Journal of International Economics 124 (2020) 103303

Contents lists available at ScienceDirect

Journal of International Economics

journal homepage: www.elsevier.com/locate/jie

Written for the NBER International Seminar on Macroeconomics

Household heterogeneity and the transmission of foreign shocks☆

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ARTICLE INFO

Article history:
Received 27 August 2019
Received in revised form 7 January 2020
Accepted 17 January 2020
Available online 24 January 2020

JEL codes:
F32
F41
E21

Keywords:
Sudden stops
Foreign currency debt
Exchange rate policy
Incomplete markets

ABSTRACT

We study the role of heterogeneity in the transmission of foreign shocks. We build a Heterogeneous-Agent New-Keynesian Small Open Model Economy (HANKSOME) that experiences a current account reversal. Households' portfolio composition and the extent of foreign currency borrowing are key determinants of the magnitude of the contraction in consumption associated with a sudden stop in capital inflows. The contraction is more severe when households are leveraged and owe debt in foreign currency. In this setting, the revaluation of foreign debt causes a larger contraction in aggregate consumption when debt and leverage are concentrated among poorer households. Closing the output gap via an exchange-rate devaluation may therefore be detrimental to household welfare due to the heterogeneous impact of the foreign debt revaluation. Our HANKSOME framework can rationalize the observed "fear of floating" in emerging market economies, even in the absence of contractionary devaluations.

1. Introduction

In the aftermath of the East Asian financial crisis, a debate emerged about the desirability of floating exchange rate regimes. Contrary to the view that floating exchange rate regimes were beneficial and that the severe economic costs of the crisis were due to a lack of exchange rate adjustment, Calvo and Reinhart (2002) documented a phenomenon since then known as "Fear of floating". This phenomenon refers to the observation that policymakers in many countries are unwilling to let nominal exchange rates experience large fluctuations, preferring to make use of official reserves to absorb external pressures.

Interest in the topic of optimal exchange rate adjustment in response to a contraction in capital inflows has received renewed attention after the Global Financial Crisis. In Europe, various countries experienced sudden stops and current account reversals, which were associated with severe recessions. Importantly, while many have focused on the experience of countries in the euro area, such as Greece, countries outside the monetary union like Hungary and Latvia also witnessed sharp current account reversals, which were accompanied by large depreciations of the exchange rate.

Verner and Gyongyosi (2018) document that a crucial channel of transmission of the crisis in Hungary was the one of households' foreign-currency debt, whose real value rose substantially upon the exchange rate depreciation, giving rise to large contractions in consumption for the affected households. Motivated by the evidence of the Hungarian experience, we study a model of a small open economy subject to a capital flow reversal, where the exchange rate is flexible and where households hold debt in foreign currency. While our focus in this paper is inspired by the Hungarian experience, the study applies more broadly to countries in Europe that experienced large increases in foreign currency borrowing by households (particularly to finance home purchases). Austria, Iceland, Estonia, Latvia, Lithuania, Hungary, Poland, Slovenia, Croatia, Serbia, Bulgaria, Romania, and Ukraine each had more than 20% of household debt denominated in foreign currency in the 2000s.[1]

To study the role of household heterogeneity in the transmission of foreign shocks, we develop a quantitative Heterogenous-Agent

☆ We thank Adrien Auclert, Luigi Bocola, Charles Engel, Kristin Forbes, Jeffrey Frankel, Jordi Gali, Pierre-Olivier Gourinchas, Emil Verner, our discussants, Morten Ravn and Ludwig Straub, and participants at the NBER International Seminar on Macro and the Society of Economic Dynamics Annual Meeting for valuable discussions. Support from the Ragnar Söderbergs stiftelse, and the European Research Council grant No. 759482 under the European Union's Horizon 2020 research and innovation programme is gratefully acknowledged.

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[1] Private communication from Emil Verner based on hand collected data.

https://doi.org/10.1016/j.jinteco.2020.103303
0022-1996/

New-Keynesian Small Open Model Economy (HANKSOME) that embeds domestically incomplete markets (at the heart of workhorse closed-economy macroeconomics[2]) into the leading frameworks for open-economy macroeconomics.[3] The household side follows the standard Bewley-Imrohoroglu-Huggett-Aiyagari model that can capture the rich heterogeneity in household income, consumption and wealth. The production side features New Keynesian elements: nominal rigidities in prices and capital adjustment costs. Finally, the household and domestic production blocks are integrated into the standard open-economy macro framework Obstfeld and Rogoff, 2000; Svensson, 2000; Chari et al., 2002; Gali and Monacelli, 2005).[4]

Introducing domestically incomplete markets into the standard open-economy macroeconomics framework allows us to capture the redistribution of resources across households in response to shocks. With borrowing constraints and incomplete insurance, households are heterogeneous in their marginal propensities to consume (MPCs). To the extent that shocks redistribute resources toward high or low MPC households, the effects of the shock can be amplified or muted relative to the representative agent model. In general equilibrium, adjustment of prices and quantities (e.g. wages and hours worked) can result in additional amplification depending on the incidence and implied redistribution. The advantage of the incomplete markets framework is that it provides an underlying theory for the determination of the joint distribution of income, wealth, consumption and the MPC.[5] This enables us to quantify the extent of amplification and propagation relative to the representative agent framework. Importantly, for studying exchange-rate policy it allows us to capture the heterogeneous welfare effects across the distribution, which may yield to different welfare rankings of policies relative to the representative agent paradigm.

We calibrate the model to match salient features of the Hungarian economy in the 2000s. In particular we are interested in matching the expansion of the current account, the distribution of household leverage and the extent of foreign currency borrowing that prevailed before the sudden stop in 2009. We use aggregate data as well as household level data from the Household Finance and Consumption Survey administered by the European Central Bank to discipline the model.

We then use our calibrated HANKSOME framework to study the effect of a sustained expansion in the current account and then an unexpected reversal. We find that in this setting a large exchange rate devaluation that achieves full employment is detrimental from a welfare perspective due to the foreign debt revaluation it entails. Our framework can therefore provide a rationalization for "fear of floating" even in the absence of contractionary devaluations. In addition, we find that the households' portfolio composition is a key determinant of the magnitude of the contraction associated with sudden stop in capital inflows. The contraction is more severe when poor households are more leveraged and owe more debt in foreign currency. Why? Poor households have higher MPCs than richer ones. When the sudden stop occurs, the terms of trade deteriorate, resulting in a revaluation of the foreign currency debt. For higher levered households, this implies a greater shock to their net wealth. If low net wealth households are also highly levered (as in the Hungarian data), then this results in a large contraction in consumption, since it is exactly the high MPC households that experience large negative shocks to net wealth. That drop in consumption leads to a further deterioration in the terms of trade, further amplifying the shock to net wealth, resulting in significant amplification in general equilibrium. By contrast, under a fixed exchange rate, the revaluation of debt, and thus the shock to net wealth, is much smaller, muting the feedback channel described above. The adjustment instead comes from aggregate hours worked (as opposed to the terms of trade) which imply a much more equal incidence of the shock across the net wealth and MPC distribution, which leads to significantly less amplification. We elucidate these mechanisms through a series of counterfactuals under different exchange rate policies, distributions of household leverage and denomination of household debt.

1.1. Related literature

We contribute to the strand of the literature on international macroeconomics that investigates why exchange rate devaluations may be an ineffective, or detrimental, policy response to an external shock suffered by a small open economy.

As mentioned, Calvo and Reinhart (2002) is a seminal paper in this literature, documenting empirically the "fear of floating" in nominal exchange rates. The authors suggest that policy-makers may be reluctant to let large devaluations take place, as these would damage the credibility of monetary policy. In turn, the loss of credibility could lead to dollarization of liabilities, and thus to the inability by the central bank to act as a lender of last resort. We share the focus of Calvo and Reinhart (2002) on investigating the rationale for why a large devaluation may be undesirable from the point of view of a small open economy. Foreign-currency denomination of liabilities also plays a crucial role in our model, but it is a cause rather than an averted consequence of the central bank's reluctance to devaluate the exchange rate. The reluctance of policy makers to let nominal exchange rates float freely appears to remain pervasive in more recent times. In fact, Ilzetzki et al. (2019) document that, almost two decades after Calvo and Reinhart (2002), fear of floating is still present, and many open economies continue to peg or manage their nominal exchange rate to the US Dollar.

Frankel (2005) documents empirically that currency devaluations can have detrimental effects on countries that experience them, as manifested by the frequent loss of office of political leaders in power when currency crashes take place. The author points to adverse balance-sheet effects of currency devaluations as the key driver of their deleterious implications. Céspedes et al. (2004) show using a structural framework how adverse balance sheet effects can lead to an output contraction following a currency devaluation.[6] Our model differs substantially from theirs, in that we focus on household debt denominated in foreign currency, rather than on corporate balance sheets. In addition, we do not impose the assumption that a weaker balance sheet has direct effects on the cost of borrowing in the economy. Instead, the implications of the currency devaluation on aggregate variables in our economy crucially depend on the marginal propensity to consume of agents whose debt rises in value upon the currency crash. Finally, we find fixed exchange rates to be desirable from a welfare perspective during a sudden stop—in an economy calibrated to Hungary—when poor households owe a substantial amount of foreign-currency debt.

The question of whether, in a world characterized by tight financial integration, fluctuations in nominal exchange rates can insulate small open economies from shocks originating abroad has received considerable attention following Rey (2015). Her seminal work has highlighted how, differently from the traditional view, when gross financial positions are large and capital markets are open, floating exchange rates are ineffective at stabilizing a small open economy from fluctuations in the global financial cycle. The presence of this new channel would

[2] We refer the reader to Kaplan and Violante (2018) who provide a review of this frontier closed-economy literature combining incomplete-markets models with nominal rigidities. Early contributions include, among others, Oh and Reis (2012), Guerrieri and Lorenzoni (2017), Gornemann et al. (2012), Kaplan et al. (2018), Auclert (2016), Lütticke (2015), McKay et al. (2016), Bayer et al. (2019), Ravn and Sterk (2017), Den Haan et al. (2017), Auclert and Rognlie (2017), Hagedorn et al. (2019a) and Hagedorn et al. (2018)

[3] We thank Thomas Drechsel for suggesting the HANKSOME acronym.

[4] In an earlier version of the paper we considered an alternative form of nominal rigidities, namely downward nominal wage rigidity in the style of Schmitt-Grohe and Uribe (2016a).

[5] Models with two agents, so-called TANK models, can generate heterogeneity in MPCs, but require start assumptions on the distribution of wealth and the MPC.

[6] Other seminal contributions on the contractionary effects of devaluations and balance sheets include (Aghion et al., 2004; Krugman and Taylor, 1978)

imply that open economies face a dilemma between independent monetary policy and integration in international capital markets, even when they allow their nominal exchange rate to float.

Gourinchas (2018) builds on the intuition in Rey (2015) to analyze what the optimal response of a small open economy's central bank should be to monetary policy shocks originating in countries at the core of the international financial system. He highlights the fact that for monetary policy to have "perverse" effects—i.e. for an exchange rate devaluation to be contractionary, the effects of the exchange rate on residents' balance sheets have to be sufficiently large in magnitude. We build on this insight, showing that the distribution of leverage among borrowing constrained and wealthy households is an important determinant of the strength of this effect.

Some recent papers have also analyzed the effects of sudden stops on capital inflows in models with limited household heterogeneity. In Cugat (2019), households face sector-specific income risk, motivated by evidence that in the Mexican crisis of 1995 households that suffered the most where those who received income from firms in the non-tradable sector. In this paper, we focus on a different margin of heterogeneity, namely the extent of the revaluation of foreign-currency debt that households experience, following the evidence on the importance of this channel for Hungary in 2008–09 presented by Verner and Gyongyosi (2018). Differently than in the paper by Cugat (2019), we find that a fixed exchange rate may be beneficial for the vast majority of households, as in our model a peg can prevent a large foreign-currency debt revaluation from taking place. Also in a model with limited household heterogeneity, Iyer (2015) studies the optimal monetary policy in response to cost-push shocks in a small open economy. She finds that with a high share of hand-to-mouth agents, a currency peg is preferable relative to domestic or CPI inflation targeting. This result is reminiscent of our findings, however, her results are driven purely from the wage and CPI effects on the hand-to-mouth agents' consumption baskets and abstract from any effects of foreign debt and revaluation. Sunel (2018) studies the welfare effects of a gradual disinflation using a heterogeneous-agent open-economy model with a cash-in-advance friction. Unlike our framework, he does not consider foreign shocks, nor debt revaluation effects or nominal rigidities. Finally, Diaz-Alejandro (1963) is a classic paper introducing a setting where an exchange rate devaluation has redistributive effects across the households that inhabit the open economy. Precisely due to its redistributive effects, a devaluation can simultaneously lead in that setting to an improvement in the country's trade balance and to a contraction in the demand-determined level of output.

