resulting in capital reversal to some extent. This market run on the banking sector generates currency crisis as shown in Figure 15. It is important to highlight that capital reversal takes the form of foreign households selling their assets in Iceland to a certain limit after they realise that the foreign financial institutions have stopped lending to the economy. However, the debt held by foreign financial institutions remains trapped because no one is able or willing to buy such a large pile of a country’s debt that is going through a crisis.

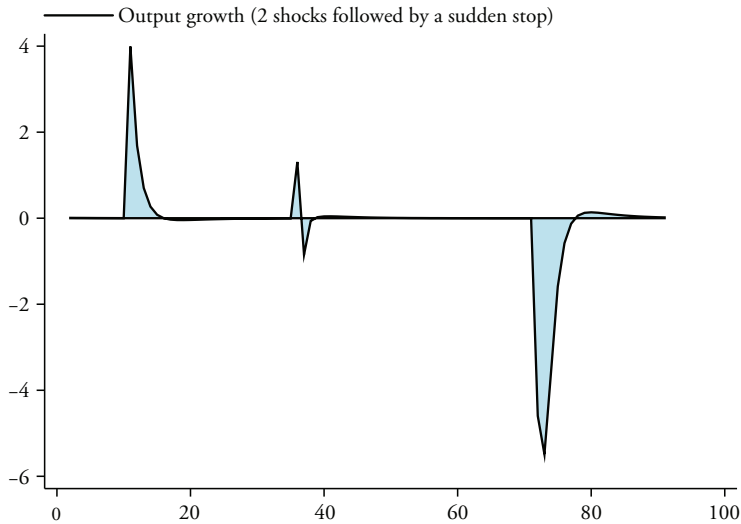


Figure 14 Real GDP

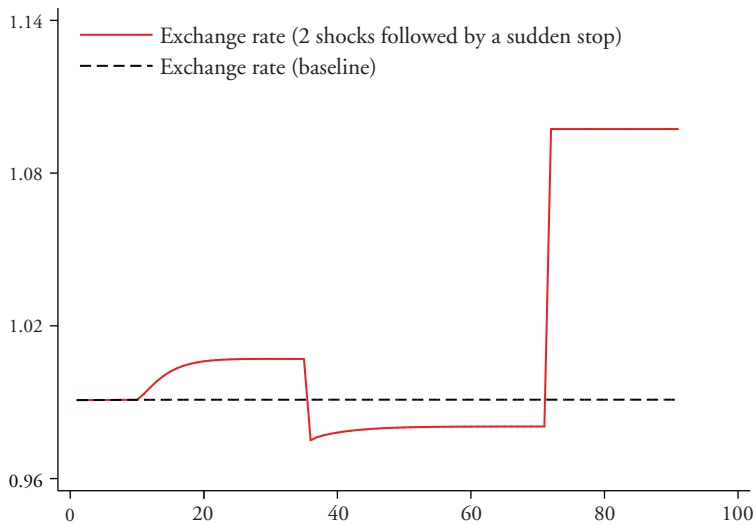


Figure 15 Exchange rate

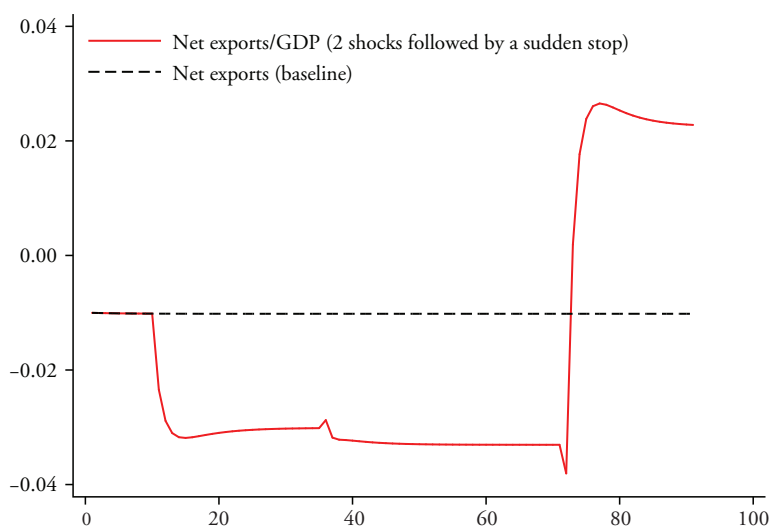


Figure 16 Net exports

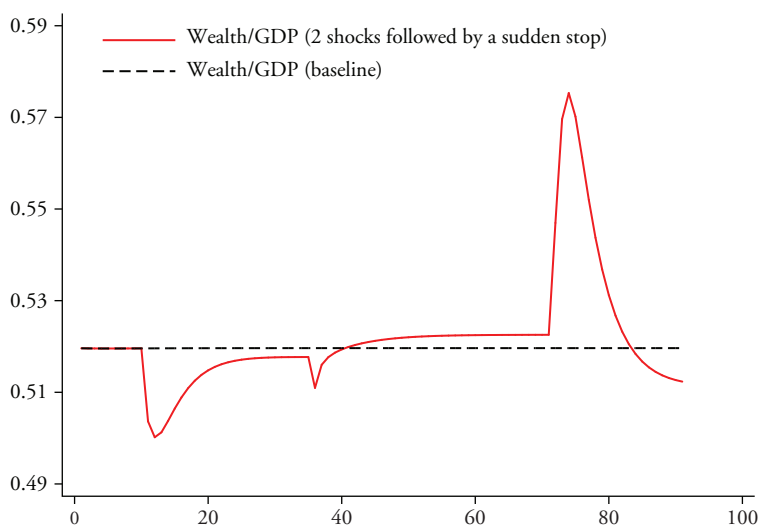


Figure 17 Wealth

The crisis due to a sudden stop also results in the collapse of the real economy as shown by the contraction of output in Figure 14. The level of economic activities greatly reduces, resulting in a phase of economic recession which in our model is explained by a compression of domestic demand. Apart from domestic demand compression, as shown in Figures 18 and 19, currency depreciation after the crisis in our model results in a significant reduction in real imports, improving the trade balance (see Figure 16). This transforms the growth engine of the economy from investment-led to export-led. In addition, there is a strong

