Wealth, Uninsurable Idiosyncratic Risk and International Risk-Sharing*

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Abstract

This paper evaluates the role of uninsurable idiosyncratic risk and wealth distribution in international risk-sharing. The dynamics of net international capital flows in a HANK model featuring idiosyncratic income risk, distribution of wealth, and two types of assets (liquid and illiquid) traded with the rest of the world are determined by the relative strength of three effects: First, low consumption-smoothing ability of borrowing-constrained households dampens aggregate savings responses to business cycles. Second, idiosyncratic risk increases the savings of unconstrained households. Finally, endogenous changes in the share of constrained households amplify savings responses when idiosyncratic risk is high and wealth levels are low; in the reverse scenario, responses are dampened. Quantitative simulations show that the first effect dominates the latter two. As a result, the current account is more countercyclical in HANK than in RANK. The gross international position, which in a HANK model arises from cross-country trade in two types of assets, is long in illiquid assets and short in liquid assets during expansions in a wealthy country. A wealth-poor country holds the opposite position. Idiosyncratic risk shifts the composition of assets in favor of larger liquid asset investments. Two household-level surveys were used to calibrate the model devised in this paper to the wealth-rich US and wealth-poor Russian economies, and to obtain empirical responses of the respective share of borrowing-constrained households to TFP shocks.

JEL: F32, F41, E21, E25, E32, D31, D52

Keywords: intertemporal approach, current account, HANK, precautionary savings, distributional effects, RLMS, PSID

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1. Introduction

What drives international capital flows is a central question in international macroeconomics. Traditionally, intertemporal consumption smoothing of a representative household is viewed as the key driver of the current account (Obstfeld and Rogoff, 1996). However, a growing literature[1] underscores the importance of wealth and uninsurable idiosyncratic income risk within a country in understanding aggregate savings dynamics and their impact on the macroeconomy. This paper studies the business cycle fluctuations of net and gross capital flows between countries driven by a distribution of households that face aggregate and idiosyncratic risks and differ in their levels of wealth.

Employing a Heterogeneous Agent New Keynesian (HANK) model, three novel effects are uncovered when a distribution of consumption-smoothing households saves intertemporally. First, borrowing-constrained households' low marginal propensities to save lead to a decrease in aggregate savings responses to total factor productivity (TFP) shocks. Second, optimizing households save more when accounting for idiosyncratic risk, due to precautionary motives, and save more the wealthier they are. Third, endogenous changes in the distribution of households in response to shocks can amplify or dampen the effects of TFP shocks on aggregate savings.

In an economy where idiosyncratic risk is high, and wealth levels low, changes in the share of borrowing-constrained households magnify business cycle volatility of aggregate savings. In response to a positive TFP shock households accumulate liquid buffers, to insure against idiosyncratic and aggregate risks, and the share of consumption-smoothing households increases. In contrast, during an expansionary period in an economy with wealthy households that face low idiosyncratic risk, households' holdings of illiquid assets, delivering higher returns, increase. The latter results in a rise in the share of constrained households, which dampens aggregate savings responses. Both wealth and idiosyncratic risk contribute to the direction of change in the shares of consumption-smoothing and borrowing-constrained households, with idiosyncratic risk quantitatively having a larger impact.

The relative intensity of the three effects determines the response of aggregate savings

1 Kaplan, Moll and Violante (2018) and many papers afterwards.

and the current account to business cycle fluctuations. The quantitative contributions of these effects were assessed through the lens of a two-asset small open economy HANK model calibrated to two countries: the US and Russia. These countries represent the limiting case of a relatively wealthy country with relatively large insurance against idiosyncratic risk on the one hand, and a relatively poor country with high idiosyncratic risk on the other.

Results show that compared to a representative agent model (RANK), savings of heterogeneous agents are smaller due to a large share of borrowing-constrained households. An increase in aggregate savings puts downward pressure on the real interest rate, therefore, larger savings lead to larger investment responses. The direct effect of marginal propensities to save on aggregate savings dominates the indirect effect on investments, and smaller savings lead to a more countercyclical current account in both countries. In the emerging economy, because of larger precautionary savings and countercyclical changes in the share of borrowing-constrained households, both of which amplify savings responses, current account responses in HANK are closer to the responses in RANK than in the developed country.

Wealth and idiosyncratic risk also impact the countries' gross positions vis-à-vis the rest of the world. In the model calibrated to Russia, households have low levels of wealth and face high idiosyncratic risk. This endogenously generates a large demand for liquid assets in response to a positive TFP shock, which a financial intermediary passes on to the rest of the world. In the US, in contrast, households are wealthier and idiosyncratic risk is lower. As a result, in an expansion, households invest in high-return illiquid assets and even liquidate liquid holdings. Consequently, in a boom, the wealthy country holds a long position in illiquid and a short position in liquid assets.

Counterfactual analysis shows that both idiosyncratic risk and wealth substantially impact the direction of the international liquid and illiquid positions, with the former having a somewhat larger impact on the demand for liquid assets and the latter on illiquid asset demand. Counterfactuals were obtained by decomposing the dynamics of the capital flows into aggregate and idiosyncratic risk smoothing components and subsequently setting calibration parameters in the model for Russia to the US values.

A quantitative HANK model utilized to obtain results features heterogeneous households facing Bewley-type idiosyncratic labor income shocks. Households can save in liquid and illiquid assets. They are heterogeneous in income and wealth, but homogeneous in terms of their consumption basket of foreign and domestically produced goods. A sophisticated financial intermediary aggregates households' savings and invests them in domestic and foreign liquid and illiquid assets. Firms face capital adjustment costs, which are crucial for current account dynamics (see Mendoza, 1991), and nominal rigidities. The latter is also important in open economies, as sticky prices may affect the pass-through of shocks to the real exchange rate, especially under different monetary policy regimes (which are explored for the emerging country). [2] Model impulse response functions are analyzed in response to a 1% TFP shock.

The micro-moments used to calibrate the small open economy HANK model are computed using one household-level survey each for Russia and the US. The US Panel Study of Income Dynamics (PSID) is widely used to calibrate the HANK models. For Russia, the Russia Longitudinal Monitoring Survey (RLMS) contains rich information on income and consumption for a large representative sample of households. Another advantage of the Russian survey compared to other household-level surveys in emerging countries is that it has been running for over 20 years, and features a panel component that can be used to estimate households' earnings process. The limitation is that, as in PSID, information about households at the very top of the wealth distribution is limited.

Turning to the empirical support of the model results, I utilize panel components of both surveys that allow for an empirical estimation of the endogenous changes in the wealth distribution of households in response to TFP shocks, and for a comparison to analogous changes obtained in the quantitative model. Using local projections, I estimate the probability of being borrowing-constrained for households in a range of income and wealth percentiles. I show that in the emerging country, households' probability of being borrowing-constrained, even at the top of the income and wealth distributions, decreases by 0.2% in response to a positive TFP shock that increases these households' income by 1%. In contrast, for US households, the same probability rises by 0.4%. This leads to a countercyclical evolution

2 See Aguiar, Amador and Arellano (2022) and Acharya, Challe and Dogra (2020) for the study of optimal policies in heterogeneous-agent models.

of the share of borrowing-constrained households in the emerging country which amplifies aggregate savings responses and boosts current account and to a procyclical evolution of the share in the US. For gross flows this means that households' demand for liquid assets is procyclical in Russia but countercyclical in the US. These empirical dynamics are well aligned with the dynamics in the quantitative model.

Empirical results also show that the changes in the shares of borrowing-constraint households for both countries are mainly driven by households at the top of the income distribution. Since this group's share of unconstrained households is also larger, mainly savings of these households impact current account dynamics. These novel empirical results highlight the importance of income and asset distribution for the dynamics of capital flows.

The paper is organized as follows. Below, I briefly discuss the related literature. Section 2 describes the data, with Section 3 presenting empirical responses obtained using household-level data and local projections. Section 4 outlines a quantitative HANK model and presents quantitative results. Section 5 concludes.

Related literature. Comparably few papers study international macroeconomic questions in an environment with heterogeneous households. The work most closely related to this paper is de Ferra, Mitman and Romei (2021). The authors also study how household heterogeneity affects the current account. However, the theoretical focus is on financial liberalization and the depth of financial markets rather than on the intertemporal approach to the current account studied in this paper. On the empirical side, de Ferra et al. (2021) use aggregate statistics from a large sample of countries, whereas this paper uses household-level data from the two distinct economies. In this respect, the empirical analysis presented in this paper can be seen as complementary. Other small open economy HANK papers study sudden stops: de Ferra, Mitman and Romei (2020), foreign monetary policy shocks: Guo, Ottonello and Perez (2020), and Zhou (2022), and exchange rate shocks: Auclert, Rognlie, Souchier and Straub (2021).

On the international macroeconomics literature front, the paper extends the intertemporal approach to the current account extensively analyzed in Obstfeld and Rogoff (1996). Implications of the intertemporal approach to the current account were tested in Nason and Rogers

(2006) and many others. Most tests failed, and the framework was extended along numerous dimensions. Mendoza, Quadrini and Rıos-Rull (2009), and Angeletos and Panousi (2011) use extensions related closest to this paper. They also use Bewley-type uninsurable idiosyncratic risks and assess the importance of precautionary savings for the current account. However, both papers focus on financial liberalization rather than on TFP shocks. They do not feature idiosyncratic labor income risk and assets of different degrees of liquidity that are crucial in modeling heterogeneous marginal propensities to consume and, thus, determining aggregate savings.