A recent strand of the literature has studied the role of exchange rate policies in mitigating external crises, in settings where the exchange rate itself determines the severity of the borrowing constraint that the small open economy faces. As in Fornaro (2015) we find that a monetary policy rule that delivers strict inflation targeting is not optimal when external crises can occur. However, his framework calls for a more volatile exchange rate that magnifies the price of collateral, and thus reduces the detrimental effects of an external crisis. In our framework, the results go in the opposite direction, in that a fixed exchange rate regime is preferable to the inflation targeting rule. Here, we focus on the adverse effects of the exchange rate devaluation on the magnitude of the country's external liabilities, in a setting where these are denominated in foreign currency and where the supply of external credit does not depend on endogenous market prices. Ottonello (2013) addresses a related question in a setting where an exchange rate devaluation reduces a country's ability to borrow. Again, our key results differ from those in that paper, in that we find that a fixed exchange rate policy can deliver higher welfare than flexible exchange rate policies, due to its beneficial effect on the small open economy's terms of trade, a channel that is absent in that framework. Benigno et al. (2016) study optimal real exchange rate policies in a framework with occasionally binding collateral constraints, whose tightness depends on the endogenous level of the real exchange rate. As in our paper, they find that it is optimal for policy to support the real exchange rate during a crisis, although because of a different channel than the one at play here. In that setting, policies that support the real exchange rate relax the severity of the borrowing constraint that the small open economy faces. Here, fluctuations in the real exchange rate determine the magnitude of foreign-currency denominated external debt.

Finally, a different strand of the literature has focused on the importance of downward nominal wage ridigity in driving fluctuations in small open economies. Schmitt-Grohe and Uribe (2016b) is a recent important contribution that highlights the costs of exchange rate pegs in the presence of downward nominal wage rigidity. We contribute to this literature by introducing a model where nominal rigidities and foreign-currency denominated debt coexist. We abstract from wage rigidities in our framework as the consensus is that Hungary displays relatively low wage rigidities relative to other advanced economies (see, e.g. Horváth and Szalai, 2008; Boeri and Garibaldi, 2006)).

The paper is organized as follows. Section 2 presents our small open economy incomplete markets model with nominal rigidities. In section 4 we discuss how we bring the model to the data. We outline our main experiments in section 5 and describe our results in section 6. Finally, section 8 concludes.

2. Model

The model is a small open economy with nominal price rigidities as in Gali and Monacelli (2005), augmented with capital and domestically incomplete markets for households as in Huggett (1993); İmrohoroğlu (1989, 1992); Aiyagari (1994, 1995). As our focus here is on the behavior of the small open economy, we model the rest of the world as reduced-form asset supply and goods demand functions described below. Variables with a star superscript refer to the rest of the world economy.

2.1. Households

The economy consists of a continuum of agents normalized to measure 1 who are ex-ante homogeneous, and have CRRA preferences over consumption of home and foreign goods and leisure:

$$U = E_0 \sum_{t=0}^{\infty} \beta^t [u(c_t) - g(l_t)]$$

where

$$u(c) = \begin{cases} \dfrac{c^{1-\sigma}-1}{1-\sigma} & \text{if } \sigma \neq 1 \\ \log(c) & \text{if } \sigma = 1 \end{cases}$$

$$g(l_t) = \varphi \frac{l_t^{1+1\eta}}{1+1\eta}$$

$\beta \in (0,1)$ is the households' subjective discount factor, η is the Frisch elasticity of labor supply, and c is a CES aggregate of home and foreign goods with elasticity of substitution θ:

$$c = \left[(\chi)^{\frac{1}{\theta}} (c_H)^{\frac{\theta-1}{\theta}} + (1-\chi)^{\frac{1}{\theta}} (c_F)^{\frac{\theta-1}{\theta}} \right]^{\frac{\theta}{\theta-1}}$$

χ is the weight of home good in consumption.

Households' labor productivity $\{s_t\}_{t=0}^{\infty}$ is stochastic and is characterized by an N-state Markov chain that can take on values $s_t \in S = \{s_1, \cdots, s_N\}$ with transition probability given by $\gamma(s_{t+1}|s_t)$ and $\int s = 1$. Households rent their labor services, $l_t s_t$, to firms for a real wage w_t per effective hour.

Following Erceg et al. (2000), we assume that each household i produces a differentiated variety of labor services with productivity s_{it}. There exists a technology to convert the household differentiated labor services into aggregate effective labor, L_t:

$$L_t = \left(\int_0^1 s_{it} (l_{it})^{\frac{\varepsilon_L - 1}{\varepsilon_L}} di \right)^{\frac{\varepsilon_L}{\varepsilon_L - 1}} \tag{1}$$

where ε_L is the elasticity of substitution across differentiated labor.

A recruiting firm operates the technology to generate the aggregate effective labor. That firm purchases individual households labor services $s_{it}h_{it}$ from a union representing the households at the wage w_{it}. The recruiting firm minimizes costs, given aggregate labor demand L_t by the intermediate goods sector:

$$\int_0^1 W_{it} s_{it} l_{it} di \tag{2}$$

implying a demand for the labor services of household i:

$$l_{it} = l(W_{it}; W_t, L_t) = \left(\frac{W_{it}}{W_t} \right)^{-\varepsilon_L} L_t \tag{3}$$

where W_t is the (equilibrium) nominal wage which can be expressed as

$$W_t = \left(\int_0^1 s_{it} W_{it}^{1-\varepsilon_L} di \right)^{\frac{1}{1-\varepsilon_L}}$$

The union sets a nominal wage $\hat{W}_t$ for an effective unit of labor (so that $W_{it} = \hat{W}_t$) to maximize profits. Absent a unique objective function for the union in the presence of heterogeneous households, we follow the assumptions of Hagedorn et al. (2019b) on how to aggregate household preferences.[7] The union's wage setting problem is assumed to maximize the aggregate real revenue of supplying labor net of the aggregate utility cost

$$\max_{\hat{W}_t} \int_0^1 \left(\frac{s_{it} \hat{W}_t}{P_t} l\left(\hat{W}_t; W_t, L_t\right) - \frac{g\left(l\left(\hat{W}_t; W_t, L_t\right)\right)}{u'(C_t)} \right) di \tag{4}$$

where C_t is aggregate consumption and P_t is the price of a unit of consumption in terms of domestic currency, or the consumer price index (CPI).[8] Using symmetry, $l_{it} = L_t$ and $\hat{W}_t = W_t$, the first order condition from the union's problem implies

$$W_t = P_t \frac{\varepsilon_L}{\varepsilon_L - 1} \frac{g'\left(l\left(\hat{W}_t; W_t, L_t\right)\right)}{u'(C_t)} \tag{5}$$

Agents rent their nominal asset portfolio a_t to the asset market for a nominal rent i_t^a. Households' portfolio may potentially include several asset classes, including capital, real bonds, and nominal bonds denominated in domestic and foreign currencies. We describe the household portfolio and the arbitrage conditions across the multiple asset classes in more detail below.

[7] We introduce the union despite having flexible wages to eliminate the individual labor supply response to shocks. First, significant heterogeneity in wealth across the distribution would lead to counterfactually large dispersion in hours worked. Second, in response to an aggregate shock this formulation captures the fact that households at the bottom of the distribution may not be able to increase labor supply to smooth consumption, as many of these households in the data were involuntarily unemployed.

[8] Note that in the limit as idiosyncratic risk goes to zero, this would converge to the standard labor-leisure in the representative agent framework. The assumption implies that the union does not keep track of individual marginal utilities, but instead uses the marginal utility of the "as-if" representative household.

At time t an agent faces the following nominal budget constraint, in units of domestic currency:

$$P_t c_t + a_{t+1} = (1 + i_t^a) a_t + W_t l_t s_t + d_t$$

where d_t are dividends distributed by firms and the CPI P_t satisfies: $P_t = [\chi(P_{H,t})^{1-\theta} + (1-\chi)(P_{F,t})^{1-\theta}]^{\frac{1}{1-\theta}}$. Total consumption expenditure satisfies:

$$P_t c_t = P_{H,t} c_{H,t} + P_{F,t} c_{F,t}$$

where $P_{H,\,t}$ and $P_{F,\,t}$ are the nominal prices of home and foreign goods, respectively. In addition, households are subject to a borrowing constraint:

$$a_{t+1} \geq \bar{a}$$

implying that assets carried into the following period cannot be lower than the threshold $\bar{a}$.

Households take prices as and wages as given. Thus, we can rewrite the agent's problem recursively as follows:

$$\begin{aligned} V(a, s; \Omega) = & \max_{c \geq 0, a' \geq \bar{a}} u(c) - g(l) + \beta \sum_{s \in \mathcal{S}} \gamma(s'|s) V(a', s'; \Omega') \\ & \text{subj.to} \quad Pc + a' = (1 + i^a) a + Wls + \pi \\ & \qquad \Omega' = \Upsilon(\Omega) \end{aligned} \tag{6}$$

where $\Omega(a,s)$ is the distribution on the space $X = \mathcal{A} \times \mathcal{S}$ of agents' asset holdings $a \in \mathcal{A}$, and labor productivity $s \in \mathcal{S}$, across the population, which will, together with the policy variables, determine the equilibrium prices. Let $\mathbb{B}(X) = \mathcal{P}(\mathcal{A}) \times \mathcal{P}(\mathcal{S})$ be the σ-algebra over X, defined as the cartesian product over the Borel σ-algebra on $\mathcal{A}$ and the power sets of $\mathcal{S}$. Define our space $M = (X, \mathbb{B}(X))$, and let $\mathscr{M}$ be the set of probability measures over M. Υ is an equilibrium object that specifies the evolution of the distribution Ω.

2.1.1. Households' portfolio

There are two broad classes of assets, bonds and capital. In turn, bonds may be denominated in domestic currency, in foreign currency, or in real terms. In general, nominal assets carried by the household into the following period are equal to:

$$a_{t+1} = b_{H,t+1} + e_t b_{F,t+1} + P_{H,t} \left(q_t k_{t+1} + \tilde{b}_{H,t+1} \right) \tag{7}$$

where $b_{H,t+1}$ and $b_{F,t+1}$ denote nominal bonds denominated in domestic and foreign currency, respectively, e_t is the nominal exchange rate, expressed as the price of a unit of foreign currency in terms of domestic currency, q_t denotes the real price of capital in units of home good, and $\tilde{b}_{H,t+1}$ are real bonds in units of home good.[9]

In equilibrium, and in the absence of aggregate uncertainty, returns are equalized across asset classes. The arbitrage condition between nominal bonds denominated in domestic currency and real bonds yields a familiar Fisher equation:

$$1 + i_{H,t+1} = (1 + r_{H,t+1}) \frac{P_{H,t+1}}{P_{H,t}} \tag{8}$$

where $i_{H,t+1} = i_{t+1}^a$ is the return on domestic nominal bonds and $r_{H,t+1}$ is the return on real, home-good bonds. Arbitrage between nominal bonds denominated in different currencies gives rise to a covered-interest parity condition:

[9] Real bonds in units of foreign good are redundant as long as the price of foreign goods in foreign currency is constant, being determined in the rest of the world.

$$1+i_{H,t+1}=(1+i_{F,t+1})\frac{e_{t+1}}{e_t} \tag{9}$$

Finally, the return on capital net of depreciation equals the return on real bonds:

$$\frac{r^k_{t+1}+(1-\delta)q_{t+1}}{q_t}=1+r_{H,t+1} \tag{10}$$

where r^k_t denotes the real rental rate of capital, in units of home good, in period t and δ is the depreciation rate of capital.[10]

2.2. Production

2.2.1. Final-good producing firms

There exists a representative final-goods producing domestic firm that operates a CES production technology that aggregates domestic intermediate goods Y_{jt} indexed by $j\in[0,1]$:

$$Y_t=\left(\int_0^1 Y_{jt}^{\frac{\varepsilon-1}{\varepsilon}}dj\right)^{\frac{\varepsilon}{\varepsilon-1}}$$

where ε is the elasticity of substitution across goods. Given a level of aggregate demand Y_t, cost minimization for the final goods producer implies that the demand for the intermediate good j is given by

$$Y_{jt}=Y\left(p_{jt};P_{H,t},Y_t\right)=\left(\frac{p_{jt}}{P_{H,t}}\right)^{-\varepsilon}Y_t \tag{11}$$

where p_{jt} is the price of intermediate good j and $P_{H,t}$ is the (equilibrium) price of the final good which can be expressed as

$$P_{H,t}=\left(\int_0^1 p_{jt}^{1-\varepsilon}dj\right)^{\frac{1}{1-\varepsilon}}$$