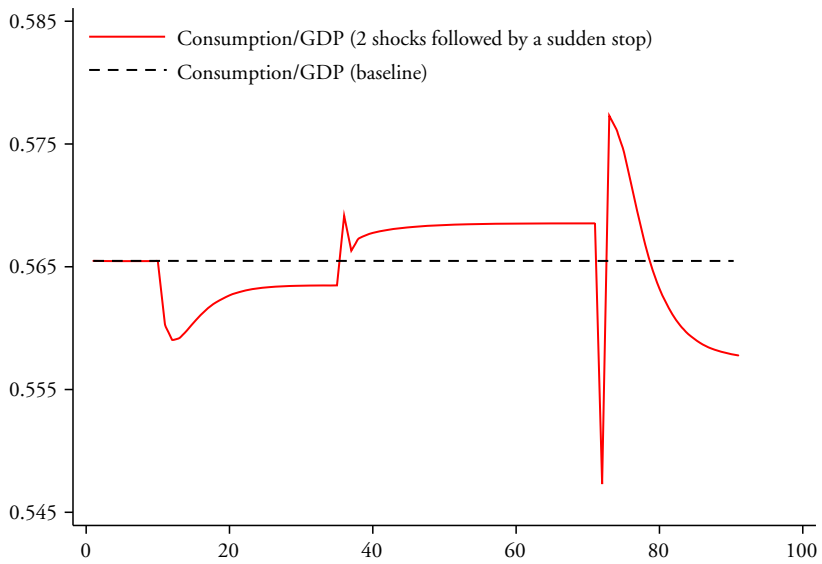


Figure 18 Consumption

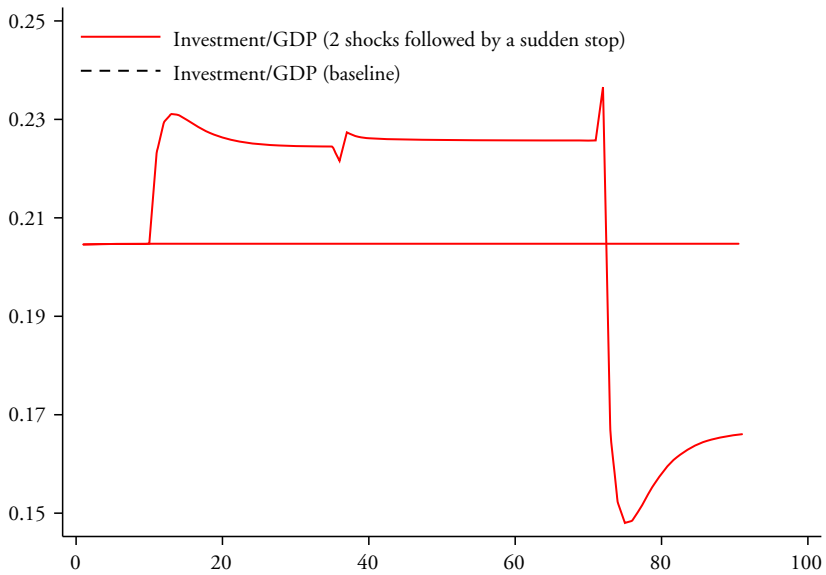


Figure 19 Investment

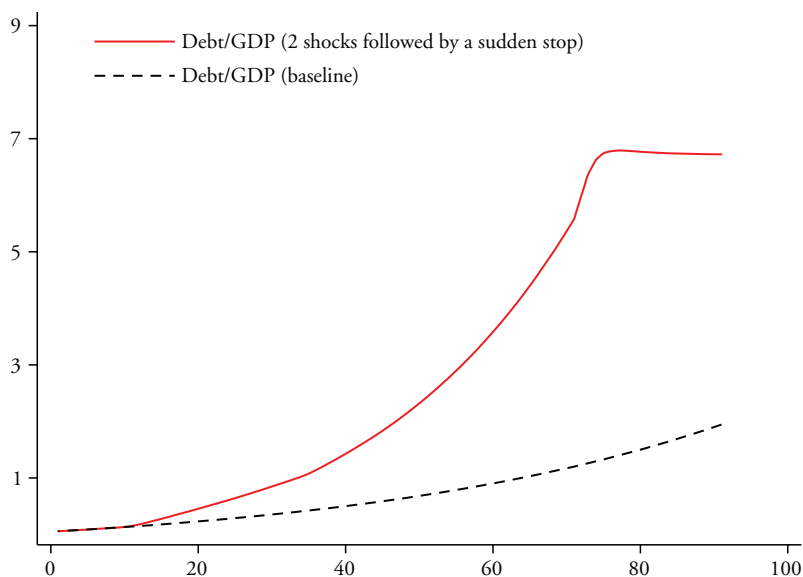


Figure 20 Debt

exchange-rate pass-through to prices as shown in Figure 21, which is in line with the experience of Iceland after the crisis.²¹

Our model assumes asymmetric effects regarding exchange-rate dynamics, that is, the depreciating effect of capital outflow on the currency is much stronger than the appreciating effect associated with the capital inflows in the years before the crisis. This, as explained earlier, is due to the shift in the strategy of international investors. This result is consistent with the Icelandic crisis as well as many other currency crises of the past.

3.4.2 Capital controls and leakages

As shown above, once the crisis hits, the current-account deficit cannot be maintained as the economy is not able to finance the deficit due to a sudden stop. Consequently, the economy cannot pay any interest on its debt and has to implement capital controls in order to prevent any further outflows.

We now add the following conditions to equations (16) and (17):

$$\underbrace{\Delta B_{ice}^{h,row,d} = 0}_{\text{capital controls}}, \text{ if } \underbrace{\Delta B_{row}^{eb,s} = 0}_{\text{sudden stop}} \tag{16a}$$

$$\underbrace{\Delta B_{row}^{h,ice,d} = 0}_{\text{capital controls}}, \text{ if } \underbrace{\Delta B_{row}^{eb,s} = 0}_{\text{sudden stop}} \tag{17a}$$

Figure 22 shows a plausible scenario after the implementation of strong capital controls in our model. The country is not able to pay any interest on the external debt trapped in

21. The stock effects of a sudden stop can be seen in Figures 20 and 17, showing the dynamics of debt and household wealth in the economy respectively.