Regarding the heterogeneous households literature, this paper is most closely related to Auclert, Bardóczy, Rognlie and Straub (2019). This paper's model is an open economy extension of the authors' two-asset HANK model; this model is also solved in discrete time using the sequence-space Jacobian method. The comparison between HANK and RANK/two-agent (TANK) models that is conducted in this paper is also studied in closed economies in, among others, Bayer, Born and Luetticke (2020), Bhandari, Evans, Golosov and Sargent (2017), and Werning (2015). [3]

The results of this paper regarding the liquid asset demand of an emerging country vis-à-vis the rest of the world are also related to the strand of literature that studies the demand for safe assets. The larger demand for safe assets from emerging economies was extensively documented in Gourinchas and Rey (2007). Among recent papers, Kekre and Lenel (2021) study demand for safe dollar bonds in a model in which risk-bearing capacity in the US is greater than that of in the rest of the world. Conversely, this paper studies wealth and idiosyncratic risk endogenously forming household portfolios.

2. Data

This section describes data from two household-level surveys, PSID for the US and RLMS for Russia, used throughout this paper. These surveys are used in the empirical analysis in Section 3 and for model calibration for the US and Russian economies in Section 4. Since

3 A heterogeneous agent framework is incorporated into general equilibrium models in McKay and Reis (2016), Kaplan et al. (2018), Bayer, Lütticke, Pham-Dao and Tjaden (2019), Auclert and Rognlie (2018), Auclert, Rognlie and Straub (2018), Faia, Kudlyak and Shabalina (2021) and others.

the share of borrowing-constrained households and its evolution play an important role in the dynamics of capital flows, its identification is described in detail in Section 2.2.

2.1. Description of PSID and RLMS Surveys

2.1.1. US household-level data

The description of the PSID for the US economy is kept brief, as it is widely used in the literature. A wealth variable, which has been continuously reported in PSID only since the 1999 wave, is needed to calculate the shares of borrowing-constrained households (see Section 2.2 for details). Thus, the sample period is limited to from 1999 to the most recent wave, 2019. The data cleaning procedure and identification of borrowing-constrained households follows Kaplan, Violante and Weidner (2014). For computation of taxes, NBER's TAXSIM 32 program is employed. A comparison of per capita labor income from survey data and aggregate statistics [4] alongside the shares of borrowing-constrained households across income and wealth percentiles is presented in Appendix B.

2.1.2. Russian household-level data

For Russia, Russia Longitudinal Monitoring Survey (RLMS) data is used. Since 2000, this survey has been conducted annually. This paper uses data up until the most recent wave, which covers the year 2019.[5] The RLMS survey asks around 5000 households in each wave in detail about their consumption and income.[6]

The RLMS data is cleaned following Aguiar and Bils (2015), see Appendix A for details. All restrictions imposed jointly exclude 20% of the data, suggesting a high percentage of reliable responses.[7]

Comparing aggregate income/consumption data obtained from the RLMS survey to data presented in aggregate statistics suggests that the survey lacks households at the top of the

4 National Income and Product Accounts (NIPA) is used as a source of aggregate data.
5 There are four waves prior 2000: 1994, 1995, 1996, 1998, however, continuous time series can only be constructed from 2000.
6 The dataset for each wave is paired with a constructed variables dataset provided on the RMLS website.
7 Table 10 in Appendix A shows how many observations were excluded by each restriction. In the PSID 30% of the responses were excluded.

income distribution (see Appendix B). However, the difference between survey and aggregate statistics for Russia is comparable to the difference between survey and aggregate statistics for the US (see Appendix B), which suggests that both surveys lack households at the top of the income/wealth distribution to a roughly equal extent.

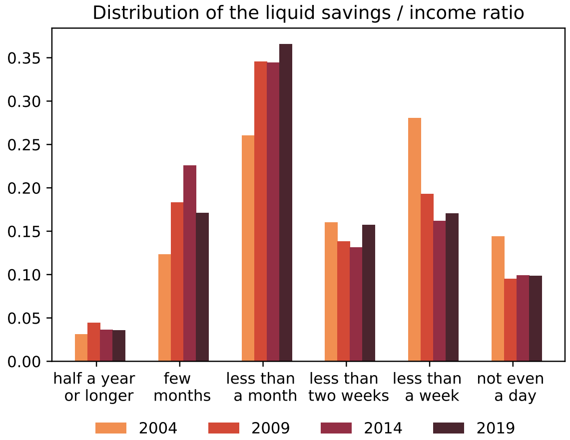
2.2. Identification of borrowing-constrained households

In Kaplan et al. (2014) borrowing-constrained households are defined as those with liquid wealth equal to a week or less of earnings. The share of borrowing-constrained (or hand-to-mouth) households obtained by the authors relying on the Survey of Consumer Finances (SCF) dataset varies from 17.5% to 35%. Aguiar and Bils (2020) using the same definition of borrowing-constrained households but PSID data identify 40% of households to be borrowing-constrained. For the sample considered in this paper, the corresponding mean share of borrowing-constrained households amounts to 38%.[8]

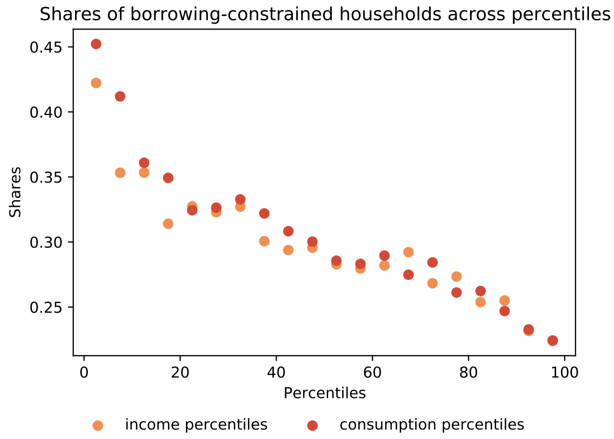
RLMS data contains limited information about the liquid assets of households. However, the survey features the following question: "Imagine an unpleasant situation in which all members of your family lost their sources of income. How long do you think your family would be able to live at your present level - in other words, without decreasing your expenditures - without any income? Consider only your savings, not selling any of your possessions." This question, in the following referred to as question F12_A, allows for the computation of the same ratio Kaplan et al. (2014) use for the identification of the borrowing-constrained households, i.e. the amount of liquid assets of the households as a ratio of consumption (which is equal to income for constrained households). Surveyed households are presented with six options to answer this question, ranging from "not even a day " to "half a year or longer". The distribution of household responses to question F12_A is presented in Figure 1a. More responses are concentrated around low levels of liquid assets, with sizable increases after economic crises in Russia in 2008 and 2014.

For comparability with PSID and the Kaplan et al. (2014) methodology households are

8 Calculated using family weights.



(a) **Shares of households across liquidity bins**



(b) **Shares of borrowing-constrained households**

Figure 1: Shares of Borrowing-Constrained Households in RLMS. The left-hand side graph shows shares of households that give answers specified on the X-axis to question F12_A in the RLMS (about the period for which a household can sustain their consumption level using only liquid savings, i.e. without receiving income or selling assets). Shares are presented for 2004, 2009, 2014, and 2019 years (bars from left to right correspond to the years in ascending order). The right-hand side figure shows shares of borrowing-constrained households across income and consumption percentiles. Borrowing-constrained households answer "less than a week" or "not even a day" to question F12_A in the RLMS.

considered borrowing-constrained when they answered "not even a day" or "less than a week" in response to question F12_A (i.e. 33% of the households on average).

The shares of borrowing-constrained households across income and consumption percentiles in Russia are plotted in Figure 1b. These shares are larger for the bottom percentiles. To understand the business cycle dynamics of the shares of borrowing-constrained households in the two countries and the driving forces underlining such dynamics Section 2.3 presents a comparison of the US and Russia.

2.3. Country Comparison

Households in the US are substantially wealthier than their Russian counterparts, see Table 1 for household income and wealth distributions in Russia and the US. [9]. The share of borrowing-constrained households among the income-rich is smaller than among the income-poor in both countries. In the US, there are more wealthy yet borrowing-constrained households.

A higher level of idiosyncratic risk in Russia can be seen from the estimated parameters of

9 Average exchange rate between the Russian ruble and the US dollar is such that in 2003 is 30.7 so that 33.6 Russian 2003 rubles are equal to one 2006 US dollar

Table 1: Sample Statistics Across Income and Wealth Percentiles. The table presents sample statistics calculated using PSID and RLMS data. The sample was divided into four subsamples based on the medians of the income and wealth distributions (for Russia, instead of the wealth median, a dummy indicating whether a household has illiquid wealth was used). The shares are shown in percentages. Income and wealth variables show mean real income and mean real wealth per group in 2006 dollars. Income is presented in hundreds of thousands, and wealth is presented in hundreds of millions. The statistics are averaged across sample years.