2.2.2. Intermediate-goods firms

A typical domestic intermediate-goods producing firm operates a Cobb-Douglas technology represented by the production function:

$$Y_{jt}=K_{jt}^{\alpha}L_{jt}^{1-\alpha} \tag{12}$$

where $\alpha\in(0,1)$, K_{jt} are capital services rented and L_{jt} are labor services rented. Factor markets for intermediate-goods firms are perfectly competitive. The market for intermediate goods is monopolistically competitive. Defining the real wage in terms of domestic goods as $w_t=\frac{W_t}{P_{H,t}}$ yields the following firm objective function:

$$S_t(Y_{jt})=\min_{K_{jt},L_{jt}} r^k_tK_{jt}+w_tH_{jt},\ \text{ and } Y_{jt} \text{ is given by (12)} \tag{13}$$

where real marginal cost is $mc_{jt}=\partial S_t(Y_{jt})/\partial Y_{jt}$,

$$mc_t=\left(\frac{1}{\alpha}\right)^{\alpha}\left(\frac{1}{1-\alpha}\right)^{1-\alpha}\left(r^k_t\right)^{\alpha}(w_t)^{1-\alpha} \tag{14}$$

and

$$\frac{K_{jt}}{L_{jt}}=\frac{\alpha w_t}{(1-\alpha)r^k_t} \tag{15}$$

Domestic intermediate-goods producers set prices subject to adjustment costs as in Rotemberg (1982). The relevant state variables for the firm are last period's individual price p_{jt-1} and the contemporaneous aggregate state $(P_{H,t},Y_t,w_t,r_t)$. The firm sets this period's price p_{jt} to maximize the present discounted value of profits. This yields the following pricing problem,

$$V_t^{IGF}\left(p_{jt-1}\right)\equiv\max_{p_{jt}}\frac{p_{jt}}{P_{H,t}}Y\left(p_{jt};P_{H,t},Y_t\right)-S\left(Y\left(p_{jt};P_{H,t},Y_t\right)\right)$$
$$-\frac{\zeta}{2}\left(\frac{p_{jt}}{p_{jt-1}}-1\right)^2Y_t+\frac{1}{1+r_t}V_{t+1}^{IGF}\left(p_{jt}\right)$$

The solution to this problem yields the standard New Keynesian Phillips Curve

$$(1-\varepsilon)+\varepsilon mc_t-\zeta(\pi_{H,t}-1)\pi_{H,t}+\frac{1}{1+r_t}\zeta(\pi_{H,t+1}-1)\pi_{H,t+1}\frac{Y_{t+1}}{Y_t}=0$$

where $\pi_{H,t}\equiv P_{H,t}P_{H,t-1}$ is domestic inflation (recall, the CPI in our economy is P_t). The equilibrium real profit of each intermediate goods firm, rebated to the households as dividends, is

$$d_t=Y_t-S(Y_t)$$

2.2.3. Investment-goods producing firms

There exists a unit-mass continuum of competitive firms who produce investment goods. They have access to a technology to convert home good into the investment good, subject to a convex adjustment cost. The problem of the representative investment-good producing firm is as follows:

$$\Pi_{I,t}=\max_{I_t} q_tI_t-[I_t+\Psi(I_t,K_t)] \tag{16}$$

where q_t denotes the relative price of investment good to home good, which is taken as given by the firms, and I_t denotes investment. Firms also take as given the aggregate amount of capital installed in the economy K_t, which affects the severity of adjustment costs.

The first order condition associated with this problem is:

$$q_t=1+\frac{\partial\Psi(I_t,K_t)}{\partial I_t} \tag{17}$$

Finall, the law of motion for the aggregate capital stock in the economy is given by:

$$K_{t+1}=(1-\delta)K_t+I_t \tag{18}$$

2.3. Rest of the world

2.3.1. Foreign credit supply

Residents of the rest of the world issue credit to the small open economy. In each period t, rest-of-the-world residents inelastically purchase a quantity of bonds equal to $\overline{B}_{t+1}$ units of home good.

2.3.2. International good markets

The law of one price holds.[11] This implies that the prices of home and foreign goods in the small open economy are equal to prices in the rest of the world once converted in units of domestic currency:

[10] As we are modeling the rest of the world in a reduced-form manner, these no-arbitrage conditions technically are only guaranteed to hold for households in the small open economy.

[11] We abstract from trade in intermediate inputs. This saves us from having to fully specify the production function for the rest of the world. This is without loss of generality if the CES technology for producing the foreign final good is the same as the domestic final good. Then, the law of one price would hold at the intermediate good level, which by implication would make the law of one price hold at the final good level.

$$P_{H_t} = e_t P^*_{H_t}, \quad P_{F_t} = e_t P^*_{F_t} \tag{19}$$

For simplicity, it will be convenient to normalize $P^*_{F_t}$ to unity and thus set $P_{F_t} = e_t$. We define the terms of trade as the relative price of exports to imports:

$$x_t = \frac{P_{H,t}}{e_t} \tag{20}$$

Demand for consumption of home good in the rest of the world, $C^*_{H,\,t}$, is a decreasing function of the terms of trade:

$$C^*_{H,t} = x_t^{-\theta^*} D \tag{21}$$

where θ^* is the elasticity of demand of residents of the rest of the world, and D is a demand shifter that captures the magnitude of the rest of the world market.

Total resources produced in the domestic economy are equal to the sum of domestic absorption for consumption, investment and investment adjustment costs and the foreigners' consumption of the domestically produced good. Thus, the aggregate resource constraint for the domestic economy is given by:

$$Y_t = K_t^\alpha L_t^{1-\alpha} = C_{H,t} + C^*_{H,t} + I_t + \Psi(I_t, K_t) \tag{22}$$

where $C_{H,\,t} = \int c_{H,\,t}(a_t, s_t) d\Omega_t$.

2.4. Monetary policy

We consider two different regimes for the conduct of monetary policy. First, in the fixed exchange rate regime the central bank of the small open economy is committed to a strict nominal exchange rate peg:

$$e_t = e \text{ for all } t \tag{23}$$

Second, we consider a flexible exchange rate regime. In this setting, the central bank adjusts the exchange rate to achieve the flexible price allocation in the domestic economy. This is done by ensuring that the nominal price of the home good $P_{H,t}$ is constant in equilibrium, so that nominal rigidities do not have real effects.

2.5. Equilibrium

Given a sequence of foreign assets supplied by the rest of the world, $\overline{B}_{t+1}$, and an exchange-rate regime, an equilibrium of the small open economy is characterized by a sequence of prices $\{w_t, q_t, P_{H,t}, P_{F,t}\}$ and allocations $\{K_{t+1}, B_{H,t+1}, B_{F,t+1}, \tilde{B}_{H,t+1}, L_t, C_{H,t}, C^*_{H,t}, Y_t\}$ such that:

1. Labor demanded by intermediate firms equal labor supplied by households.
2. Assets supplied by residents of domestic households and the rest of the world equals the total capital demanded by intermediate goods firms.
3. The union sets the nominal wage optimally.
4. Firms optimize given factor prices and the price level.
5. Households optimize given prices.
6. The resource constraint is satisfied.
7. The law of one price holds.
8. No arbitrage across assets.

3. Understanding the role of heterogeneity

What role do domestically incomplete markets play in shaping the aggregate response to foreign shocks? It is instructive to consider the consumption response of domestic households in partial equilibrium to gain intuition for the ultimate general equilibrium adjustment.[12] Consider an unexpected shock to the exchange rate, Δe_t. The implied change in wealth, Ξ_{it}, as a result of this shock varies across households, and is given by:

$$\Xi_{it} = \Delta e_t b_{F,t}$$

The revaluation in debt is an unexpected shock to wealth of households. When leverage is heterogeneous, the implied change in wealth varies across households. The consumption response to the one-time unexpected change in wealth is same as the consumption response to a transitory income shock:

$$\partial c_{it} = MPC_{it} \times \Xi_{it}$$

In partial equilibrium, we can aggregate across households to compute the aggregate consumption change as given by:

$$\partial C_t = \overline{MPC}_t \times \overline{\Xi}_t + Cov(MPC_{it}, \Xi_{it})$$

where $\overline{MPC}_t$ is the average MPC in the economy and $\overline{\Xi}_t$ is the average change in wealth due to the change in the exchange rate. In the absence of heterogeneity, $\partial C_t = \overline{MPC}_t \times \overline{\Xi}_t$, as would be the case in the representative agent model where all agents have the same MPC. Thus, the contribution of the domestically incomplete markets is captured through the covariance term $Cov(MPC_{it}, \Xi_{it})$, which captures which households are more exposed to the redistribution induced by a shock. If high MPC households tend to be more exposed, then the partial equilibrium consumption response would be amplified, and would be indicative of amplification of the ultimate general equilibrium response. Of course, in general equilibrium additional prices and quantities will adjust, resulting in potentially different patterns of redistribution. Ultimately, it is a quantitative question, which we explore below, whether incomplete markets will amplify or dampen aggregate shocks relative to the representative agent case. Crucially, our heterogeneous agent framework delivers a theory of the joint distribution of earnings, wealth, consumption and the MPC, such that quantitatively we will capture the relevant pattern of redistribution across agents.

4. Calibration

We calibrate the framework described above to the economy of Hungary — an example of a small open economy with high concentration of foreign denominated debt going in to the Global Financial Crisis. The main contribution is to study the effect of the sudden outflow of credit from the Hungarian economy and subsequent devaluation of the Hungarian Forynt on aggregate as well as household-level outcomes. A key object of our analysis is whether Hungarian households would have been better off, had it been possible to maintain the Hungarian Forynt pegged to a basket of foreign currencies. To elucidate the forces at play, we also consider various counterfactuals to highlight the effects of the particular choice of monetary policy on the part of Hungary, and make clear the implications of borrowing in foreign vs domestic debt. We solve the model in discrete time, and we calibrate it at a quarterly frequency. The calibrated parameters are summarized in Table 1.

4.1. Households

4.1.1. Preferences

Households have constant relative risk aversion (CRRA) preferences over a constant-elasticity of substitution aggregator of home and foreign consumption goods. As is standard in the macroeconomics literature,

[12] The results in this section are similar to those developed in the closed economy HANK literature, e.g. Auclert (2016); Auclert and Rognlie (2017); Hagedorn et al. (2019a).

Table 1
Calibration.

Parameter	Value	Target
Intertemporal EOS	$\sigma = 1$	Standard value
Home and foreign good EOS in home	$\theta = 1$	Feenstra et al. (2018)
Home and foreign good EOS in foreign	$\theta^* = 3$	Feenstra et al. (2018)
Share of home goods in consumption	$\chi = 0.6$	Exported value added to GDP, 33%
Discount factor	$\beta = 0.983$	Aggregate net wealth to GDP, 8.26 (ECB, 2016)
Persistence of labor productivity	$\rho_l = 0.97$	Dispersion in income, Hungary 2016
Standard deviation, labor productivity	$\sigma_l = 0.2$	Fraction of borrowing constrained households, Hungary 2016
Capital share	$\alpha = 0.33$	Standard value
Depreciation rate	$\delta = 0.02$	Real rate of 4.3%
Capital adjustment cost parameter	$\psi = 17$	Elasticity of investment to Tobin's Q.
Supply of foreign credit	$\overline{B} = -2$	Private debt to GDP, Hungary 2008
EOS between home varieties	$\varepsilon = 10$	Steady state markup, 10% of output
Rotemberg adjustment cost parameter	$\zeta = 100$	Kaplan et al. (2018)

we set the elasticity of intertemporal substitution 1σ, equal to 1 and the household Frisch elasticty of labor supply to 1. We set the elasticity of substitution between home and foreign goods, θ equal to 1. We set the share of home goods in consumption, χ equal to 0.6, implying a ratio of exported value added to GDP of 33%.[13] We choose the subjective discount factor $\beta = 0.983$ to match a ratio of aggregate net wealth to quarterly GDP of 8.26 (ECB, 2016) We choose the tightness of the household borrowing constraint $\overline{a}$ to 0, to reflect the fact that the majority of household debt in Hungary was collateralized, as reported in the second wave of the Household Finance and Consumption Survey (HFCS) run by the European Central Bank (ECB).[14]

4.1.2. Productivity process

The HFCS only features on cross-sectional observation for the Hungarian economy. The lack of panel data on individuals or households makes direct estimation of the household labor productivity process impossible. As such, as is standard in the incomplete markets literature (see e.g. (Krueger et al., 2016)), we assume that labor productivity follows an AR(1) process with persistence 0.97 and normal innovations with standard deviation 0.2, calibrated to match the cross-sectional dispersion in income in the HFCS and 10% of households in Hungary that are at the borrowing constraint. We discretize the income process into a seven point Markov chain via the Rouwenhorst method.

4.1.3. Technology

We set the capital share $\alpha = 0.33$. The quarterly depreciation rate is set to 0.02 so that the return on capital net of depreciation is equal to the real return on bonds when the economy matches the observed capital to output ratio of 9.70 in the data. We assume a standard quadratic adjustment cost on capital:

$$\Psi(I, K) = \frac{\psi}{2}\left(\frac{I - \delta K}{K}\right)^2 K$$

We set the value of ψ equal to 17 to match an elasticity of investment to Tobin's Q from the data (Eberly et al., 2008).

4.1.4. Foreign sector

We choose the foreign demand shifter D to normalize the steady state value of the terms of trade to unity.