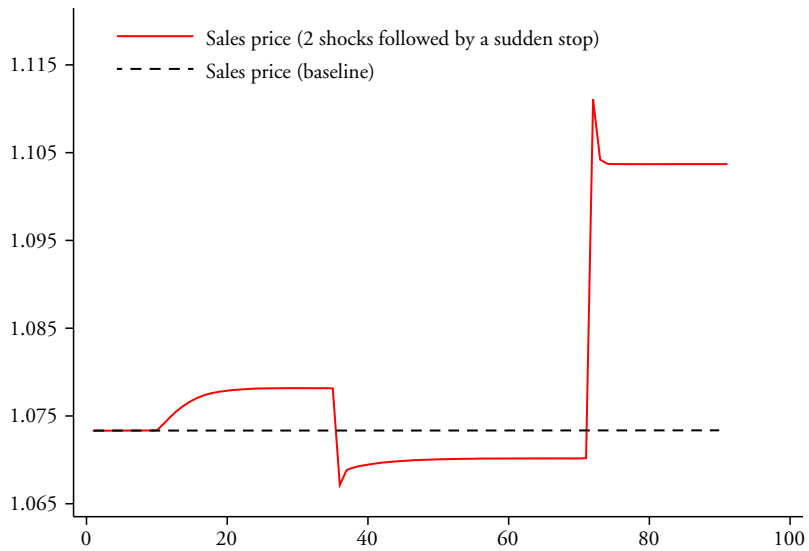


Figure 21 Domestic price of goods

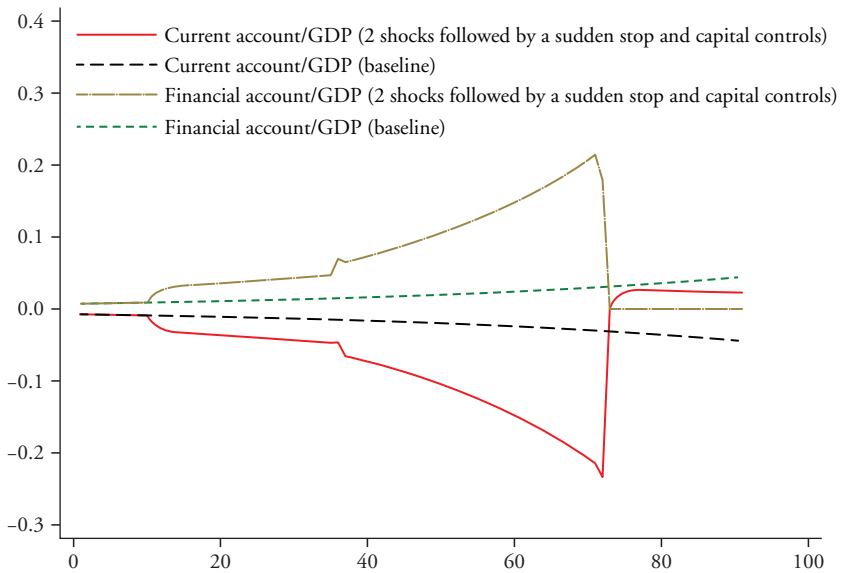


Figure 22 Balance of payments

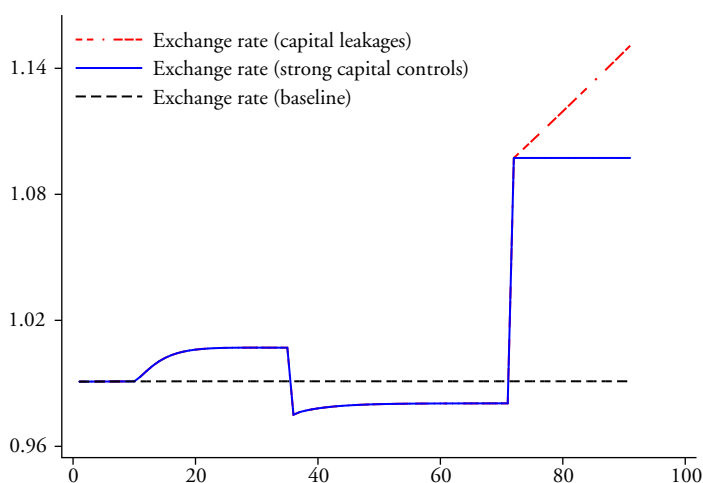


Figure 23 Exchange rate

the economy as a wave of bankruptcies propagates through the balance sheets of all the sectors in the economy. This situation forces the economy to implement capital controls immediately in order to restrict outflows and prevent a currency crisis.

The situation in Figure 22 is based on a proactive response by the authorities, where capital controls with zero leakages are implemented before the outflow has occurred. In reality, international traders are quicker to sell their assets before the authorities can respond. Thus, implementation of capital controls can never fully prevent outflows. Moreover, tighter capital controls with zero leakages are practically impossible, and international traders will take their capital out of the economy whenever there is an opportunity. Capital controls, however, can slow down the outflow of international capital.

We introduce capital leakages into our model by allowing a small fraction of foreign capital to escape in every period. Figure 23 shows the dynamics of exchange rates after capital leakages in every period. If the capital continues to leak, the exchange rate will continuously depreciate, as shown in Figure 23. The gradual depreciation due to leakages is still less harmful than a full-blown currency crisis taking place in a very short period of time. In our model, small leakages have some effect on the currency but in reality small leakages may or may not put any pressure on the currency.

Capital controls give a country enough time to restructure the financial structure and stabilise the economy. During a strong capital control regime or even with low leakages, the country can gradually lower the interest rates which can restore domestic demand by channelling savings into investment, having little or no impact on the currency, as was the case in Iceland. Thus, the economy can retain export-led growth and ease the burden of interest repayments on the current account. The trade surplus in the economy can be used to repay its debt. The effects of lowering interest rates, as opposed to the IMF's insistence on keeping them high under a capital control regime in the case of Iceland, are discussed in Gudmundsson/Zoega (2016).²²

22. The authors provide an extensive discussion on the effects of lowering interest rates under a capital control regime in Iceland.