Variables	bottom 50% income, bottom 50% wealth	top 50% income, bottom 50% wealth	bottom 50% income, top 50% wealth	top 50% income, top 50% wealth
	US			
share of borrowing-constrained hhs	66%	51%	24%	20%
share of poor borrowing-constrained hhs	47%	19%	0%	0%
share of wealthy borrowing-constrained hhs	19%	32%	24%	20%
income	0.26	0.75	0.31	1.05
labor income	0.26	0.73	0.30	1.00
asset income	0.001	0.01	0.007	0.05
wealth	-0.08	-0.09	3.69	2.09
liquid wealth	-0.08	-0.10	1.89	0.72
illiquid wealth	0.004	0.009	1.80	1.37
	Russia			
share of borrowing-constrained hhs	42%	33%	34%	28%
share of poor borrowing-constrained hhs	32%	27%	0%	0%
share of wealthy borrowing-constrained hhs	10%	6%	34%	28%
income $\cdot 10$	0.21	0.70	0.23	0.71
illiquid wealth $\cdot 10$	-0.001	-0.008	0.16	0.24

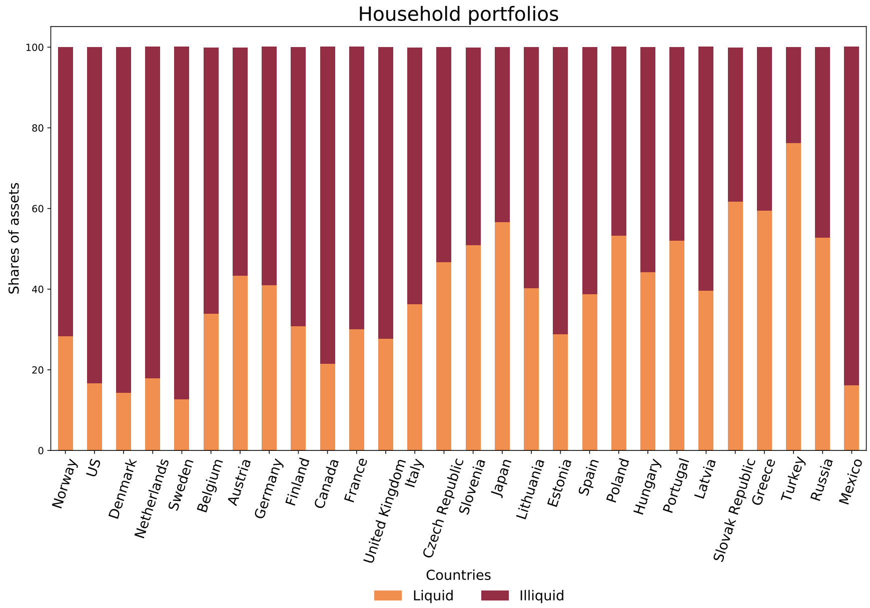
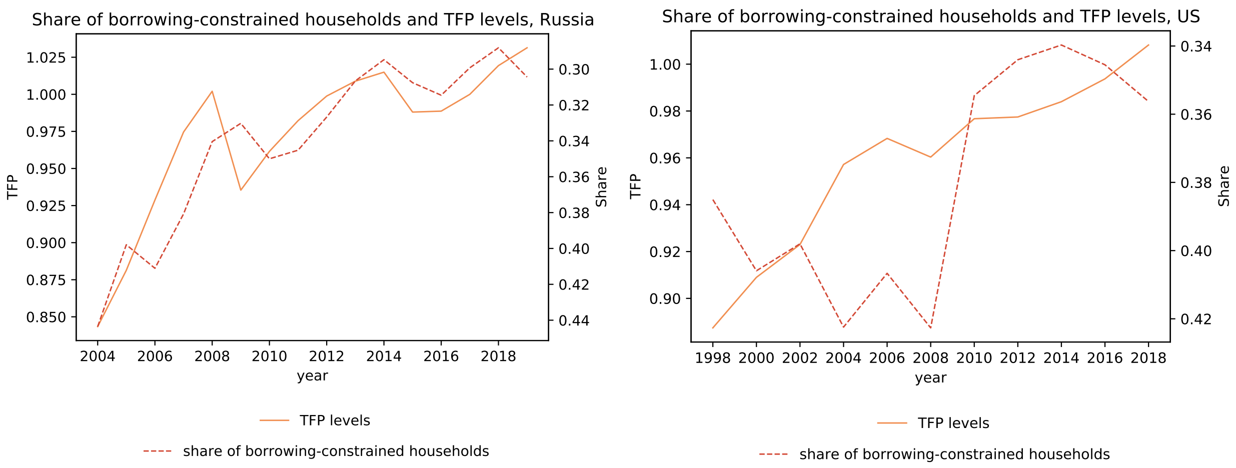


Figure 2: Household Portfolios. The figure shows the financial portfolios of households across OECD countries (excluding Luxemburg and Ireland). Liquid assets consist of currency and deposits, debt securities and loans. Illiquid assets consist of equity and investment fund shares, insurance, pensions, standardized guarantee schemes, and other accounts receivable. Portfolios are shown for the year 2021. Countries are arranged, from left to right, by GDP per capita levels in 2021 from richest to poorest.

the income process, which are presented in Section 4.2. Higher idiosyncratic risk implies that households hold larger shares of liquid assets in their portfolios to ensure against adverse shocks. To further illustrate this phenomenon for a wider geography, Figure 2 shows a noisy but discernibly upward-sloping trend in the share of liquid assets in the financial portfolios of households in a sample of OECD countries sorted according to their GDP per capita levels from richest to poorest.

Higher levels of idiosyncratic risk paired with lower levels of wealth in Russia lead to the accumulation of liquid assets during economic expansions. Meanwhile, US households largely save in illiquid assets during boom periods, as those deliver higher returns. This result, obtained empirically in Section 3 and in the model, is supported by the suggestive evidence from aggregate statistics. Figure 3a and Figure 3b show that the aggregate share of borrowing-constrained households evolves far more countercyclically in Russia than in the US (the right axis is inverted on the graphs). A TFP surge in the first ten years of the Russian sample was associated with a decrease in the share of borrowing-constrained households from 45% to around 30%, while in the US, before and after the Great Recession, TFP levels



(a) **Russia** (b) **US**

Figure 3: Cyclicality of the Shares of Borrowing-Constrained Households. The figures show the cyclicality of the shares of borrowing-constrained households. TFP is presented on the left Y-axis. Shares are presented on the right inverted Y-axis. Data for TFP levels is obtained from Feenstra, Inklaar and Timmer (2015). Shares were calculated using RLMS (Russia) and PSID (US) household-level surveys. The X-axis shows time in years.

increased in tandem with that share. The financial crisis in the US was associated with a considerable decrease in the number of borrowing-constrained households due to a marked decrease in the number of wealthy hand-to-mouth that liquidated their illiquid assets (see Appendix B for correlations with real per capita GDP instead of TFP levels).

Other suggestive evidence comes from balance of payment statistics. In the model, introduced in Section 4, bonds are liquid, and claims on all equities in the economy are illiquid. The financial intermediary passes households' demand for assets of different degrees of liquidity on to the rest of the world. Similarly, in Russia the debt subcomponent of the financial account, which, apart from the capital account, mirrors the current account, shows procyclical patterns, whereas the same metric for the US shows countercyclical dynamics (see Figure 12). [10] This is in line with the dynamics of the shares of borrowing-constrained households as the financial account also shows an increase in the demand for liquid assets in Russia and an increase in the demand for illiquid assets in the US during expansionary periods. As a result, in a boom, the developed country holds a short position in liquid assets, whereas the emerging economy holds a long position. The quantitative model outlined in

10 For classification into liquid and illiquid assets according to Lane and Milesi-Ferretti (2017) see Figure 10b. It shows more procyclical behavior of net liquid assets in Russia than in the US.

Section 4.1 calibrated to match household savings portfolios reproduces these debt and equity elasticities to GDP fairly well (see Section 4.2).

In terms of income and wealth inequalities, both countries are similarly unequal, see Figure 10a as well as the ratios of mean incomes of the top 50% compared to the bottom 50% of the income distributions in Table 1.

3. Empirical Responses to TFP Shocks

The empirical analysis presented in this section shows impulse responses of the shares of borrowing-constrained households to TFP shocks. It is crucial to obtain responses of the shares empirically, since the direction of the change is ambiguous. The empirical responses adequately match those in the model this paper introduces, as shown in Section 4.2. Responses of the shares are obtained using local projections with externally obtained TFP shocks controlling for income and wealth percentiles of households' respective distributions. The general equilibrium effects of savings on the current account are studied in the quantitative HANK model in Section 4.

3.1. Identification of the TFP Shocks

In this empirical analysis externally constructed series of TFP shocks are used. TFP series are taken from Feenstra et al. (2015)[11] for both countries. Additionally, for the US, the TFP series constructed by J. Fernald[12] is used as a robustness check. The first series is constructed using the Törnqvist quantity index of factor endowments, whereas the second series relies on utilization-adjusted Solow residuals constructed from sectoral data.

For all TFP series, Dickey-Fuller unit root tests for all widely used levels of significance do not reject the null hypothesis of the presence of the unit root. Therefore, as in Fernald (2014), TFP shocks are obtained using the first differences of TFP levels.

11 Penn World Table 10.0

12 https://www.johnfernald.net/TFP accessed on 22.06.22

3.2. Empirical Specification

Similar to Cloyne, Ferreire and Surico (2020), and Coibion, Gorodnichenko, Kueng and Silvia (2017), Jordà (2005)'s local projections are used to characterize the effects of aggregate shocks on households' behavior. The outcome of interest is how households in different income and wealth percentiles respond to changes in their income induced by TFP shocks. Therefore, a two-stage regression model is employed. In the first stage, for each group of households (groups are constructed based on the households' positions in the income and wealth distributions), changes in their income are regressed on TFP shocks and a vector of household demographics, see Equation (1). In the second stage, Equation (2), the dummy of being borrowing-constrained is regressed on its lags (to control for trends before the shocks), the instrumented variable, and the households' demographics:

$$y_{i,t} = \nu_i + B^j(L)y_{i,t-1} + C^j(L)\hat{z}_{i,t} + \beta_1^j X_{i,t} + \varepsilon_{i,t} \tag{1}$$

$$z_{i,t} = \mu_i + D^j(L)g_t + H^j(L)g_t \cdot X_{i,t} + \beta_2^j X_{i,t} + \eta_{i,t} \tag{2}$$

where $y_{i,t}$ is household i's dummy for being borrowing-constrained at time t, fixed effects are captured in ν_i and μ_i, z represents changes in the logarithm of household real income, X are controls, [13] and g_t are TFP shocks. Each regression is run separately for each of the four groups indexed by j, obtained by bisecting income and wealth distributions at the respective medians. [14] $B(L), C(L), D(L)$, and $H(L)$ are lag polynomials. Appendix B presents responses for real liquid and real illiquid holdings for the US sample, as well as consumption responses for Russia. These responses provide additional insights and support the empirical results discussed below.