We allow for two different values for the elasticity of substitution across home and foreign goods in the preferences of domestic and foreign households, given by θ and θ^*, respectively. From the point of view of foreign households, the parameter θ^* corresponds to the elasticity of substitution across varieties produced by different countries. Hence, its empirical counterpart is the micro-elasticity across different foreign sources of imports estimated in the trade literature. From the point of view of domestic households, instead, goods produced domestically and abroad may be less close substitutes than goods produced in different foreign countries. Hence, the relevant empirical counterpart for this elasticity is the macro-elasticity between domestic and imported goods. We pick a value of $\theta^* = 3$ and $\theta = 1$ to match recent evidence by Feenstra et al. (2018) who estimate the macro-elasticity between home and imported goods and the micro-elasticity between foreign sources of imports using highly disaggregated data. Consistently with this intuition, Feenstra et al. (2018) estimate the macro-elasticity of substitution across home and foreign goods to be close to unity, the value we set in this paper.

We set the supply of foreign credit $\overline{B}$ to match a net-foreign-asset-to-quarterly-GDP ratio for Hungary of -2. This matches the private sector debt ratio of 50% of annual GDP (IMF, 2008). While the total international investment position of Hungary was larger than this figure, credit to the private sector is the relevant calibration target here, given the absence of government debt in this setting.

4.1.5. Nominal rigidities

We set the elasticity of substitution between domestic varieties $\varepsilon = 10$ such that the steady state markup is 10% of output. We pick the Rotemburg adjustment cost parameter to be $\zeta = 100$, implying a slope of the New-Keynesian Phillips curve of $\varepsilon/\zeta = 0.1$ in the middle range of empirical estimates.

5. Experiments

To study the implications of a reversal in capital flows on the model economy, we run two separate experiments. For our first experiment, we consider an experiment inspired by the Hungarian current account expansion and reversal of the early and late 2000s. We model the expansion and subsequent contraction of the current account as two separate unexpected shocks. Starting from an initial steady state with low external liabilities, the economy experiences a sustained expansion in the current account that then stabilizes. We model that expansion as an unexpected "MIT shock", where at time zero the future path for the current account is revealed and we compute the perfect-foresight transition to the new steady state with no future shocks. The contraction in the current account is modeled as an unexpected interruption along the perfect foresight transition. Thus, agents in the economy experience a second MIT shock where their ability to borrow internationally contracts when they were expecting it to continue to expand. The economy

[13] On average, this ratio was equal to 38% in Hungary between 2000 and 2007, according to data from the OECD Trade in Value Added Dataset.

[14] The HFCS provides harmonized household level data on household balance sheets and consumption across the Euro Area and additional European Union members.

[15] The impulse response function obtained from this experiment could be used to linearize the model and solve for the economy with recurrent shocks as shown in Boppart et al. (2018).

then follows a new perfect foresight transition path toward a permanently lower level of foreign liabilities. Modeling an unexpected current account contraction while the economy was expecting continued expansion of the current account captures the expected growth prospects and subsequent reversal of Hungary in the 2000s.

In the baseline experiment we assume that the model economy follows a floating exchange rate regime and with all debt foreign-currency denominated, consistent with the Hungarian experience. To investigate the contribution of this exchange rate policy to the severity of the recession we consider a counterfactual scenario where instead the exchange rate is held fixed.

Our second experiment is focused on elucidating the conditions under which flexible or floating exchange rates are desirable for economy in response to foreign shocks, and how the answer to that question is shaped by household heterogeneity and the amount of foreign denominated debt in the economy. To investigate the complicated interactions between exchange rate policy and household heterogeneity, we consider a simpler experiment that isolates the effect of the contraction in the current account. We consider a series of economies that start off in steady state that experience unexpected, mean-reverting contractions in the current account. We again compute the perfect-foresight impulse response to the "MIT Shock".[15] The economies studied vary in the distributions of households leverage, the share of debt that is denominated in foreign currency and the exchange rate regime.

6. Sudden stop

The main experiment of interest is studying the reversal of foreign credit supply under the baseline scenario of a flexible exchange rate and foreign-currency denominated debt — the empirically relevant case for Hungary during the Global Financial Crisis, where 69% of household debt was denominated in foreign currency (Verner and Gyongyosi, 2018). We initialize the economy at a steady state with no foreign debt. At time 0 the agents in the economy learn that the current account will expand by 7.4% of quarterly GDP in the initial period, and continue to do so, but at a declining rate, given by ρ_B. The evolution of the net foreign asset position (NFA) is the accumulation of the current accounts and summarized by

$$\overline{B}_t = \overline{B}_{t-1} + \rho_B^t \varepsilon_{B,t}$$

where $\overline{B}_t$ is denominated in units of the home good, which limits the effect of the debt denomination on credit supply. Note, that no revaluation effects are associated with this expansion in the current account as we assume that the economy begins with a zero net and gross foreign asset position.[16] Debt revaluation effects instead play a crucial role subsequently at the time of the sudden stop. We pick the level of the initial increase in the current account to match the average increase in Hungary from 2000 to 2009. The path for the NFA is the light blue dashed line in Fig. 1.

In response to the expansion in the current account the economy experiences a sustained investment boom as it transits toward a new steady state with a permanently higher level of capital. Aggregate consumption also jumps on impact of the shock as the home economy now has access to borrowing, and then gradually declines to the new steady state level. While demand for the home good is high, due to the investment boom, households substitute away from consumption of the home good to the foreign good. Then they slowly reverse this pattern as the home economy grows and the supply of home good becomes more abundant.

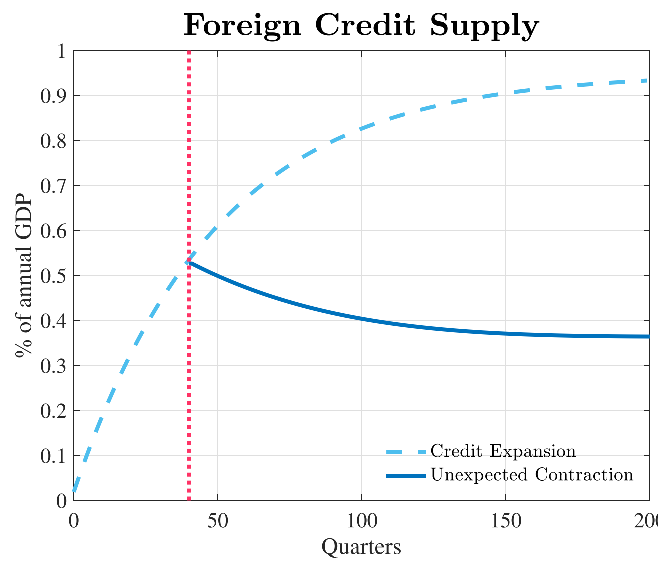

Fig. 1. Foreign credit supply shocks.

Domestic output declines on impact, because of a domestic wealth effect on labor supply that leads to a contraction in labor early in the transition. The contraction in output coupled with the increased demand for investment causes a jump in the terms of trade that leads to a contraction in demand by foreigners and hence a drop in exports. The full impulse responses for the economy are plotted in Figs. 2 and 3.

Ten years after the initial shock, while the economy is undergoing a transition to the higher NFA position, the current account suddenly and unexpectedly reverses, yielding a new path for the NFA given by the solid dark blue line in Fig. 1. The timing of the shock is highlighted by the vertical dotted red line and is chosen to match the reversal in Hungary's current account that began in 2009. At that point on the original transition path the economy was experiencing a strong boom in consumption, investment and real wages, similar to the position of Hungary in the late 2000s. How did the reversal in the current account affect the evolution of the economy?

Along the perfect foresight transition path, because of certainty equivalence, the household portfolio is indeterminate. When the unexpected contraction occurs, foreign debt will be revalued when the exchange rate adjusts. The implied wealth redistribution from the portfolio revaluation is a crucial object of interest, and as such we try to replicate the observed leverage distribution in Hungary when the current account reversed. For simplicity, we assume a parametric leverage distribution characterized by a slope and an intercept term. The intercept term is disciplined by the level of gross debt relative to net worth held by the bottom quintile of the wealth distribution in Hungary. The slope term is set to match the total leverage position of the economy (defined as the the domestic capital stock divided by domestic net worth). Specifically, the bottom quintile of wealth distribution had zero net wealth, but held a gross asset position equal to approximately 6% of the aggregate gross assets of the economy (Boldizsár et al., 2016). The leverage distribution is plotted as the black line in Fig. 9. In section 7.3, we explore the implications of alternative distributions of leverage for the aggregate and welfare results.

The impulse responses for prices and quantities in response to the sudden stop are plotted as the blue solid lines in Figs. 4 and 5. Under a flexible exchange rate policy, consumption of home and foreign goods by domestic consumers contract sharply because of the unexpected withdrawal of foreign credit and the fall in wealth due to the debt revaluation. Output, however, increases sharply as labor supply expands in

[15] The impulse response function obtained from this experiment could be used to linearize the model and solve for the economy with recurrent shocks as shown in Boppart et al. (2018).

[16] We have experimented with different starting debt levels, but found they have virtually no impact on the effects of the contraction that occurs a decade later.

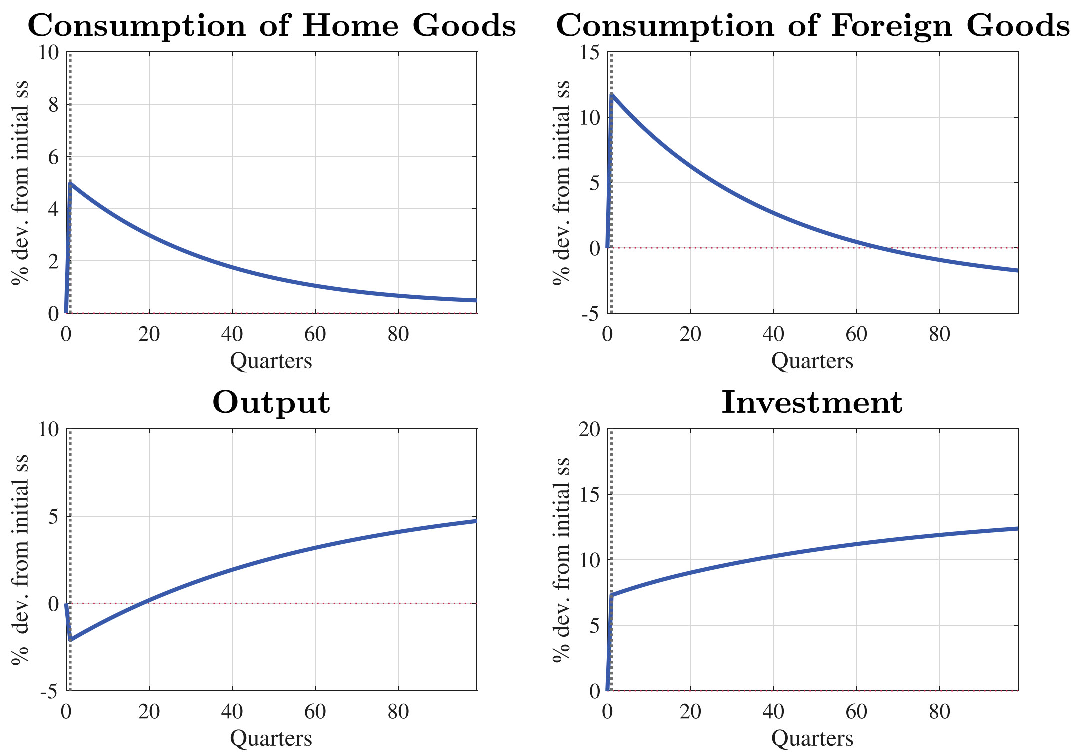

Fig. 2. Impulse response of quantities to current account expansion.

response to the fall in consumption induced by the revaluation and contraction of foreign credit.[17] The sharp deterioration in the terms of trade generate a surge in foreign demand for the home good, which rationalizes the simultaneous output boom and fall in consumption and investment. Note that the decline in the terms of trade is larger than the increase in output, so denominated in foreign currency the value of domestic output still falls.

Now we consider the same shock, but under the counterfactual scenario where the monetary authority had kept a fixed exchange rate vis-a-vis the rest of the world. The impulse responses under the fixed exchange rate regime are plotted as the red dashed lines in Figs. 4 and 5.

Under the fixed exchange rate the HANKSOME economy still experiences a tightening of external credit, however, the debt revaluation channel is absent. Domestic output contracts because nominal rigidities become binding when the exchange rate is fixed. Lower domestic output implies a smaller contraction of the terms of trade relative to the flexible benchmark. In turn, the stronger terms of trade imply a milder real revaluation of households' foreign currency debt.[18] The milder debt revaluation implies a more muted decline in consumption relative to the flexible exchange rate regime, further reinforcing the stronger terms of trade. Further, labor supply contracts despite the negative wealth effect from the tightening of external credit because of a substitution effect due to the large drop in the real wage.

Finally, investment contracts under both exchange rate regimes due to the scarcer supply of credit as a result of the sudden stop. In the flexible exchange rate regime the contraction is associated with a simultaneous rise in the real interest rate that depresses the demand for capital. Under the fixed regime the real interest rate falls slightly on impact because of the simultaneous contraction in labor supply, which depresses the return on capital.