We now turn to the sensitivity analysis of our model by changing the values of key parameters. We focus on the parameter values determining the balance of payments and exchange-rate dynamics in the model. After changing the parameter values, we simulate the model for the two shocks – an investment shock followed by an interest rates differential shock – defined in Section 3.3.

As expected, changes in key parameters lead to different steady states. However, the effects of the shocks and the implications of our original model do not change in any fundamental way, that is, the simulations of the system still reveal the same dynamics.²³ The only major impact is observed in the case of exchange rates which achieve a very different steady state in response to a change in the portfolio allocation, but the effects of the shocks are still in line with our main analysis. Overall, we can argue that our model is not sensitive to changes in the values used in the baseline.

4 CONCLUSION

This paper proposed a framework for a small open economy with sovereign currency while focusing on the role of international financial flows. We demonstrated that borrowing to finance real investment under lower interest rates has a mild impact on the current-account balance and a stronger impact on the real output. In contrast, international borrowings in a small open economy with sovereign currency often require offering better incentives to international investors than its competitors due to exchange-rate risks. This, in Iceland, took the form of higher interest returns on Icelandic financial assets relative to foreign assets. In this regard, our analyses suggested that positive interest-rate differentials attract a large amount of short-term inflows by creating an opportunity for profits. These persistent inflows are found to overvalue the exchange rate, deteriorate the trade balance and generate an economic boom with a fast growing debt.

The accumulation of external debt may or may not reach unsustainable levels, but nonetheless will at some point create concerns in the markets regarding the potential of debt repayments. These market fears take the form of a sudden stop as international short-term capital, due to its fleeting nature, flows out of the economy in a very short period of time. These sudden outflows convert liquidity crises into solvency crises and sustainable debts into unsustainable debts, creating serious financial and real economic crises.