Sargan-Hansen tests indicate that the instruments are valid. LM tests for the relevance of the instruments indicate that the instruments are relevant where responses are significant. Relevance of the instrument does, however, decrease in further periods of local projections.

13 Changes in age and age squared of the household head, and changes in the number of family members.

14 The first group is those in the bottom 50% of the income distribution and the bottom 50% of the wealth distribution, another group is those in the top 50% of the income distribution and the bottom 50% of the wealth distribution, etc.

Table 2: Empirical Cumulative Impulse Responses. The table shows cumulative impulse responses obtained from the regression model presented in eq. (1) and eq. (2). Cumulative responses are obtained by summing up responses for the first four years after the shock. 90% confidence intervals are shown in brackets.

Variable, Country	**Cumulative IRFs with 90% CI**			
	Income Poor, Wealth Poor	Income Rich, Wealth Poor	Income Poor, Wealth Rich	Income Rich, Wealth Rich
	Probability of being borrowing-constrained			
p(borrowing-constrained), US	0.16 (-0.23 0.56)	-0.27 (-0.88 0.34)	-0.23 (-0.84 0.38)	0.58 (0.03 1.13)
p(borrowing-constrained), Russia	0.08 (-0.23 0.39)	-0.24 (-0.51 0.03)	-0.01 (-0.29 0.27)	-0.26 (-0.41 -0.10)
	Other Variables			
liquid, US	-0.23 (-2.82 2.36)	-0.42 (-3.25 2.41)	1.98 (-1.03 4.98)	-1.80 (-4.90 1.30)
illiquid, US	-0.60 (-1.86 0.65)	5.14 (0.46 9.83)	-0.29 (-3.14 2.56)	-1.78 (-5.14 1.60)
consumption, Russia	-0.17 (-0.73 0.39)	0.52 (0.18 0.86)	0.53 (-0.09 1.15)	0.92 (0.63 1.22)
	First Stage			
income, US	-0.01 (-0.03 0.02)	0.09 (0.06 0.11)	-0.06 (-0.10 -0.02)	0.05 (0.03 0.07)
income, Russia	-0.01 (-0.03 0.02)	0.02 (-0.003 0.03)	-0.01 (-0.03 0.01)	0.02 (0.01 0.04)

In the robustness checks, Arellano-Bond estimates are compared to fixed-effects regression estimates, and high-dimensional fixed effects are compared to standard fixed effects estimates. By including and excluding variables I also experiment with lags of the dependent variable in the second stage, lags of the dependent variable and time trend in the first stage, and interaction terms (household demographics with TFP shocks) in both stages.

Additionally, for the US, different series are used for TFP shocks (see Section 3.1 for the description of the TFP shocks). Finally, reduced form estimates where y is directly regressed on TFP shocks are also obtained. Results are qualitatively robust to all of these alterations.

3.3. Empirical Results

Empirical impulse responses for the shares of the borrowing-constrained households in Russia and the US are presented in Figure 4. Cumulative responses of different variables are shown in Table 2. In Appendix B.2 impulse responses for the liquid and illiquid assets in the US, for consumption in Russia, and the first-stage impulse responses in both countries are displayed.

Figure 4 showcases stark differences in the behavior of income-rich households in Russia and the US: while in the US, the number of borrowing-constrained households in the income-rich bracket increases in response to a positive TFP shock, the share of constrained households among the income-rich in Russia decreases. US households largely increase savings in

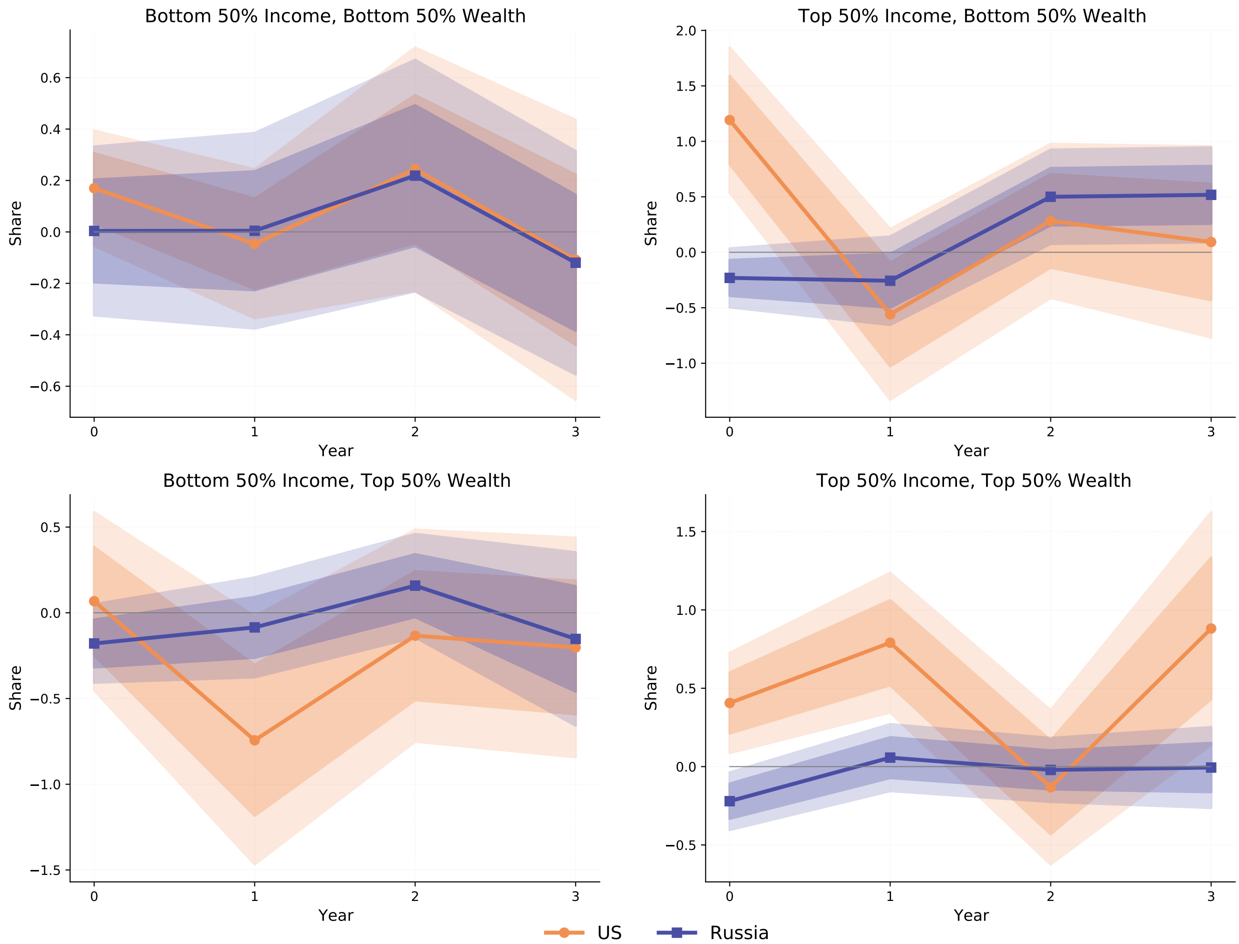


Figure 4: Empirical Impulse Responses of Probabilities of Being Borrowing-Constrained to Income Shocks. The figure shows impulse response functions (IRFs) for four groups of households (income poor/rich, wealth poor/rich). The lines correspond to the mean IRFs (orange for the US and violet for Russia), inner shaded areas show one standard deviation around the mean responses, outer shaded areas 90% confidence intervals. The X-axis shows time in years. The probability of becoming borrowing-constrained is shown in first differences.

illiquid assets, as they deliver higher returns (see also liquid and illiquid asset responses in Appendix B.2). In Russia, even households at the top of the income and wealth distributions save in the form of liquid assets in response to positive TFP shocks. They also have large marginal propensities to consume (MPCs), see Table 2 and Appendix B.2, in response to income shocks induced by increases in TFP.[15]

Therefore, not only is the share of unconstrained households (who save) large among the income-rich, but changes in the share of borrowing-constrained households also take place in

15 Calculated MPCs should not be seen as general MPCs, but rather as MPCs only for the income shocks induced by TFP shocks. Nevertheless, the magnitudes are comparable with estimates for Peru's economy in Hong (2020).

this group of households. Hence, the income-rich are the ones that have the largest impact on the current account dynamics.

On the other hand, the responses of income-poor households are similar in both countries. Among this group, the share of borrowing-constrained households is large, and does not vary with the business cycle. Thus, these households only impact current account dynamics through general equilibrium effects.

Wealth-rich and income-poor households consume all additional income, presenting a classic example of the wealthy hand-to-mouth households. This can be seen from insignificant responses of probabilities in both countries. For this group of households TFP shock entails a huge consumption increase in Russia, and insignificant responses of liquid and illiquid assets in the US.

Summary. Empirical results presented in this section show that savings responses to TFP shocks are heterogeneous. In Russia, households have high MPCs, save little, and do so in liquid assets. In contrast, in the US, wealthy households largely save in the form of illiquid assets. In the US, the largest increase in liquid savings in response to a positive TFP shock is obtained for income- and wealth-poor households.