We compute the welfare of households in the period of the sudden stop under the two exchange rate regimes. The sudden stop is detrimental for welfare under both regimes. We find, using a utilitarian metric, that under the flexible-exchange rate regime, welfare falls by 0.81% in consumption equivalent variation (CEV) terms. The debt revaluation that the flexible exchange rate regime entails during the sudden stop accounts for a substantial fraction of this welfare loss. In particular, low wealth households experience a large drop in wealth since they hold levered positions and, the proximity to the borrowing constraint implies that they are unable to smooth consumption in response to the shock, resulting in significant welfare losses. In fact, we find that the welfare loss associated with the sudden stop would have been of smaller magnitude in a fixed-exchange rate regime, of 0.34% in CEV terms, implying that the fixed exchange rate regime would have increased welfare by 0.47 percentage points in CEV terms relative to floating.

More than 92% of households would have benefited from the fixed-exchange rate policy. Despite the fact that the fixed exchange rate generates a domestic recession — due to the presence of nominal rigidities — the fixed exchange rate policy is preferred by the vast majority of households. This result holds even when abstracting from the utility that households receive from having additional leisure in the recession.[19] Our framework therefore generates a rationale for "fear of floating" even in the absence of a contractionary devaluation. In the subsequent section we explore the importance of household heterogeneity and the level of foreign debt for delivering this finding.

[17] The fact that a sudden stop leads to a domestic boom is a well known feature of neoclassical models with flexible exchange rates. See, e.g. Chari et al. (2005).

[18] In nominal terms with the fixed exchange rate there is no revaluation of the debt in units of domestic currency. The value of debt rises nontheless in real terms because of domestic deflation.

[19] Our model abstracts from involuntary unemployment, which may not carry the same welfare benefits as pure leisure. When considering only consumption in the welfare calculation, the utilitarian welfare gain is 0.21% CEV and 74% of households prefer the fixed to the floating regime. Therefore, even if leisure were unvalued the majority of households would prefer the fixed regime.

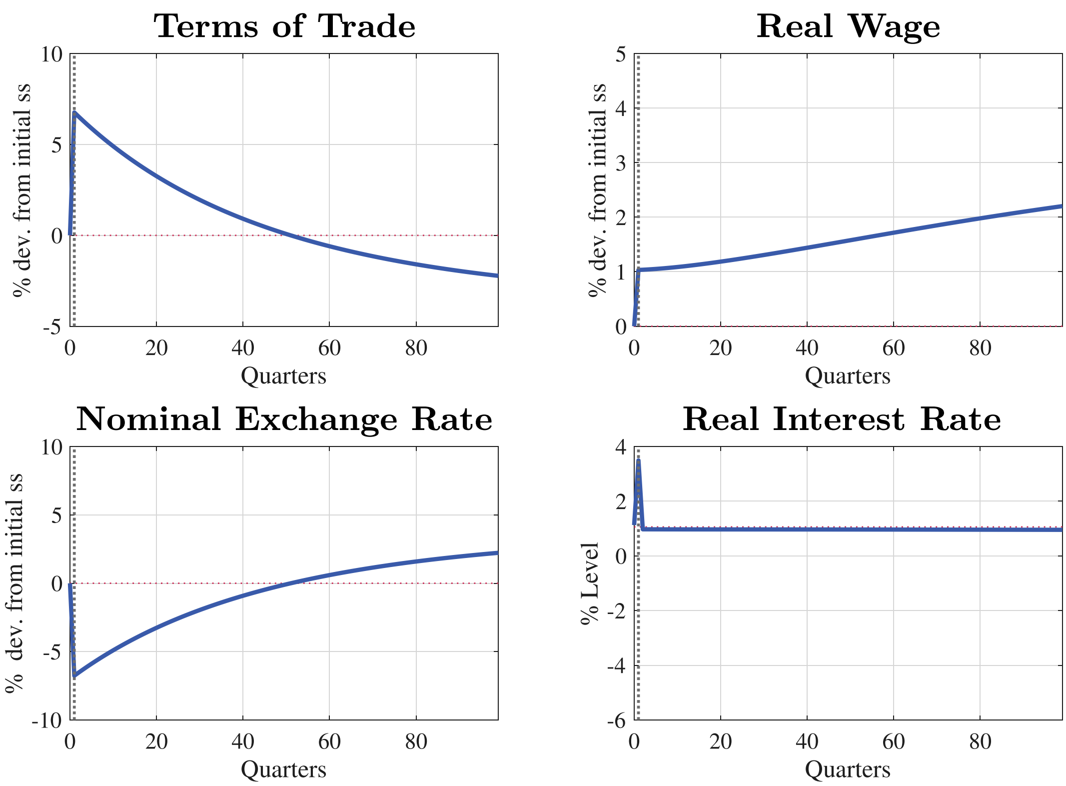

Fig. 3. Impulse response of prices to current account expansion.

7. Inspecting the mechanism: household leverage and the level of foreign debt

The foregoing experiment was designed to mimic the experience of Hungary and other European countries that borrowed heavily in foreign currency and then experienced sudden stops during the Global Financial Crisis. In this section we perform a series of simpler experiments that we think are instructive in understanding the forces that underlie our positive and welfare results for the sudden stop.

To isolate the effect of the contraction (as opposed to a reversal following an expected expansion) we model the reduction in foreign credit supply as a mean reverting "MIT shock", such that the

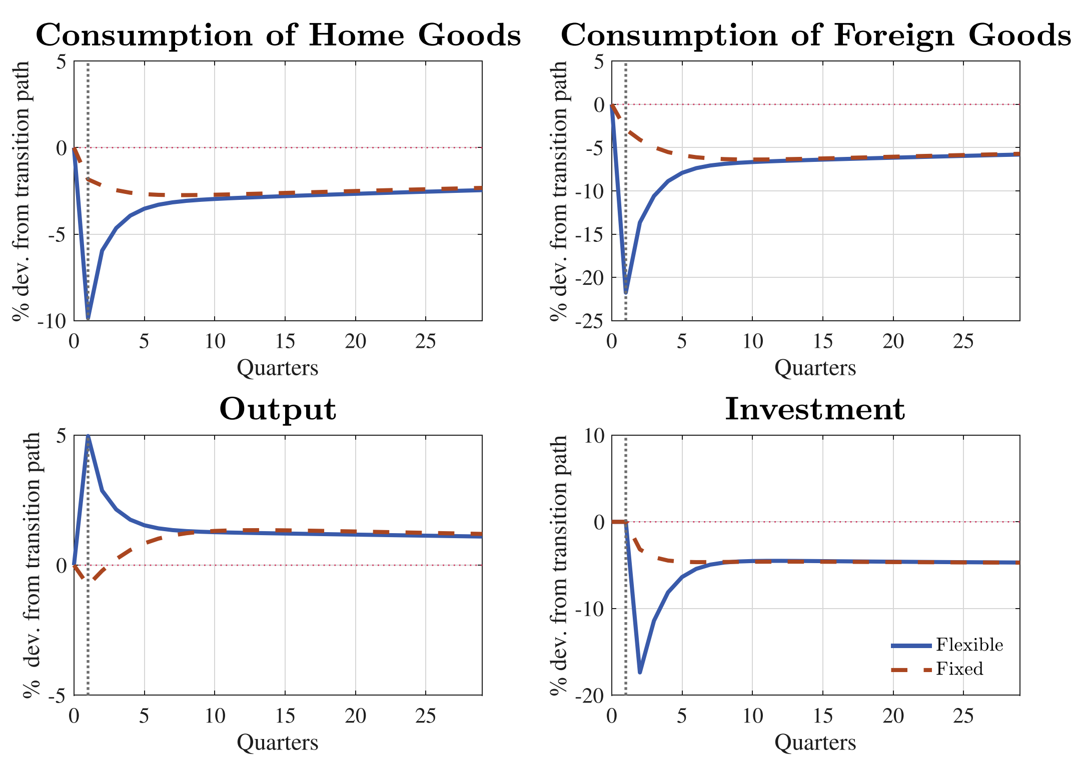

Fig. 4. Impulse response of quantities to current account reversal.

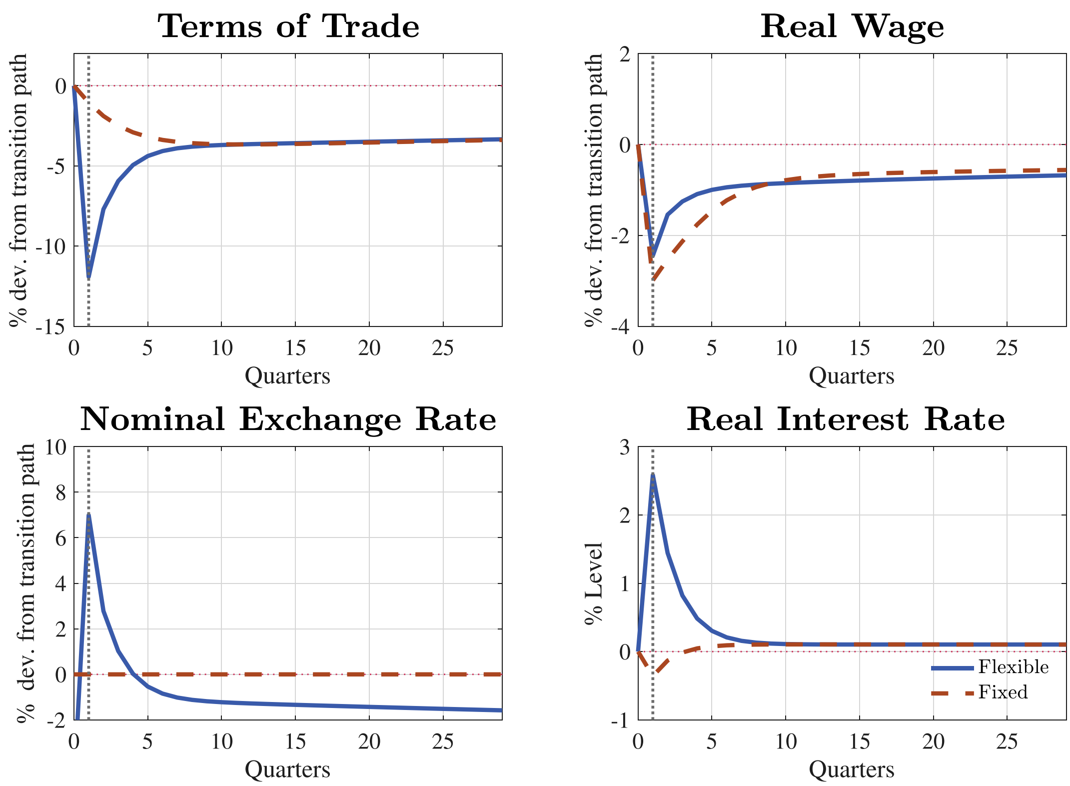

Fig. 5. Impulse response of prices to current account reversal.

HANKSOME economy returns to the initial steady state. We assume that the economy starts in its long-run steady state, then foreign supply of credit falls by 22% on impact, then reverts back to the original steady state level with a half-life of 5 quarters as illustrated in Fig. 6. We study below the dynamics of the model economy in response to this shock.

The main experiment of interest is the credit supply shock under the baseline scenario of a flexible exchange rate and foreign denominated debt — the empirically relevant case for Hungary during the Global Financial Crisis (and the one studied in the previous section). In order to build intuition and understand those results, we consider this shock under three different scenarios, which we describe below in more detail. The three scenarios differ in terms of the exchange rate policy conducted by the central bank, and in terms of the denomination of households' debt. In addition, we consider the implications for aggregate variables of the distribution of leverage across the heterogeneous households in the economy.

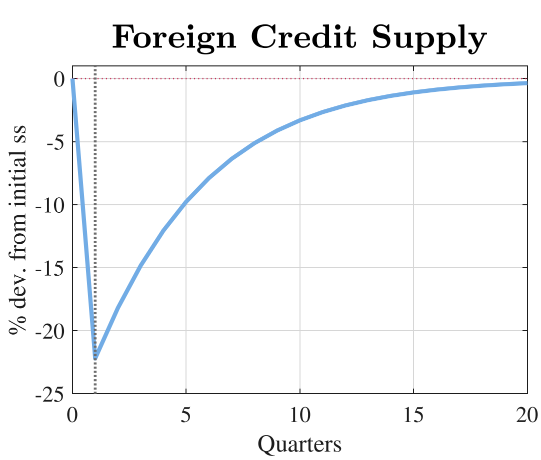

Fig. 6. Foreign credit supply shock considered in the simpler experiments in Section7.

First, we consider a real benchmark. This is a setting where households owe foreigners real debt, denominated in units of home good, and where nominal rigidities are absent. In the presence of nominal rigidities, the central bank can replicate the equilibrium allocation of this benchmark economy by letting the nominal exchange rate fluctuate. The central bank can also replicate the benchmark economy if households owe nominal debt denominated in units of domestic currency.[20] Original sin is not present in this economy, because a depreciation of the nominal exchange rate or of the terms of trade does not magnify the country's debt-to-GDP ratio.