A sudden outflow severely impacts the whole economy. It generates a balance-of-payments crisis and also compresses domestic demand, resulting in a severe recession. A small open economy reliant on international credit is not able to finance its economic activities after the channel of international capital is closed. An appropriate immediate response in the short run is to impose strong capital controls in order to stabilise the currency and gain enough time to restructure the economy. To facilitate the balance-of-payments adjustment and a quick economic recovery, capital controls require the backing of careful monetary policy decisions. The cost of borrowing at the time of the crisis skyrockets, and a financial crisis usually leaves the country to operate in an environment of high interest rates due to fears of inflation and currency crisis. This further triggers the ‘paradox of thrift’ effect with a rise in savings and a considerable decline in real investments due to economic uncertainties and the heavy cost of borrowing.

Monetary authorities can gradually reduce interest rates to recover domestic demand in order to facilitate economic growth. In a capital control regime, interest rates can have

23. These results are not reported, to conserve space, however they can be provided upon request.

weak or no significant effects on the currency as the channel of trading financial assets is restricted. Thus, lowering interest rates will not affect export-led growth in the capital control regime but will ease the burden of interest payments to international creditors, further improving the balance of payments. This argument in Iceland's particular case is supported by Gudmundsson/Zoega (2016). The removal of capital controls, however, remains a challenge for small open economies going forward. The effects of relaxation in capital controls, and the future strategy regarding capital inflows in Iceland, are discussed in Zoega (2016).

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APPENDIX 1

Table A1 Transaction flow matrix (TFM)

Flows	Small economy					RoW			
	Households	Firms	Govt	Banks	Foreign branch	Households	Firms	RoW banks	
	Current		Capital						
Consumption	$-C$	$+C$	-	-	-	-	-	-	
Investment	-	$+I$	-	-	-	-	-	-	
Govt exp.	-	$+G$	$-G$	-	-	-	-	-	
Exports	-	$+X$	-	-	-	$-M_{row}$	$+X_{row}$	-	
Imports (GDP)	-	$-M$	-	-	-	-	-	-	
Wages	$+WB$	$[Y]$	-	-	-	-	-	-	
Tax	$-T^h$	$-WB$	$+T$	-	-	-	-	-	
Interest on deposits in Iceland's domestic banks	$+r_{ice}^D (D_{ice}^{h,ice,d})$	-	$-r_{ice}^D (D_{ice}^{h,ice,d})$	-	-	-	-	-	
Interest on deposits in Iceland's foreign banks	-	-	-	-	$-r_{ice}^{D,row} (D_{row}^{h,ice,d}) + r_{ice}^{D,row} (D_{row}^{h,ice,d})$	-	-	-	
Interest on deposits in RoW banks	-	-	-	-	$+r_{row}^D (D_{row}^{h,row,d})$	-	$-r_{row}^D (D_{row}^{h,row,d})$	-	
Interest on FX denominated loans in Iceland	-	$-r_{ice}^{L,row} (L_{row,d})$	-	$+r_{ice}^{L,row} (L_{row,d})$	-	-	-	-	
Interest on ISK denominated loans in Iceland	-	$-r_{ice}^{L,ice} (L_{ice,d})$	-	$+r_{ice}^{L,ice} (L_{ice,d})$	-	-	-	-	
Interest on Icelandic banks' bills	$+r_{ice}^B (B_{ice}^{b,d})$	-	-	$-r_{ice}^B (B_{ice}^{b,s})$	-	$+r_{ice}^B (B_{row}^{h,ice,d})$	-	$+r_{ice}^B (B_{row}^{b,b,d})$	
Interest on RoW bills	$+r_{row}^B (B_{row}^{h,row,d})$	-	-	-	-	$+r_{row}^B (B_{row}^{h,row,d})$	$-r_{row}^B (B_{row}^{f,s})$	-	
Profits (firms)	-	$-Ff$	$+Ff$	-	-	-	-	-	

Change in Icelandic banks' bills	$-\Delta B_{ice}^{ice,d}$	-	-	$+\Delta B_{ice}^{b,s}$	-	$-\Delta B_{row}^{b,ice,d}$	-	$-\Delta B_{ice}^{b,s}$
Change in RoW bills	$-\Delta B_{ice}^{b,row,d}$	-	-	-	-	$-\Delta B_{row}^{b,row,d}$	$+\Delta B_{row}^{f,s}$	-
Change in Iceland's FX denominated loans	-	-	$+\Delta I_{row,d}^{f,row,d}$	$-\Delta L_{row,s}$	-	-	-	-
Change in Iceland's ISK denominated loans	-	-	$+\Delta I_{ice,d}^{f,ice,d}$	$-\Delta L_{ice,s}$	-	-	-	-
Change in deposits in Icelandic domestic banks	$-\Delta D_{ice}^{b,ice,d}$	-	-	$+\Delta D_{ice}^{b,ice,d}$	-	-	-	-
Change in deposits in Icelandic foreign banks	-	-	-	-	$+\Delta D_{row}^{b,ice,d}$	$-\Delta D_{row}^{b,ice,d}$	-	-
Change in deposits in foreign banks	-	-	-	-	-	$-\Delta D_{row}^{b,row,d}$	-	$+\Delta D_{row}^{b,row,d}$
	0	0	0	0	0	-	-	-

Note: Rest of the world is largely exogenous. In our transaction flow matrix, we only report those flows through which the domestic economy is connected to the rest of the world. The columns for the rest of the world sector may not sum to zero.