The implications for the current account are straightforward, as it directly depends on the amount of savings. In addition, subject to the supply of liquid and illiquid assets in the economy, the savings responses of households form the demand for both types of assets vis-à-vis the rest of the world.

4. Quantitative HANK model

The model this paper builds on is a discrete-time two-asset HANK model developed by Auclert et al. (2019). Their model is extended to a small open economy framework and calibrated to the Russian and US economies.

The model features heterogeneous households that face idiosyncratic income risk and save in the form of liquid and illiquid assets. The two-asset structure is needed to disentangle demand for different savings forms and compare its dynamics across countries. In addition, two assets are essential to reproduce large average marginal propensities to consume, as shown in Kaplan and Violante (forthcoming). Households are homogeneous in the consumption basket of home- and foreign-produced goods. On the supply side, monopolistically competitive firms face capital adjustment costs, which are important for current account dynamics (Mendoza, 1991). Nominal rigidities are included to study the impact of different monetary policy regimes. A debt-elastic interest rate ensures determinacy. The fiscal authority follows a balanced-budget policy.

4.1. Model Description

4.1.1. Households

Idiosyncratic risk. At the beginning of each period t households experience an idiosyncratic productivity shock. The shock follows an n_e-state Markov process with a transition matrix $P(e_{t+1}|e_t)$ and stationary distribution $\pi(e)$.

Labor income. Real after-tax labor income ξ_t of a household at time t is a function of the idiosyncratic productivity state e_t, real wage w_t, labor hours n_t, and tax rate τ_t:

$$\xi_t = (1-\tau_t)e_t w_t n_t \tag{3}$$

Bellman equation. In each period t each household decides on consumption c_t and savings in illiquid assets a_t and liquid assets b_t. A representative household head chooses labor hours, n_t. The state in period t is (e_t, a_{t-1}, b_{t-1}) where e_t is the idiosyncratic productivity shock. Each household maximizes the following value function, given the state:

$$\begin{aligned} V(e_t, a_{t-1}, b_{t-1}) &= \max_{c_t, a_t, b_t} u(c_t, n_t) + \beta E_e V(e_{t+1}, a_t, b_t) \\ \text{s.t.} \quad & c_t + a_t + b_t = \xi_t + (1+r_t^a)a_{t-1} + (1+r_t^b)b_{t-1} - \Phi(a_t, a_{t-1}) \\ & a_t \geq 0, \quad b_t \geq \underline{b} \end{aligned} \tag{4}$$

where ξ_t is labor income, and r_t^a and r_t^b are interest rates on illiquid and liquid assets, respectively. $\Phi(.)$ is the convex portfolio adjustment cost defined below, and β the time discount factor. The instantaneous utility function takes the standard separable form

$u(c,n) = \frac{c^{1-\sigma}}{1-\sigma} - \frac{n^{1+\rho}}{1+\rho}$. For liquid assets, the condition $b_t \geq \underline{b}$ acts as a borrowing constraint; illiquid assets can be only positive. The value function depends on the idiosyncratic income shock, e_t, through ξ_t. Portfolio adjustment costs take the following functional form:

$$\Phi(a_t, a_{t-1}) = \frac{\chi_1}{\chi_2} \left| \frac{a_t - (1+r_t^a)a_{t-1}}{(1+r_t^a)a_{t-1} + \chi_0} \right|^{\chi_2} [(1+r_t^a)a_{t-1} + \chi_0] \tag{5}$$

with $\chi_0 > 0$, $\chi_1 > 0$ and $\chi_2 > 1$. Note that $\Phi(a_t, a_{t-1})$ is bounded, differentiable [16] and convex in both arguments.

Labor hours are chosen by the household head and are determined through the following intratemporal first-order condition:

$$\varphi n_t^{\rho} = \frac{1}{\mu_w} \int u_c(e_t, a_{t-1}, b_{t-1}) \frac{\partial \xi_t}{\partial n_t} dD(e_t, a_{t-1}, b_{t-1}) \tag{6}$$

where μ_w is a wage markup that has no impact on results but is kept for comparability with Auclert et al. (2019). The solution to the optimization problem are policy functions $c(e_t, a_{t-1}, b_{t-1})$, $a(e_t, a_{t-1}, b_{t-1})$ and $b(e_t, a_{t-1}, b_{t-1})$ that depend on the interest rate and tax path $\left\{r_s^a, r_s^b, \tau_s\right\}_{s \geq t}$, taken as given by households.

Home and Foreign Goods. The consumption good is a composite of home- and foreign-produced goods with a CES aggregation technology that is homogeneous across households. Therefore, aggregate demand for home- and foreign-produced goods can be linked to aggregate consumption of households in the following way

$$C_{H,t} = (1-\gamma) \left(\frac{p_{H,t}}{p_t}\right)^{-\eta} C_t \tag{7}$$

$$C_{F,t} = \gamma \left(\frac{p_{F,t}}{p_t}\right)^{-\eta} C_t \tag{8}$$

$$C_{H,t}^* = \left(\frac{p_{H,t}}{p_{F,t}}\right)^{-\eta_f} Y_{F,t}^* \tag{9}$$

where γ governs the home bias. $C_{H,t}$ and $C_{F,t}$ are consumption of home- and foreign-produced goods respectively. The price of home-produced goods is $p_{H,t}$ and p_t the price level

16 Except at $a_t = (1+r_t^a)a_{t-1}$

in the home economy. Finally, η is the elasticity of substitution between those goods. Foreign households have a downward-sloping demand for the country's exports, $C^*_{H,t}$, driven by the foreign country's income, $Y^*_{F,t}$. The slope of this demand is governed by η_f. The supply of the foreign good is assumed to be completely elastic at a fixed price normalized to 1 in the foreign currency. The law of one price holds at the goods level, thus, $p_{F,t} = \mathcal{E}_t$ with $\mathcal{E}_t$ being the nominal exchange rate.

Household aggregates. Aggregate policy functions for consumption and asset holdings are obtained by integrating individual policy functions weighted by the measure of households in state e_t that own assets in sets A_- and B_- at the start of date t, which is given by $D(e_t, A_-, B_-,) = Pr(e = e_t, a_{t-1} \in A_-, b_{t-1} \in B_-)$.

$$\mathcal{A}_t(r^a_t, r^b_t, \tau_t, N_t, w_t) = \int a(e_t, a_{t-1}, b_{t-1}) dD(e_t, a_{t-1}, b_{t-1}) \tag{10}$$

$$\mathcal{B}_t(r^a_t, r^b_t, \tau_t, N_t, w_t) = \int b(e_t, a_{t-1}, b_{t-1}) dD(e_t, a_{t-1}, b_{t-1}) \tag{11}$$

$$\mathcal{C}_t(r^a_t, r^b_t, \tau_t, N_t, w_t) = \int c(e_t, a_{t-1}, b_{t-1}) dD(e_t, a_{t-1}, b_{t-1}) \tag{12}$$

4.1.2. Firms: Labor Demand, Capital Demand, and Pricing Decisions

Each intermediate-good firm s produces output by combining capital and labor inputs in a Cobb-Douglas production function:

$$y_{s,t} = z_t k^{\nu}_{s,t-1} N^{1-\nu}_{s,t} \tag{13}$$

where $y_{s,t}$ is the intermediate output, z_t total factor productivity, $k_{s,t-1}$ and $N_{s,t}$ are capital and labor inputs, respectively, and ν is the capital share.

Each firm chooses capital and labor demands, $k_{s,t}$ and $N_{s,t}$, the price of their good's variety, $p_{s,t}$, and investment, $I_{s,t}$, to maximize the sum of future discounted real profits, which recursively reads as follows:

$$J_{s,t}\left(k_{s,t-1}\right) = \max_{p_{s,t},k_{s,t},I_{s,t},N_{s,t}} \left\{ \frac{p_{s,t}}{p_t} y_{s,t} - w_t N_{s,t} - I_{s,t} - \frac{\eta}{2\kappa} \ln(1+\pi_{s,t})^2 Y_t + \frac{J_{s,t+1}(k_{s,t})}{1+r_{t+1}} \right\} \quad (14)$$

$$\text{s.t.} \qquad k_{s,t} = (1-\delta)k_{s,t-1} + I_{s,t} - \frac{1}{2\delta\varepsilon_I}\left(\frac{k_{s,t}-k_{s,t-1}}{k_{s,t-1}}\right)^2 k_{s,t-1} \quad (15)$$

$$p_{s,t} = \left(\frac{Y_t}{y_{s,t}}\right)^{\frac{1}{\eta}} p_{H,t} \quad (16)$$

$$y_{s,t} = z_{s,t} k_{s,t-1}^{\nu} N_{s,t}^{1-\nu} \quad (17)$$

where equation (15) is the capital accumulation equation, δ is the depreciation rate of capital, and $\frac{\eta}{2\kappa}\ln(1+\pi_{s,t})^2 Y_t$ quadratic price adjustment costs. Firms face quadratic adjustment costs on physical capital, with a standard functional form of $\frac{1}{2\delta\varepsilon_I}\left(\frac{k_{s,t}-k_{s,t-1}}{k_{s,t-1}}\right)^2 k_{s,t-1}$, which leads to a variable price of capital.