Next, we move to the empirically relevant scenario for Hungary, a flexible exchange rate setting with foreign-currency denominated debt. Again, the setting with flexible exchange rates is equivalent to a real economy, as the central bank offsets the nominal rigidities through fluctuations in the exchange rate. In this case, however, the value of households' real debt is magnified by the external shock, because it entails a terms of trade and nominal exchange rate depreciation.

Third, we are interested in the policy counterfactual where the central bank chooses to keep the nominal exchange rate fixed. Under this scenario, output can deviate from the real flexible-price benchmark due to nominal rigidities. When debt is nominal, the implications of fixed exchange rates are ambiguous.[21] While output contracts, the lack of an exchange rate depreciation limits the extent of the foreign debt revaluation. A fixed exchange rate regime can thus prove to be advantageous since it prevents adverse balance sheet revaluations in response to external shocks. This result is informative on why central

[20] This is because, in this equilibrium, the domestic-currency price of home good remains constant in response to the credit supply shock.

[21] Note that, when the exchange rate is fixed, there is no distinction between domestic- or foreign-currency denominated nominal debt.

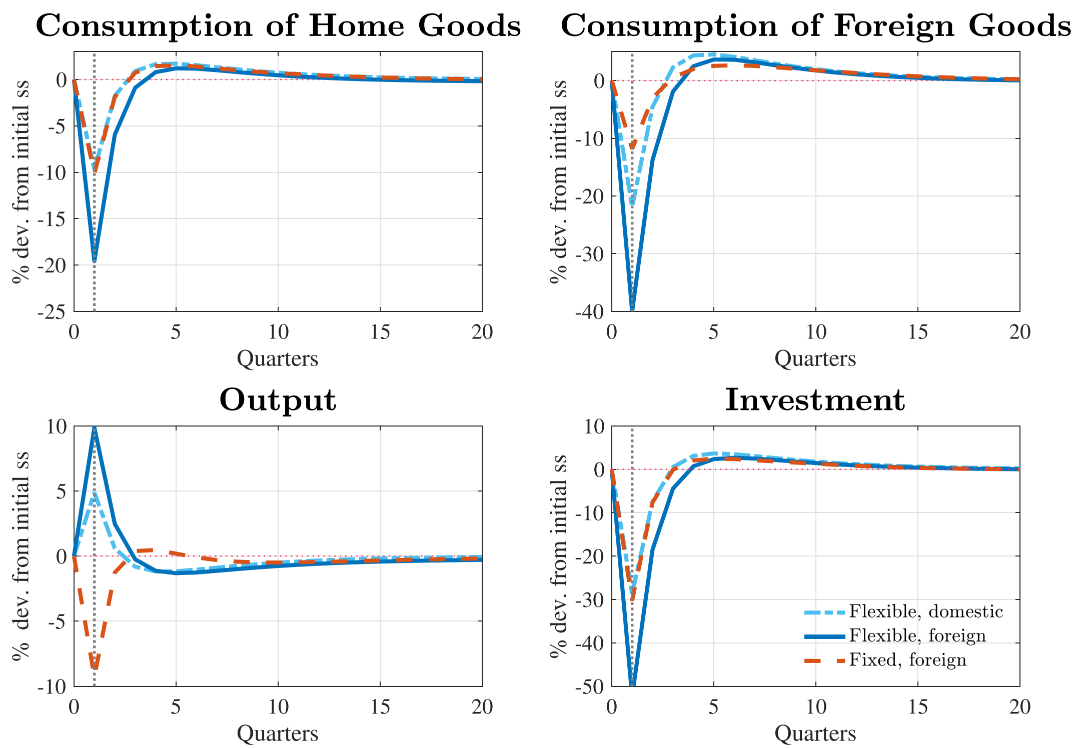

Fig. 7. Impulse response of quantities to credit supply shock, all scenarios.

banks might be reluctant to let a large exchange rate depreciation take place or exhibit "fear of floating."

Finally, we evaluate the welfare implications of the different exchange rate policies. In particular, we study the desirability of a fixed exchange rate upon the contraction of foreign supply. We conduct this normative analysis from the point of view of the heterogeneous households that inhabit the SOE. We characterize how the answer to this normative question depends on the distribution of leverage across households and the fraction of debt that is denominated in foreign currency.

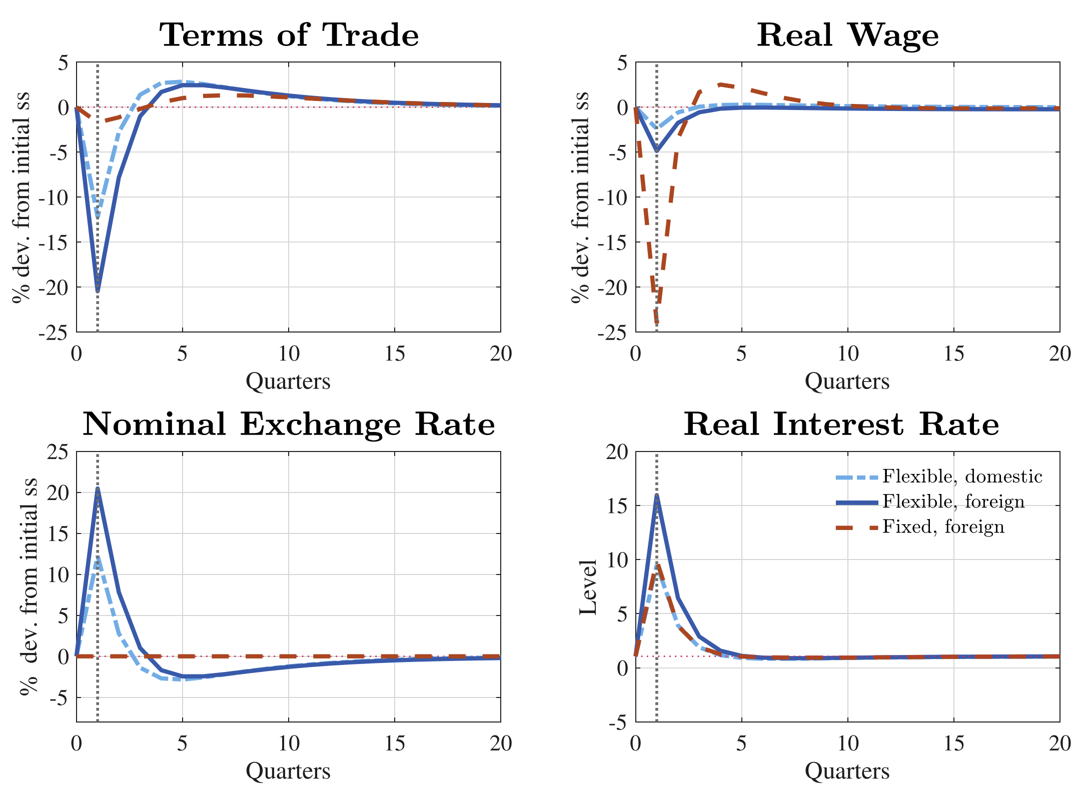

Fig. 8. Impulse response of prices to credit supply shock, all scenarios.

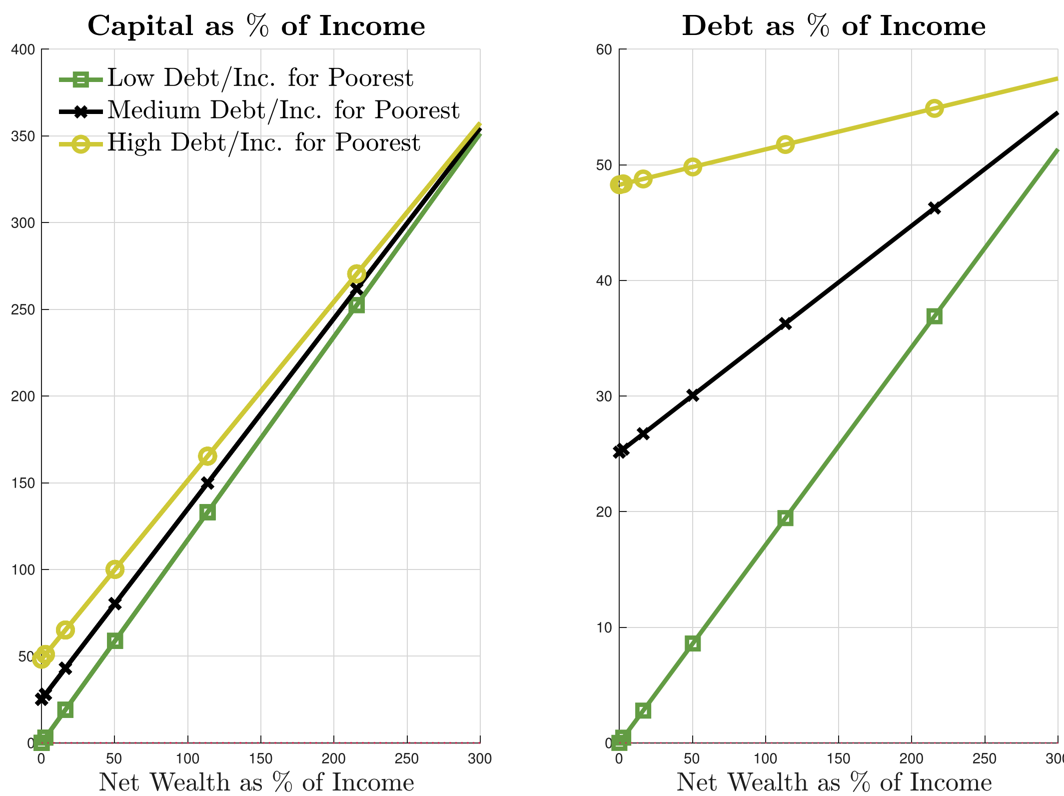

Fig. 9. Distribution of gross asset and debt position across households, as a function of household net wealth. All asset positions are expressed as the ratio of average household yearly labor income. The three cases displayed are the ones where the poorest households have no leverage (green line with square markers), a middle level of leverage (black line with plus markers), and a high level of leverage (yellow line with circle markers).

7.1. Real benchmark or flexible exchange rates

We detail below the evolution of aggregate variables in the model economy during the reversal of capital flows. We consider first the case where the exchange rate is flexible and where household debt is real and denominated in units of home good. While most household debt in Hungary was denominated in foreign currency, this setting with real, home-good denominated debt allows us to describe some important dynamics of the model in the absence of debt revaluation effects.

The contraction in foreign credit induces a fall in aggregate consumption and investment, as well as in the terms of trade and in the real wage. The nominal exchange rate depreciates upon the shock to generate a devaluation in the terms of trade while limiting fluctuations in domestic prices. The real interest rate rises as the supply of credit is more scarce.

Fig. 7 presents the impulse response functions of aggregate quantities to the credit supply shock (light-blue dot-dashed line). Fig. 8 displays the impulse response functions of the terms of trade, the real wage, the real interest rate and the nominal exchange rate.

As the supply of foreign credit dries up, the real interest rate rises. The real rate rising leads to a drop in investment from domestic firms and a drop in consumption from domestic households. The latter leads to an associated increase in labor supply of domestic households, which in turn leads to an increase in domestic output on impact, as capital is predetermined. The simultaneous contraction in the domestic demand for domestic goods (both investment and consumption) and the expansion in supply imply that in equilibrium the terms of trade contract upon the shock.

Under the flexible exchange rate regime that stabilizes domestic prices, the entire movement in the terms of trade is driven by a depreciation in the nominal exchange rate. The nominal exchange rate devaluation leads a relatively larger drop in consumption of foreign good relative to that of home good. The increase in labor supply puts downward pressure on the real wage, which falls further because of the contraction in the value of output produced by domestic firms.

7.2. Foreign-currency denominated debt

We now consider a setting where households' debt is denominated in units of foreign currency. The key feature of the setting with foreign-currency denominated debt, relative to the real benchmark, is that any

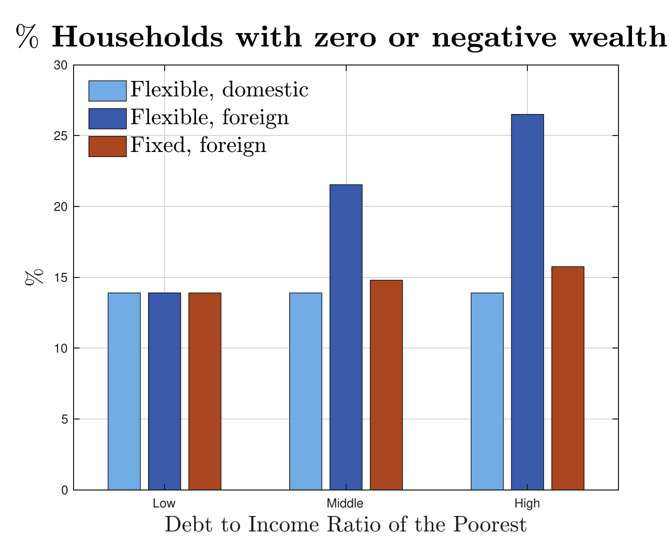

Fig. 10. Fraction of households with negative net wealth upon credit supply shock.