A1.1 Model equations*A1.1.1 Firms*

Gross domestic product (GDP)

$$Y = C + I + G + X - M$$

Sales in Iceland

$$S = C + I + G + X$$

Value of real output

$$y = c + i + g + x - m$$

GDP deflator

$$P^y = Y/y$$

Employment

$$N = y/A$$

Wage bill

$$WB = W(N)$$

Unit cost

$$UC = (WB + M)/s$$

Price of domestic goods

$$P^s = (1 + \phi)(UC)$$

Domestic sales price

$$P^{ds} = \frac{S - X}{s - x}$$

Real sales

$$s = c + g + i + x$$

Real investment

$$i = \gamma(k^T - k_{t-1}) + da$$

Targeted stock of capital

$$k^T = \eta(y_{t-1})$$

Depreciation of capital

$$da = \delta(k_{t-1})$$

Change in stock of capital

$$\Delta k = i - da$$

Nominal value of investment

$$I = i(P^{ds})$$

Nominal value of sales

$$S = s(P^s)$$

Profit of the firms

$$F^f = Y - WB - T^f$$

$$T^f = F^f(\theta)$$

Demand for loans

$$\mathbb{L}^{f,d} = L_{t-1}^{f,d} + I - F^f + r_{t-1}^{L,ice}(L_{t-1}^{f,ice,d}) + r_{t-1}^{L,row}(L_{t-1}^{f,row,d})$$

Demand for ISK and foreign denominated loans

$$L^{f,ice,d} = L^{f,d}(\Psi_1 - \omega_2 r_{ice}^{L,ice} + \Psi_3 r_{ice}^{L,row})$$

$$L^{f,row,d} = L^{f,d}(\Psi_4 + \Psi_5 r_{ice}^{L,ice} - \Psi_6 r_{ice}^{L,row})$$

A1.1.2 Households

Households disposable income

$$YD = WB + r_{ice(t-1)}^B(B_{ice(t-1)}^{ice,d}) + r_{row(t-1)}^B(B_{ice(t-1)}^{row,d}) + r_{ice(t-1)}^D(D_{ice(t-1)}^{h,ice,d}) - T^h$$

$$T^h = YD(\theta)$$

Haig–Simons disposable income

$$YD_{HS} = YD + (\Delta x r) B_{ice}^{row,s}$$

Wealth accumulation

$$V = V_{t-1} + YD_{HS} - C$$

Real Haig–Simons disposable income

$$yd_{hs} = \frac{YD}{P^{ds}} - \frac{v_{t-1}(\Delta P^{ds})}{P^{ds}}$$

Real wealth

$$v = V/P^{ds}$$

Consumption function

$$c = \alpha_1(yd_{hs}) + \alpha_2(v_{t-1})$$

Real consumption

$$C = c(P^{ds})$$

Portfolio allocation:

Portfolio allocation of domestic households

$$\begin{bmatrix} D_{ice}^{b,ice,d} \\ B_{ice}^{b,ice,d} \\ B_{ice}^{b,row,d} \end{bmatrix} = \begin{bmatrix} \lambda_{10} \\ \lambda_{20} \\ \lambda_{30} \end{bmatrix} V + \begin{bmatrix} \lambda_{11} & \lambda_{12} & \lambda_{13} \\ \lambda_{21} & \lambda_{22} & \lambda_{23} \\ \lambda_{31} & \lambda_{32} & \lambda_{33} \end{bmatrix} \begin{bmatrix} r_{ice}^D \\ r_{ice}^B \\ r_{row}^B + dxre \end{bmatrix}$$

Portfolio allocation of foreign households

$$\begin{bmatrix} D_{row}^{b,row,d} \\ D_{row}^{b,ice,d} \\ B_{row}^{b,row,d} \\ B_{row}^{b,ice,d} \end{bmatrix} = \begin{bmatrix} \lambda_{50} \\ \lambda_{60} \\ \lambda_{70} \\ \lambda_{80} \end{bmatrix} V + \begin{bmatrix} \lambda_{51} & \lambda_{52} & \lambda_{53} & \lambda_{54} \\ \lambda_{61} & \lambda_{62} & \lambda_{63} & \lambda_{64} \\ \lambda_{71} & \lambda_{72} & \lambda_{73} & \lambda_{74} \\ \lambda_{81} & \lambda_{82} & \lambda_{83} & \lambda_{84} \end{bmatrix} \begin{bmatrix} r_{row}^D \\ r_{ice}^{D,row} \\ r_{row}^B \\ r_{ice}^B - dxre \end{bmatrix}$$