Defining $q_{s,t}$ as the Lagrange multiplier on the capital accumulation equation (hence a shadow price of capital), the firm's first-order condition for capital is:

$$\begin{aligned}(1+r_{t+1})q_{s,t} = \nu z_{t+1}\left(\frac{N_{s,t+1}}{k_{s,t}}\right)^{1-\nu} mc_{s,t+1} - \\ - \left[\frac{k_{s,t+1}}{k_{s,t}} - (1-\delta) + \frac{1}{2\delta\varepsilon_I}\left(\frac{k_{s,t+1}-k_{s,t}}{k_{s,t}}\right)^2\right] + \frac{k_{s,t+1}}{k_{s,t}} q_{s,t+1}\end{aligned} \quad (18)$$

where $mc_{s,t+1}$ is the Lagrange multiplier on the production constraint and represents real marginal costs. The first-order conditions for investment and labor are

$$q_{s,t} = 1 + \frac{1}{\delta\varepsilon_I}\left(\frac{k_{s,t}-k_{s,t-1}}{k_{s,t-1}}\right) \quad (19)$$

$$w_t = (1-\nu)\frac{y_{s,t}}{N_{s,t}} mc_{s,t} \quad (20)$$

The first-order condition with respect to prices leads to the Phillips curve:

$$\log(1+\pi_{s,t}) = \kappa\left(mc_{s,t} - \frac{1}{\mu_p}\frac{p_{s,t}}{p_t}\right) + \frac{Y_{t+1}}{Y_t}\log(1+\pi_{s,t+1})\frac{1}{1+r_{t+1}} \quad (21)$$

4.1.3. Asset Returns

Let r_t denote the ex-post return on government bonds. Let v_t be the aggregate price of equity and d_t aggregate dividends. The real return on equity is $\frac{d_{t+1}+v_{t+1}}{v_t}$. The no-arbitrage condition is given by: $v_t = \frac{d_{s,t+1}+v_{s,t+1}}{1+r_{t+1}}$. As in Kaplan et al. (2018) bonds are liquid, and equities are illiquid. A financial intermediary collects all liquid and illiquid savings of households and invests them in government bonds, domestic equities, and foreign liquid and illiquid assets. The demand for foreign liquid and illiquid assets is determined by the difference between demand for and supply of each type of asset in the home economy:

$$(1+r_t^a) = \left(\frac{v_{t-1}}{\mathcal{A}_{t-1}}\right)\frac{d_t+v_t}{v_{t-1}} + \left(1-\frac{v_{t-1}}{\mathcal{A}_{t-1}}\right)(1+r_t^*)\frac{q_{t+1}}{q_t} \tag{22}$$

$$(1+r_t^b) = \left(\frac{B^g}{\mathcal{B}_{t-1}}\right)(r_t-\psi) + \left(1-\frac{B^g}{\mathcal{B}_{t-1}}\right)(1+r_t^*-\psi)\frac{q_{t+1}}{q_t} \tag{23}$$

where q_t is the real exchange rate defined as $q_t \equiv \frac{\mathcal{E}_t}{p_t}$. The liquidity premium is equal at home and abroad. The government does not issue new debt and pays interest on a constant debt level B^g. In Appendix B.2 an alternative specification, where bonds are illiquid as in Auclert et al. (2019), is considered.

The uncovered interest rate parity ties the nominal rate in the economy to the world interest rate r^* through movements in the nominal exchange rate $\mathcal{E}$ and a debt-elastic risk premium which depends on a parameter ϕ and net foreign assets NFA_t.

$$1+i_t = (1+r_t^*)\frac{\mathcal{E}_{t+1}}{\mathcal{E}_t} - \phi(exp(-NFA_t)-1) \tag{24}$$

Net foreign assets are the cumulative sum of trade balances, which is written in the recursive form as follows:

$$NX_t = \frac{p_{H,t}}{p_t}C_{H,t}^* - \frac{p_{F,t}}{p_t}C_{F,t} \tag{25}$$

$$NFA_t = (1+\tilde{r}_t)NFA_{t-1} + NX_t \tag{26}$$

where $1+\tilde{r}_t = \frac{\mathcal{A}_{t-1}-v_{t-1}}{NFA_{t-1}}(1+r_t^*)\frac{q_{t+1}}{q_t}+\frac{\mathcal{B}_{t-1}-B^g}{NFA_{t-1}}(1+r_t^*-\psi)\frac{q_{t+1}}{q_t}$ is the return on the net foreign asset position, i.e. the weighted sum of returns on liquid and illiquid foreign assets. The current account is determined according to its balance of payment definition $CA_t = NX_t+r_tNFA_{t-1}$.

4.1.4. Monetary and Fiscal Policy

Fiscal policy G_t follows a balanced-budget policy:

$$\tau_t w_t N_t = r_t B^g + G_t \tag{27}$$

Monetary policy follows a simple Taylor-type rule:

$$i_t = \bar{r} + \phi_\pi \pi_{H,t} \tag{28}$$

where i_t is the monetary policy interest rate, ϕ_π is the weight on domestic inflation $\pi_{H,t}$. The natural interest rate is given by $\bar{r}$, which is equal to the steady state real interest rate. In the baseline specification, the exchange rate is assumed to be flexible. Appendix B presents impulse responses in the model calibrated to the emerging economy (Russia) with nominal exchange rate targeting. Finally, the Fisher equation reads as $1 + r_t = \frac{1+i_t}{1+\pi_t}$.

4.1.5. Market Clearing: Labor, Goods and Asset Markets

Aggregate goods supply is equal to aggregate demand, hence:

$$Y_t - \psi\mathcal{B}_t - \Phi_t = \mathcal{C}_t + G_t + I_t + NX_t, \tag{29}$$

where aggeragte consumption is obtained through the households' income and wealth distribution D_t, defined above. Asset market clearing implies

$$\mathcal{A}_t + \mathcal{B}_t = v_t + B^g + NFA_t, \tag{30}$$

where aggregation is once more obtained through distribution D_t. Labor demand equals labor supply.

4.1.6. Equilibrium

Definition 1: Competitive Equilibrium

A Competitive Equilibrium of the economy satisfies the following definition:

- The sequence $[c_t, a_t, b_t]_{t=0}^{\infty}$ solves households' consumption-saving decisions, given the distribution of idiosyncratic shocks, $P(e_{t+1}|e_t)$, and the sequence of prices r_t^a, r_t^b, r_t, w_t.
- Aggregate household consumption and asset holdings are equal to the product of individual optimal policy functions and the distribution of households across assets.
- Firms choose labor demand $N_{s,t}$ and capital inputs $k_{s,t}$ in order to optimize their real discounted profits, given in eq. (14).
- Monetary policy determines the short-term interest rate according to eq. (28). Fiscal policy follows a balanced budget rule as in eq. (27).
- No arbitrage conditions between all types of assets and the law of one price at the goods level are satisfied.
- Market clearing and aggregate resource constraints are satisfied.

4.2. Model Calibration

The model is calibrated for the US following Auclert et al. (2019), and Kekre and Lenel (2021) for the open economy parameters. Calibration for Russia is primarily based on Malakhovskaya and Minabutdinov (2014) and Semko (2013). Wealth targets were calculated using RLMS and household savings data from the Russian Central Bank's database. The model is calibrated at quarterly frequency for both economies. Table 3 and Table 7 summarize parameter values for the household model blocks. Table 4 and Table 8 summarize parameter values for the rest of the respective economy. Details on the computation of wealth targets and on estimation of the labor income process for Russia can be found in Appendix A.

Model parameters for the US and Russia mainly differ in their values for the respective labor income process, wealth levels, and capital adjustment costs parameters. While households in the US are much wealthier, Russian households hold relatively more liquid wealth and face higher labor income risk. Russian firms face a larger capital depreciation rate, but smaller

Table 3: US: Household Parameter Values, Description and Source

Parameter	Description	Value and source
β	Time discount factor	0.977, target interest rate
χ_0	Portfolio adj. cost pivot	0.25, Auclert et al. (2019)
χ_1	Portfolio adj. cost scale	10.11, target $\mathcal{B}_h = 1.04Y$
χ_2	Portfolio adj. cost curvature	1.985, target htm= 0.38[17]
σ	EIS	0.5, Auclert et al. (2019)
ρ	Inverse Frisch elasticity	1, Auclert et al. (2019)
ρ_z	Autocorrelation of earnings	0.966, Auclert et al. (2019)
σ_z	Cross-sectional std of log earnings	0.92, Auclert et al. (2019)
φ	Disutility parameter	1.78 (target $N = 1$)

capital and price adjustment costs. The latter leads to more volatile investment dynamics. Additionally, the labor income tax rate is lower and the elasticity of substitution between home- and foreign-produced goods in Russia is also lesser.

Labor income process for Russia. Individual-level data from RLMS for 2000 to 2019 is used to estimate the labor income process for Russia. The data is cleaned following Guvenen, Karahan, Ozkan and Song (2021). [18] The functional form of the income process in Auclert et al. (2019)'s discrete-time HANK model for the US is a simple AR(1) process with normally distributed errors. Therefore, for consistency, I chose the same functional form for the labor income process in Russia. As targets in the Generalized Method of Moments (GMM) estimation the same moments as in Kaplan et al. (2018) are selected, with two exceptions: [19] Kurtosis is not targeted as excess kurtosis in an AR(1) process with normally distributed errors is never positive. Also, standard deviations are chosen as target moments instead of variances, so that the levels of moments are closer to one other, allowing for the identity weighting matrix's use in GMM estimation. [20] For alternative choices of targeting moments and weighting matrices see Table 12. The main trade-off in the estimation is to match large variances and, at the same time, a large mass concentrated close to zero with

17 htm = share of borrowing-constrained households.

18 for more details see Appendix A.

19 Since the Auclert et al. (2019) model is a discrete time version of Kaplan et al. (2018), the origin of income process estimates is Kaplan et al. (2018).