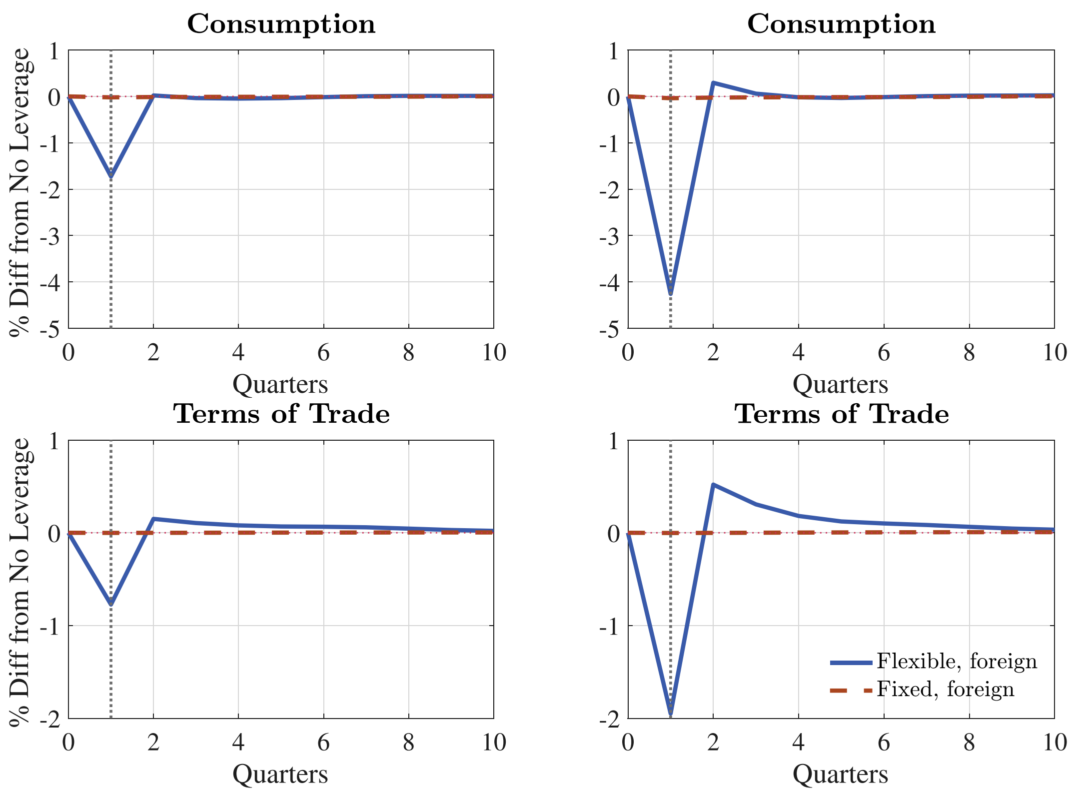

Fig. 11. Difference in impulse response functions relative to the economy with low leverage of the wealth poor households. The left two panels correspond to the economy with middle leverage of the poor and the right two panels correspond to the economy with high leverage of the poor.

contraction in the terms-of-trade induces an increase in the real value of households' debt. Hence, the contraction in demand associated with the foreign credit supply shock reduces the net wealth of households with foreign currency liabilities which further amplifies the contraction in demand.

We contrast the real benchmark with two settings that feature foreign-currency denominated debt. First, we consider again a flexible-exchange rate economy, where the domestic price level is fully stabilized and so there are no output losses due to nominal rigidities. Second, we analyze a fixed-exchange rate economy, where output may fall as a result of price stickiness, but where milder fluctuations of the terms of trade may dampen the extent of the debt revaluation.

In this setting, the distribution of initial household portfolios of gross positions has potentially important implications for the subsequent aggregate dynamics. We consider first a setting where household holdings of gross assets are proportional to their net asset holdings, so that the leverage ratio is constant across households. In Section 7.3, we explore how positive gross debt holdings among the poor magnify the effects of foreign credit supply shocks.

Figs. 7 and 8 again display the impulse response functions of quantities and prices, respectively, in the economies with foreign-currency debt, with flexible (dark-blue solid lines) or fixed (red dashed lines) exchange rates.

In the presence of foreign denominated debt, fixed vs flexible exchange rates have dramatically different implications for the dynamics of the economy in response to a foreign shock. Under the flexible exchange rate regime, a depreciation of the nominal exchange rate is necessary for the central bank to close the output gap such that nominal rigidities do not bind. The depreciation of the nominal exchange rate in the presence of foreign currency debt leads to an amplification of the responses of all endogenous variables. The revaluation in foreign debt contracts household net worth that in turn causes the significantly larger fluctuations. That fall in net worth amplifies the contraction in demand, which in equilibrium results in larger movements in quantities and prices.

Moving to the case where the exchange rate is fixed, we now see the opposite in terms of the dynamics of domestic output — namely the presence of nominal rigidities leads to a recession. In turn, the fall in domestic supply implies, in equilibrium, a smaller adjustment in the terms of trade relative to the flexible-price case. The milder terms-of-trade contraction due to the fixed exchange rate implies a more moderate revaluation of foreign-currency debt. When the stock of nominal liabilities that households owe is large, this channel is powerful, and it implies that household consumption falls by less than under flexible exchange rates. Importantly, the fall in consumption is milder even though nominal rigidities imply that output contracts more than under flexible exchange rates.

7.3. The distribution of household leverage

We have considered so far a setting where leverage is constant across the heterogeneous households that inhabit the domestic economy. We now explore through a series of experiments the implications of different leverage distributions for the aggregate, distributional and welfare implications of shocks. To isolate the effect of the distribution of debt, we keep the aggregate level of debt constant across all subsequent experiments.

In the previous section, households' holdings of gross assets and liabilities were assumed to be proportional to their net assets. Hence, a household with zero net assets had neither gross assets nor liabilities in that setting. We consider now two settings where wealth-poor households have significant gross holdings of debt. First, we calibrate the distribution of leverage to the empirical distribution from Hungary as we did in Section 6. Under that calibration, the gross debt of households with zero net worth is, on average, 24% of average household yearly labor income. We denote this setting as the one with

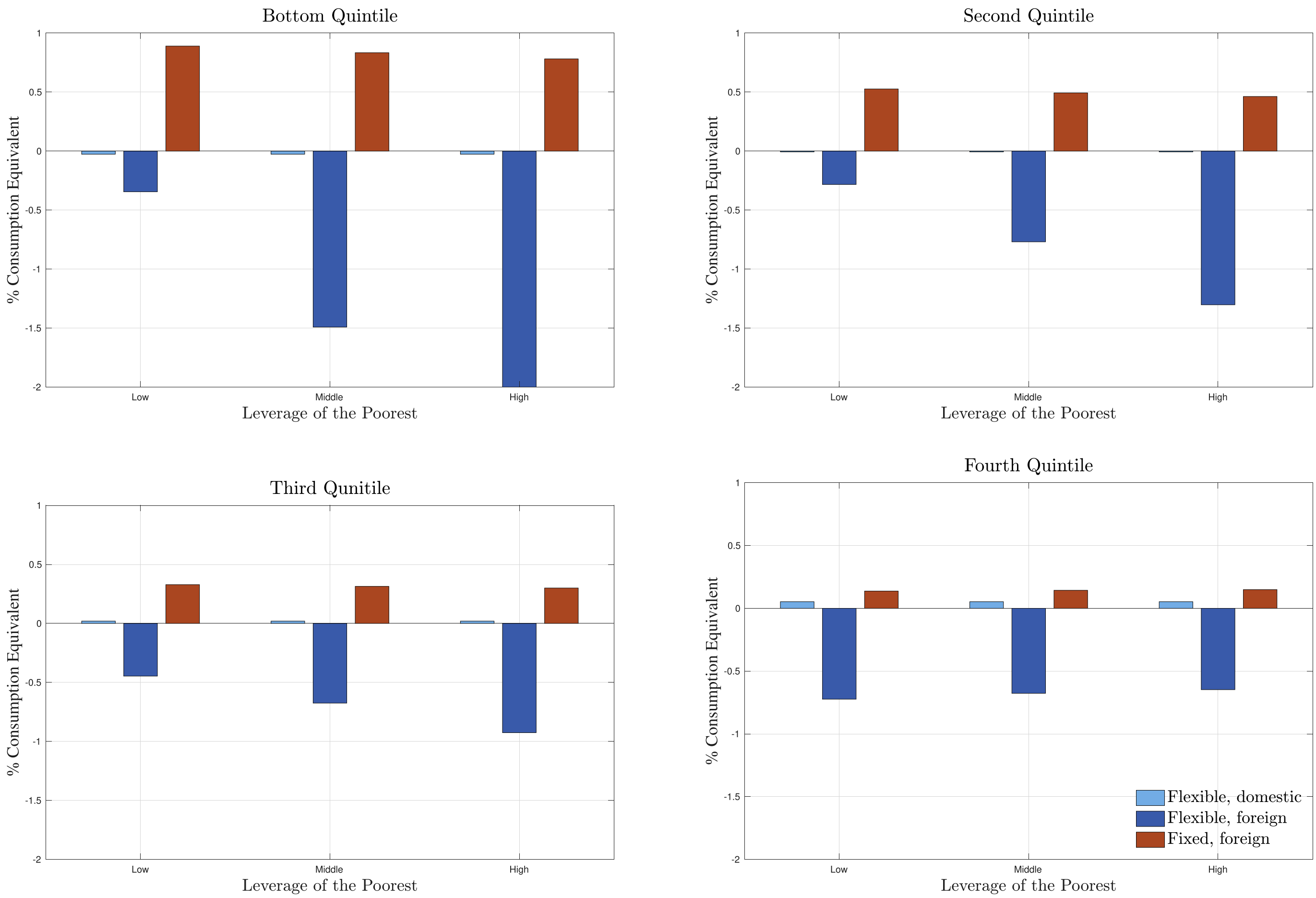

Fig. 12. Welfare implications of a foreign credit supply contraction, for households bottom (first), second, third and fourth quintile in the wealth distribution. Models with flexible exchange rate and home good-denominated debt, flexible exchange rate and foreign-currency debt, and fixed exchange rate and foreign-currency debt. Results are presented for the models where poor households have low, middle or high leverage. The consumption equivalent is defined as the percentage increase of lifetime consumption that gives a household the same change in welfare as implied by the credit supply contraction. A negative value of the consumption equivalent implies that the households is willing to forgo a fraction of consumption over its lifetime rather than the foreign credit supply shock to take place.

a middle leverage of the poor. Next, we analyze a setting where a household with zero-wealth has twice as high a gross asset position — equal to 12% of the average, per-capita stock of capital. We denote this setting as the one with high leverage of the poor (with gross debt corresponding to 48% of average household yearly labor income for zero net worth households). Fig. 9 displays the distribution of households' gross asset and debt positions in these two settings, as well as in the previously analyzed case where poor households are not leveraged.[22] Note that the wealth distribution extends far to the right of the plotted range of the figure. High-wealth households have lower leverage when the poor are highly levered, to keep the aggregate level of debt constant.

Fig. 10 displays the effects of the credit supply contraction and the associated revaluation of foreign currency debt on the fraction of households with zero or negative net wealth. In the real benchmark with flexible exchange rates and real, home-good denominated debt, this fraction is independent of the distribution of leverage. This is because no revaluation of debt takes place and the fraction of zero-wealth households is equal to its steady-state value. When debt is denominated in foreign currency, a higher fraction of households find themselves with negative net wealth after the shock, as the real value of their debt increases. As shown in the figure, this fraction is higher, the higher is the leverage of poor households, as these are hit by a larger revaluation of their debt. Consistent with the results in Section 7.2, this fraction is lower when the exchange rate is fixed, as the milder terms-of trade contraction implies a smaller foreign-currency debt revaluation.

Fig. 11 shows the impulse responses of consumption and the terms of trade to the credit supply shock in the settings with highly leveraged poor households for the two exchange-rate regimes with foreign denominated debt. The impulse response functions are expressed in percentage differences from the economy where leverage is equally distributed across households - effectively a difference-in-differences across economies with different domestic leverage distributions. First, consider the economy with a flexible exchange rate. Where poor households are more highly leveraged, a larger contraction in aggregate consumption takes place. This is the case because the fall in net wealth hits poor households with a high marginal propensity to consume, thus there is a positive correlation between the debt revaluation and the marginal propensity to consume. The higher is the amount of debt held by poor households, the larger is the contraction in aggregate consumption. Accordingly, the fall in the terms of trade is also larger when poor households are highly leveraged, due to the larger fall in domestic consumption and demand. Note that the aggregate leverage is constant across all three economies, which only differ in terms of how leverage is distributed across households. In the absence of heterogeneity in the marginal propensity to consume—as would be the case in the representative agent economy—the three economies would deliver the same aggregate responses. Thus, the differences in the consumption and terms

[22] We interpret the capital stock and leverage here broadly, to potentially include the housing stock and mortgages, which would be particularly relevant for households in the bottom half of the wealth distribution.