A1.1.3 Government

Tax revenue

$$T = T^b + T^f$$

Government budget balance

$$G = T$$

*A1.1.4 Banking sector**Icelandic banks:*

Profit of the banks

$$\begin{aligned} F^b &= r_{ice}^{L,ice} (I^f,ice,d) + r_{ice}^{L,row} (I^f,row,d) \\ &\quad - r_{ice}^{D,row} (D_{row}^{b,ice,d}) - r_{ice}^D (D_{ice}^{b,ice,d}) - r_{ice}^B (B_{ice}^{b,s}) \end{aligned}$$

Bills issued by the Icelandic banks

$$F^b = r_{ice}^{L,ice} (I^f,ice,d) + r_{ice}^{L,row} (I^f,row,d) - r_{ice}^{D,row} (D_{row}^{b,ice,d}) - r_{ice}^D (D_{ice}^{b,ice,d}) - r_{ice}^B (B_{ice}^{b,s})$$

Foreign banks:

Icelandic bills issued in the international market and held by foreign banks

$$B_{row}^{b,s} = \underbrace{B_{ice}^{b,ice,s}}_{\text{bills issued}} - \underbrace{B_{ice}^{b,ice,d} - B_{row}^{b,ice,d} (xr) - B_{ice}^{b,ice,d}}_{\text{bills demanded}}$$

A1.1.5 Balance of payments and trade

Import prices

$$P^m = P_{row}^x (xr)$$

Export prices

$$\log(P^x) = \nu_{x_0} + \nu_{x_1} \log(P_{row}^y) + (1 - \nu_{x_1}) \log(P^y) + \nu_{x_1} \log(xr)$$

Real imports

$$\log(m) = \mu_0 - \mu_1 \log\left(\frac{P^m}{P^y}\right) + \mu_2 \log(y)$$

Real exports: tourism

$$\log(x_1) = \epsilon_0 - \epsilon_1 \log\left(\frac{P^x}{P_{row}^y}\right) + \epsilon_2 \log(y_{row}^*)$$

Exports based on natural resources

$$\log(x_2) = \epsilon_0 + \epsilon_2 \log(y_{row}^*)$$

Total exports

$$x = \alpha_3(x_2) + 1 - \alpha_3(x_1)$$

Nominal imports

$$M = m(P^m)$$

Nominal exports

$$X = x(P^x)$$

Current-account balance

$$\begin{aligned} CAB = X - M + r_{row(t-1)}^B (B_{ice(t-1)}^{h,row,d}) - r_{ice(t-1)}^B (B_{row(t-1)}^{h,ice,d})xr \\ - r_{ice(t-1)}^{D,row} (D_{row(t-1)}^{h,ice,d})xr - r_{ice(t-1)}^B (B_{row(t-1)}^{eb,d})xr \end{aligned}$$

Financial-account balance

$$FAB = (\Delta B_{row}^{h,ice,d})xr + (\Delta B_{row}^{eb,d})xr + (\Delta D_{row}^{h,ice,d})xr - \Delta B_{ice}^{h,row,d}$$

Exchange-rate setting: ISK per foreign currency

$$xr = \left(\frac{B_{ice}^{h,row,d}}{B_{row}^{h,ice,d}} \right)$$

Real exchange rate

$$rxr = xr \left(\frac{P_{row}^y}{P^y} \right)$$

Exchange-rate expectations

$$dxre = \frac{\Omega(xr^* - xr)}{xr}$$

Equilibrium conditions in the model:

Total demand and supply of bills

$$B_{ice}^s = B_{ice}^{b,ice,s}$$

Total demand and supply of loans

$$L_{ice}^d = L_{ice}^{f,d} = L_{ice}^s$$

Total demand and supply of deposits in Icelandic banks

$$D_{ice}^d = \underbrace{D_{row}^{b,ice,d}(xr)}_{\text{Deposits in foreign branches}} + \underbrace{D_{ice}^{b,ice,d}}_{\text{Deposits in domestic branches}} = D_{ice}^s$$

Table A2 Parameters and exogenous variables

Parameter	Description	Value
ϕ	Price mark-up	0.24
A	Productivity in Iceland	1.25
w	Nominal wage rate in Iceland	1
θ	Tax rate	0.25
η	Parameter determining targeted stock of capital	1–1.10
r_{ice}^B	Interest on Icelandic bills	0.02–0.035
r_{row}^B	Interest on foreign bills	0.02
$r_{ice}^{L,ice}$	Interest on ISK denominated loans	0.04–0.045
$r_{ice}^{L,row}$	Interest on FX denominated loans	0.04
$r_{ice}^{D,row}$	Interest on deposits in foreign branches of Icelandic banks	0.015
$r_{ice}^{D,ice}$	Interest on deposits in domestic branches of Icelandic banks	0.015
$r_{row}^{D,row}$	Interest on deposits in foreign banks	0.015
ψ_1	Proportion of loans demanded in local currency	0.6
ψ_4	Proportion of loans demanded in foreign currency	0.4
$\psi_2 = \psi_3 = \psi_5 = \psi_6$	Sensitivity of loans to changes in interest	8
α_1	Propensity to consume out of disposable income	0.9
α_2	Propensity to consume out of wealth	0.1
α_3	Proportion of natural resource based exports	0.65
λ_{10}	Icelandic wealth allocation in deposits in local banks	0.5
λ_{20}	Icelandic wealth allocation in domestic bills	0.25
λ_{30}	Icelandic wealth allocation in foreign bills	0.25
λ_{50}	Foreign wealth allocation in deposits in foreign banks	0.25