20 Targeted variances in Kaplan et al. (2018) are of the same order of magnitude as targeted fractions. Thus no issue arises with different levels when targeting variances.

Table 4: **US: Parameter Values, Description and Source**

Parameter	Description	Value and source
Asset Markets		
r	Real interest rate	0.0125, Auclert et al. (2019)
ψ	Liquidity premium	0.005, Auclert et al. (2019)
p/Y	Steady state price of equity	11.2, target $p + Bg = 14Y$
Production		
δ	Depreciation rate	0.02, Auclert et al. (2019)
μ_w	Wage mark-up	1.1, Auclert et al. (2019)
ε_I	Capital adj. costs parameter	4, Auclert et al. (2019)
K/Y	Steady state capital-output ratio	10, Auclert et al. (2019)
Monetary and Fiscal Policy		
ϕ	Coefficient on inflation in Taylor rule	1.5, Auclert et al. (2019)
ϕ_y	Coefficient on output gap in Taylor rule	0, Auclert et al. (2019)
τ	Tax rate	0.36, target $G/Y = 0.2$
B^g	Bond supply	2.8, Auclert et al. (2019)
κ	Slope of the Phillips curve	0.1, Auclert et al. (2019)
Open economy		
γ	Home bias	0.4, Kekre and Lenel (2021)
$\eta = \eta_f$	Elasticity of substitution for home vs. foreign goods	1.5, Kekre and Lenel (2021)

Table 5: Income Process Estimation Fit for Russia. The table shows empirical moments calculated using RLMS data and model moments obtained using estimated process parameters.

Moment	Data	Model
Variance: annual log earnings	5.41	4.29
Variance: 1-year change	6.38	6.38
Variance: 5-year change	7.55	8.58
Frac. 1-year change < 10%	0.20	0.03
Frac. 1-year change < 20%	0.35	0.06
Frac. 1-year change < 50%	0.60	0.16

Table 6: Model Fit: Income and Asset Distributions, Asset Elasticities - Data vs. Model Statistics. Model statistics are computed at the steady state, except for the elasticities. Income statistics from the model include after-tax labor income and capital gains. Data on income, liquid, illiquid assets, and shares of borrowing-constrained households are obtained from the US Survey of Consumer Finance and Russian RLMS. Liquid assets consist of transaction accounts, directly held bonds, directly held stocks, and credit card balances. Illiquid assets consist of certificates of deposits, savings bonds, cash value of insurance, other managed assets, retirement accounts, stock holdings, and primary residence net of mortgage home loans. Data on Gini coefficients is from the World Inequality Database and Kaplan et al. (2018). Elasticities of the shares of borrowing-constrained households to income are derived from local projections (values in the brackets show the responses of the aggregated shares in the first and the second years, see Section 3.3). Data on bonds and equity elasticities are computed based on balance of payment statistics (Sources: BEA and CBR external sector statistics).

Statistics	Data, US	Model, US	Data, Russia	Model, Russia
Wealth distribution				
Mean Liquid Assets/GDP	0.26	0.26	0.41	0.41
Mean Illiquid/GDP	2.92	2.99	0.92	0.92
Share of borrowing-constrained hhs	0.38	0.38	0.33	0.33
Gini coefficients				
Income	0.52	0.41	0.58	0.63
Liquid assets	0.98	0.75	-	0.64
Illiquid assets	0.81	0.52	0.67	0.43
Elasticities[21]				
Share of borrowing-constrained to income	[0.41, 0.02]	[0.02, 0.02]	[-0.10, -0.04]	[-0.03, -0.05]
Corr(Bonds / GDP, GDP)	-0.08	-0.02	0.21	0.52
Corr(Equities / GDP, GDP)	0.06	0.30	0.21	0.52

a process that has normally distributed errors. The estimated process has a persistence of 0.579 and a standard deviation equal to 2.09, as shown in Table 7. Table 5 shows that the estimated process produces moments close to those in the data. Lower persistence and higher standard deviation of the income process were also obtained in the estimates of the income process for another emerging economy, China (Yu and Zhu, 2013 and Fan, Song and Wang, 2010).

To assess the fit of the fully calibrated HANK models for each of the two economies, Table 6 compares key distributional moments calculated at the model's respective steady states and in the data. The model reproduces mean liquid and illiquid asset holdings, shares of borrowing-constrained households, and income Gini coefficients. Like numerous other

21 Elasticities of the share of borrowing-constrained households to income were calculated as a ratio of IRFs: the IRF of the share to a 1% TFP shock with persistence 0.96 over the IRF of households' income. TFP persistence is taken from the data. Bonds to GDP and equity to GDP elasticities were averaged across 50 simulations. Breaking down debt instruments into short- and long-term components reveals that both debt-to-GDP elasticities are negative for the US, i.e. in booms, equity holdings increase, holdings of all types of debt decrease. In contrast, in Russia, the short-term debt component is procyclical, but the long-term component is countercyclical.

Table 7: **Russia: Household Parameter Values, Description and Source**

Parameter	Description	Value and source
β	Time discount factor	0.935, target interest rate
χ_0	Portfolio adj. cost pivot	0.25, Auclert et al. (2019)
χ_1	Portfolio adj. cost scale	0.55, target $\mathcal{B}_h = 1.64Y$
χ_2	Portfolio adj. cost curvature	2.4, target htm=0.33
σ	EIS	0.5, Semko (2013)
ρ	Inverse Frisch elasticity	1, Semko (2013)
ρ_z	Autocorrelation of earnings	0.579, estimated with RLMS
σ_z	Cross-sectional std of log earnings	2.09, estimated with RLMS
φ	Disutility parameter	1.33 (target $N = 1$)

HANK models wealth concentration is underestimated at the top. The model also performs well in matching elasticities of the share of borrowing-constrained households to their income, the empirical counterpart of which was obtained in Section 3. The model elasticities of equity and debt components of the financial account to GDP, too, match empirical data. Both metrics, the borrowing-constrained share of households and bond elasticities, do suggest, however, that demand for liquid assets in the model calibrated to the US is slightly more procyclical than in the data.

4.3. Quantitative Results

The paper's primary focus is on the intertemporal saving decisions of heterogeneous households and their impact on international net and gross capital flows. This is assessed, for the US and Russia, respectively, via impulse response functions of the calibrated HANK model to a 1% TFP shock.

In the following, the mechanism through which heterogeneous marginal propensities to save impact aggregate savings and the current account is discussed, as well as a comparison of the responses with the representative agent framework. Then, responses in the model calibrated to Russia and the US are compared, and a counterfactual analysis to disentangle the main parameters that drive opposite gross international positions in response to TFP shocks in the two modeled economies is performed. Last, a decomposition of the gross and

Table 8: Russia: Parameter Values, Description and Source

Parameter	Description	Value and source
Asset Markets		
r	Real interest rate	0.0125, Auclert et al. (2019)
ψ	Liquidity premium	0.005, Auclert et al. (2019)
p/Y	Steady state price of equity	5.04 target $p + Bg = 5.32Y$
Production		
δ	Depreciation rate	0.025, Semko (2013)
μ_w	Wage mark-up	1.2, Semko (2013)
ε_I	Capital adj. costs parameter	12.05, Malakhovskaya and Minabutdinov (2014)
K/Y	Steady state capital-output ratio	9.26, target $\alpha = 0.33$ Malakhovskaya and Minabutdinov (2014)
Monetary and Fiscal Policy		
ϕ	Coefficient on inflation in Taylor rule	1.5, Auclert et al. (2019)
ϕ_y	Coefficient on output gap in Taylor rule	0, Auclert et al. (2019)
τ	Tax rate	0.29, target $G/Y = 0.2$
B^g	Bond supply	0.28, calculated from total government bonds supply
κ	Slope of the Phillips curve	0.38, Malakhovskaya and Minabutdinov (2014)
Open economy		
γ	Home bias	0.26, Malakhovskaya and Minabutdinov (2014)
$\eta = \eta_f$	Elasticity of substitution for home vs. foreign goods	0.67, Semko (2013)

net capital flows into aggregate and idiosyncratic risk smoothing components is performed to assess the roles of both types of risks.

4.3.1. Main Mechanism

Savings responses of the constrained and the unconstrained households to a 1% TFP shock, together with the dynamics of the shares of borrowing-constrained households, are shown in Figure 5. The third panel in the second row shows the TFP shock, which is the same for all responses in the current and all subsequent sections.

The first and second panels in the first row display the evolution of constrained households' liquid and illiquid assets, respectively. Since these households are constrained, their aggregate liquid savings are zero by construction ($b = \underline{b} = 0$ for all households). [22] Illiquid assets move according to the dynamics of the shares of borrowing-constrained households. Thus, illiquid holdings increase only with the increase in the number of borrowing-constrained households.

As in the empirical responses (see Section 3), the model calibrated to the US produces an increase in the share of borrowing-constrained households in response to a positive TFP shock. Matching the empirical results, the same share in the model calibrated to Russia falls (Figure 5, first row, third panel). Section 4.3.3 shows that the main drivers of this different behavior of shares are wealth, idiosyncratic risk, and the supply of liquid assets in the home economy.

While constrained households have limited ability to smooth their consumption over time, unconstrained households engage in precautionary savings, see Figure 5, second row, first panel. Larger idiosyncratic risk in the model calibrated to Russia as compared to the model calibrated to the US, induces larger precautionary savings. US households even liquidate their liquid assets to invest in higher-return illiquid assets in response to the positive TFP shock. As a result, the increase in illiquid assets is much more pronounced in the US than in Russia (Figure 5, second row, second panel).