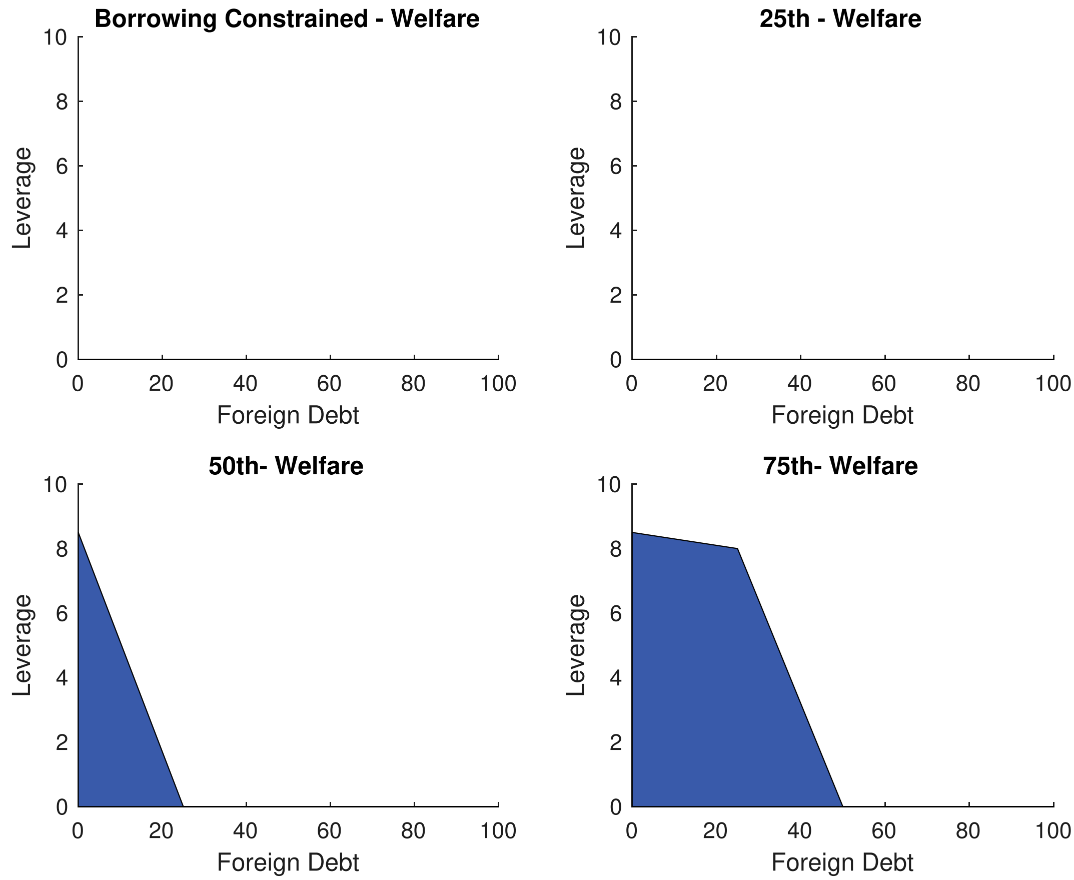

Fig. 13. Blue shaded areas indicate the combination of household leverage and the fraction of debt denominated in foreign currency where the household prefers a flexible exchange rate regime over a fixed exchange rate in response to a sudden stop.

of trade responses directly highlight the importance of market incompleteness and household heterogeneity for the transmission of aggregate shocks.

Turning now to the economy with a fixed-exchange rate, the milder terms-of-trade contraction implies that the distribution of leverage has negligible effects for the response of aggregate variables. Why? The smaller contraction in the terms of trade imply only small redistributions of wealth across agents with different gross portfolios. This implies that the correlation between the distribution of marginal propensities to consume and debt revaluation matters less.

7.4. Welfare

The analysis thus far has focused primarily on the positive effects of the sudden stop under different assumptions on the denomination of debt and exchange rate policy. We now focus on deriving the welfare implications of the contraction under the two policy regimes of fixed and flexible exchange rates, in the different scenarios considered above. Further, we explore how the distribution of household leverage and the extent of foreign denominated debt impact those welfare conclusions.

In Fig. 12 we plot the average welfare impact (in CEV terms) of the sudden stop for four cuts in the cross-sectional wealth distribution: the bottom (first), second, third and fourth quintiles of wealth. We calculate the welfare impact of the sudden stop under fixed and flexible exchange rates when debt is real or denominated in foreign currency, across the three scenarios for the distribution of household leverage.

In the empirically relevant setting for Hungary where debt is denominated in foreign currency and the exchange rate is flexible, the credit supply contraction reduces welfare for most households. The magnitude of the welfare change is, however, highly heterogeneous, depending on the exchange rate policy regime, on the denomination of household debt and within the distribution of households. In the flexible-exchange rate, foreign-currency denominated debt scenario, the key force driving the welfare loss is the revaluation of the foreign currency debt held by domestic households. For households in the bottom quintile of the wealth distribution, not surprisingly, the welfare fall is the largest the more levered they are. Being highly levered, in response to a foreign revaluation, those households experience a large fall in net worth with no buffer stock to smooth the effects of the shock. As a result, those households are willing to forgo more than 10% of their lifetime consumption to avoid the credit supply contraction. Conversely, wealthy households suffer a smaller welfare loss the more leveraged poorer households are, since they are less leveraged themselves (by construction since aggregate leverage is held constant across experiments).

The adverse effects of a flexible exchange rate policy become even more salient in contrast to when the central bank keeps the exchange rate fixed, where most households instead experience a welfare gain during the sudden stop. The key advantage that a fixed exchange rate policy delivers is the milder depreciation of the terms of trade during the sudden stop. Hence, a smaller foreign-currency debt revaluation takes place in this regime. The negative welfare effects from the decline in consumption are thus more than offset by the increase in leisure when output contracts in response to the shock.

The welfare effects of the sudden stop are mild in the economy where debt is denominated in home good and the exchange rate is flexible. This is the case since debt does not revalue in this economy. Wealthy households experience a welfare gain due to the increase in the return on their wealth, as credit becomes scarcer. Poorer households

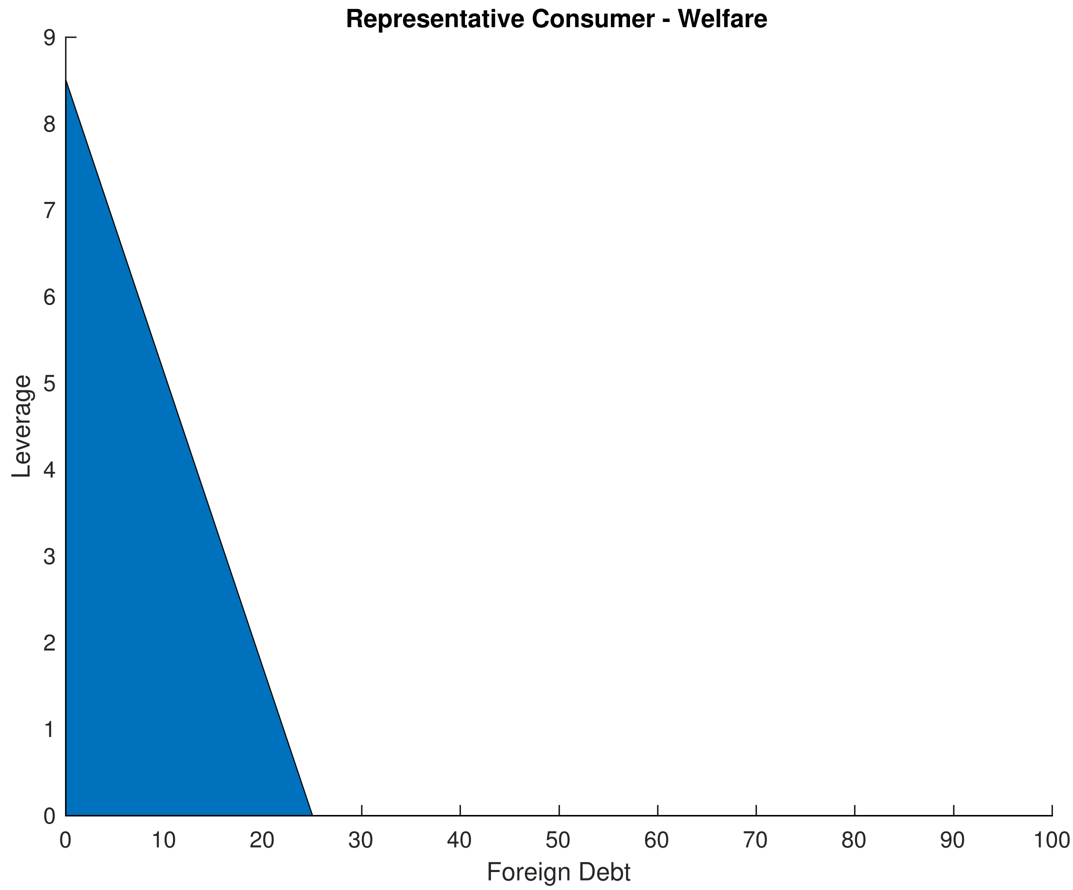

Fig. 14. Blue shaded areas indicate the combination of household leverage and the fraction of debt denominated in foreign currency where the "as-if" representative household prefers a flexible exchange rate regime over a fixed exchange rate in response to a sudden stop.

experience instead a welfare loss, due to the terms of trade depreciation and consequent contraction in their real labor income.

Thus far, we have considered the extreme cases of debt either entirely denominated in foreign or domestic currency. We now evaluate the intermediate case, with a mixture of foreign and domestic currency denominated debt. We conduct the same credit contraction experiment as before, but now we assume that only a fraction of the credit supply from foreigners is denominated in domestic currency. That fraction varies from 0 to 60% of the debt outstanding. We then compare the welfare impact of flexible vs fixed exchanged rates as a function of household leverage and the percentage of total debt that is denominated in foreign currency.

In Fig. 13 we plot the combinations of leverage and share of foreign denominated debt for which households at various points of the wealth distribution prefer the flexible over the fixed exchange rate regime. Low wealth households unambiguously prefer the fixed exchange rate regime (and so are not pictured), as they are particularly susceptible to the debt revaluation. Further, the fixed-exchange rate pushes up the real wage, benefiting the low wealth households even when they hold no debt. Wealthier households only prefer the flexible regime in cases where either the leverage of the poor is low or the fraction of foreign debt is low, again to minimize their exposure to potential revaluation effects. These results confirm that the denomination of household debt in foreign currency is a key determinant of the desirability of fixed exchange rates in this setting. To further assess the importance of heterogeneity, we perform the following thought experiment: what would the "as-if" representative agent prefer under these scenarios? To do so we compute welfare using aggregate consumption from the HANKSOME framework. We plot the scenarios under which this "as-if" representative agent prefers the flexible regime in Fig. 14. The representative agent acts much like the median household and would choose a flexible regime even when on average welfare declines using a utilitarian metric, highlighting the importance of heterogeneity due to heterogeneous incidence of the revaluation and decline in consumption across the distribution.

8. Conclusions

The aftermath of the Global Financial Crisis reignited interest in the distributional consequences of aggregate shocks and the role that household heterogeneity plays in the amplification and propagation of said shocks. While domestic market incompleteness on the household has been integrated into closed-economy macro, the proliferation of foreign currency borrowing by households in European countries has proven the need for a quantitative framework to study household heterogeneity in the international context. In this paper we constructed such a Heterogeneous Agent New Keynesian Small Open Model Economy (HANKSOME) framework, specifically designed to take these challenges in the international macroeconomics context.

We applied our HANKSOME framework to study a current account expansion and subsequent reversal inspired by the experience of Hungary in the run up to and aftermath from the Global Financial Crisis. We found that a fixed exchange rate regime would have significantly improved welfare in consumption equivalent terms, relative to a flexible exchange rate. This result obtains despite the fact that keeping the fixed exchange rate generates a recession. Our HANKSOME framework delivers a welfare rationale for the empirically observed "fear of floating", as opposed to one driven by fears of a contractionary devaluation. We perform a variety of additional experiments to help understand our findings. The desirability of a fixed vs floating exchange rate depends crucially on the distribution of household leverage, and the fraction of debt denominated in foreign currency.

There are several additional open areas for the next generation of HANKSOME models to tackle. First, the presence of domestically incomplete markets generates a fundamental lack of risk-sharing across households within a country—both in response to idiosyncratic and aggregate shocks. To what extent does that lack of domestic risk-sharing help explain the lack of international risk-sharing across countries? Second, we have considered perfect-foresight impulse responses to unexpected shocks. Incorporating aggregate fluctuations explicitly would enable a more meaningful evaluation of portfolio choice in this framework and how that impacts asset prices and investment. We leave these for future work.

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