(continues opposite)

Table A2 (continued)

Parameter	Description	Value
λ_{60}	Foreign wealth allocation in deposits in Icelandic banks	0.25
λ_{70}	Foreign wealth allocation in foreign bills	0.25
λ_{80}	Foreign wealth allocation in foreign bills	0.25
$\lambda_{11} = \lambda_{22} = \lambda_{33}$	Reaction of Icelandic portfolios to interest-rate changes	1.5
$\lambda_{12} = \lambda_{13} = \lambda_{21} = \lambda_{23} = \lambda_{31} = \lambda_{32}$	Reaction of Icelandic portfolio allocation to interest-rate changes	0.75
$\lambda_{51} = \lambda_{62} = \lambda_{73} = \lambda_{84}$	Reaction parameters of RoW portfolio allocation to interest-rate changes	1.5
$\lambda_{52} = \lambda_{53} = \lambda_{54} = \lambda_{61} = \lambda_{63} = \lambda_{64} = \lambda_{71} = \lambda_{72} = \lambda_{74} = \lambda_{81} = \lambda_{81} = \lambda_{83}$	Reaction parameters of RoW portfolio allocation to interest-rate changes	0.5
ν_{x_0}	Exogenous component of export prices	-0.00001
ν_{x_1}	Export prices reaction to prices and exchange rate	0.5
μ_0	Exogenous component of real imports	-1.05
μ_1	Price elasticity of imports	0.8
μ_2	Income elasticity of imports	1
ϵ_0	Exogenous component of real imports	-1.05
ϵ_1	Price elasticity of exports	0.4
ϵ_2	Income elasticity of exports	1
Ω	Speed of convergence towards long-run exchange rate	0.25
xr^*	Long-run path of exchange rate	1
γ	Speed of adjustment of stock of capital towards targeted capital	0.25
δ	Depreciation rate of capital	0.1

Table A3 Symbols and descriptions of variables

Symbol	Description
$B_{ice}^{h,ice,d}$	Demand for Icelandic bills by Icelandic households
$B_{ice}^{h,row,d}$	Demand for RoW bills by Icelandic households
$B_{row}^{h,row,d}$	Demand for RoW bills by RoW households
$B_{row}^{h,ice,d}$	Demand for Icelandic bills by RoW households
$B_{ice}^{b,ice,s}$	Bills issued by Icelandic banks
$B_{row}^{e,b,s}$	Icelandic bills held by foreign banks
B_{ice}^s	Total bills issued by Iceland
CAB	Current-account balance
C	Nominal consumption
c	Real consumption
da	Capital depreciation
$D_{ice}^{h,ice,d}$	Demand for deposits in Icelandic domestic banks by Icelandic households
$D_{row}^{h,row,d}$	Demand for deposits in RoW banks by RoW households
$D_{row}^{h,ice,d}$	Demand for deposits in Icelandic banks by RoW households
D_{ice}^d	Total demand for deposits in Icelandic banking system
$dxre$	Changes in exchange-rate expectations
F^f	Profit of the firms
F^b	Profit of the banks
FAB	Financial-account balance
G	Nominal government expenditure
g	Real government expenditure
I	Nominal investment
i	Real investment
K	Fixed capital
k^T	Targeted capital
L^f,d	Total demand for loans by firms
L^f,ice,d	Demand for ISK denominated loans by firms
L^f,row,d	Demand for FX denominated loans by firms
L^h,row,d	Demand for FX denominated loans by households
L^d	Total demand for loans in Iceland
L^s	Total supply of loans
M	Nominal imports
m	Real imports

(continues opposite)

Table A3 (continued)

Symbol	Description
N	Employment
P^s	Total sales price
P^{ds}	Domestic sales price
P^m	Import prices
P^x	Export prices
P^y	GDP deflator
P^y_{row}	GDP deflator of the trading partners
r_{ice}^B	Interest on Icelandic bills
r_{row}^B	Interest on RoW bills
$r_{ice}^{L,ice}$	Interest on ISK denominated loans
$r_{ice}^{L,row}$	Interest on FX denominated loans
$r_{ice}^{D,row}$	Interest on deposits in foreign branches of Icelandic banks
$r_{ice}^{D,ice}$	Interest on deposits in domestic branches of Icelandic banks
S	Nominal sales
s	Real sales
V	Nominal wealth
v	Real wealth
xr	Nominal exchange rate (ISK per FX currency)
X	Nominal exports
x	Real exports
Y	Nominal GDP
y	Real GDP
YD	Nominal disposable income
yd	Real disposable income