Section 4.3.2 shows the implications of the savings responses of borrowing-constrained and unconstrained households, and the dynamics of the share of borrowing-constrained households

22 The response does not track those who were borrowing-constrained before the shock. Rather, assets of the households who are borrowing-constrained in the specified period are shown.

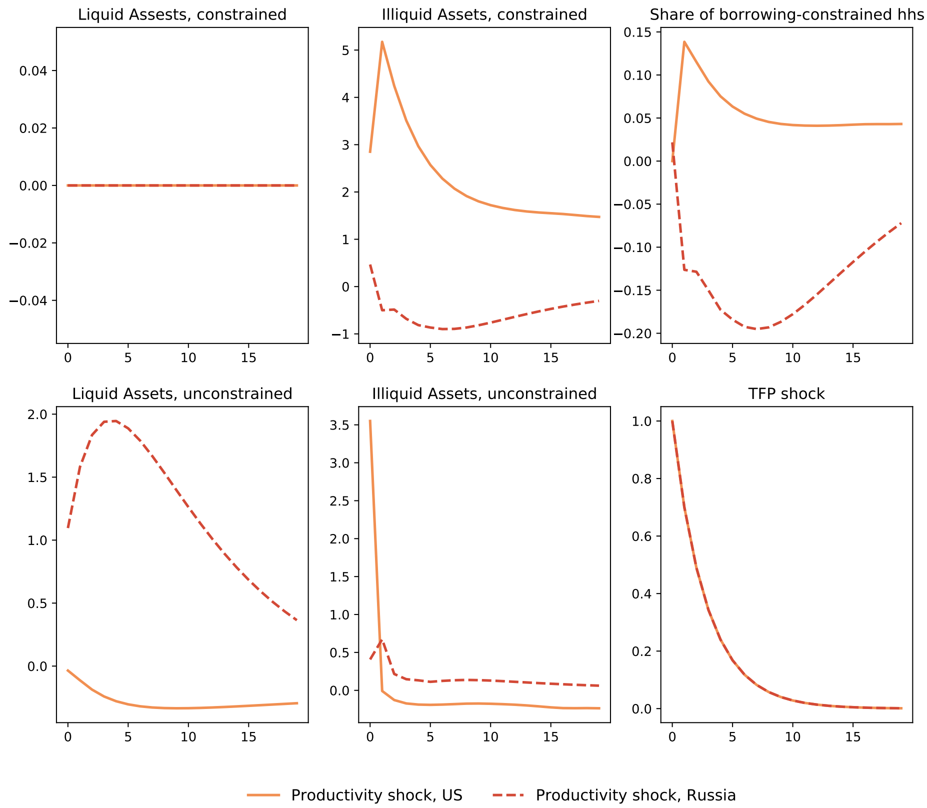


Figure 5: Impulse Responses to a TFP Shock: the Mechanism. The figure shows the percentage deviations of the specified variables from the steady state in response to a TFP shock. The shock is a 1% increase in total factor productivity; it follows an AR(1) process with persistence parameter[23] 0.7, such that the shock mostly dissipates by the 13th quarter. The figure shows the impulse responses for the model calibrated to the US (solid orange lines) and for the model calibrated to the Russian economy (dashed red lines). The X-axis shows time in quarters.

for the current account dynamics. Additionally, derivations of the current account in a toy model based on Debortoli and Galí (2017) framework are shown in Appendix D. These derivations support the described mechanism and its implications for the current account.

4.3.2. Comparison with RANK

The impulse response functions in the HANK model are compared to IRFs in a RANK model and to a HANK model with higher labor income risk in Figure 6. In a representative household framework, no households are at the borrowing constraint, entailing the largest savings increases in both countries (first panel in both rows). However, large savings put downward pressure on the real interest rate. As a result, the investment increase is also

23 The estimate of the persistence parameter for TFP shocks in the US usually employed is around 0.95 (see Smets and Wouters (2007)). However, the solutions of the models are obtained using finite numerical sequences instead of infinite analytical counterparts. Therefore, for the sake of determinacy and accuracy, a lower persistence parameter was chosen. Results are qualitatively the same for both values of persistence.

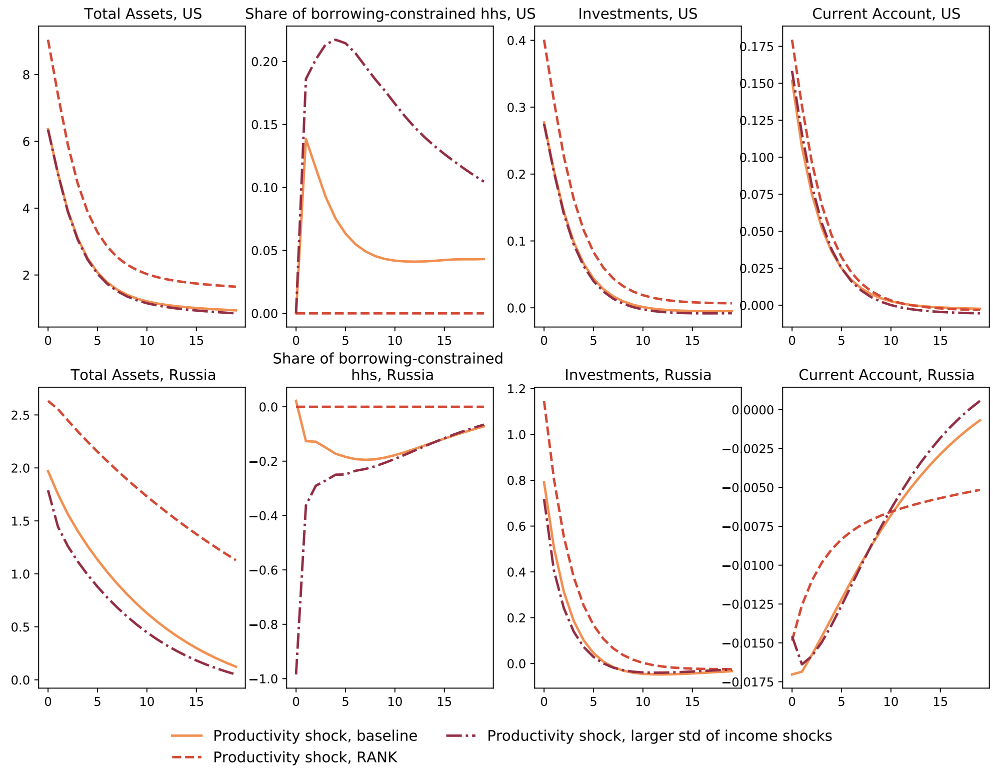


Figure 6: Impulse Responses to a TFP Shock: HANK and RANK Comparison. The figure shows the percentage deviations of the specified variables from the steady state in response to a TFP shock. The shock is a 1% increase in total factor productivity; it follows an AR(1) process with persistence parameter 0.7, such that the shock mostly dissipates by the 13th quarter. The figure shows the impulse responses for the baseline HANK model (solid orange lines), a RANK model (dashed red lines), and for a HANK model featuring idiosyncratic shocks with twice the standard deviation of shocks in the baseline model (dash-dotted burgundy lines). The X-axis shows time in quarters.

largest in RANK (third panel in both rows). The direct effect of marginal propensities to save on aggregate savings is thus shown to dominate the indirect effect on investments, with smaller savings leading to a more countercyclical current account.

Since precautionary savings are larger in Russia, the difference between HANK and RANK savings and current account responses in the model calibrated to Russia is less pronounced. Additionally, the dynamics of the share of borrowing-constrained households amplify the savings responses in Russia (second row, second panel). As a result, in the HANK model calibrated to Russia, but with the standard deviation of the idiosyncratic shocks twice as large as in the baseline calibration, a considerable decrease in the share of borrowing-constrained households and even larger precautionary savings result in the current account responses which are more procyclical than in the baseline HANK model and closer to RANK responses.

In the model calibrated to the US, precautionary savings and the dynamics of the share of borrowing-constrained households affect aggregate savings in the opposite direction. As a result, in the model with larger volatility of the idiosyncratic shocks precautionary savings are larger, but also an increase in the share of borrowing-constrained households is more sizable. These two effects cancel out one other. Consequently, savings and current account responses in the baseline HANK model and that with larger idiosyncratic risk volatility are very similar.

4.3.3. Country Comparison

Figure 7 displays the impulse responses for selected model variables. A comparison between responses for the two modelled economies reveals that, in line with empirical results, households in a developed country mostly save in the form of illiquid assets (first row, second panel). In contrast, relative to a developed country, households in an emerging economy increase their liquid holdings in response to a TFP shock (first row, first panel). The two reasons for such stark differences in the savings behavior in the two economies are wealth and idiosyncratic risk. With a CRRA utility function, lower levels of wealth in the dynamic optimization lead to less risk-taking behavior of emerging economy households. Higher labor income risk in the emerging economy furthermore induces larger precautionary savings.

A large demand for liquid assets in the emerging country through the financial intermediary is translated into a long position in liquid assets in the expansionary period (second row, first panel). In contrast, in an expansion, the US borrows liquid assets from the rest of the world and invests in illiquid assets (second row, second panel).

Investment responses are primarily driven by parameters related to the intermediate-good firm's problem: depreciation rate, capital adjustment costs, and elasticity of export demand. Thus, despite smaller savings responses in the emerging country as compared to the US (which puts less downward pressure on the real interest rate), the investment increase is larger. This in turn leads to a countercyclical response of the current account.

Counterfactual analysis in which some parameters in the model calibrated to Russia are set to US values is performed to disentangle the main drivers of the different savings responses and the gross international positions to TFP shocks. Those counterfactual results are shown

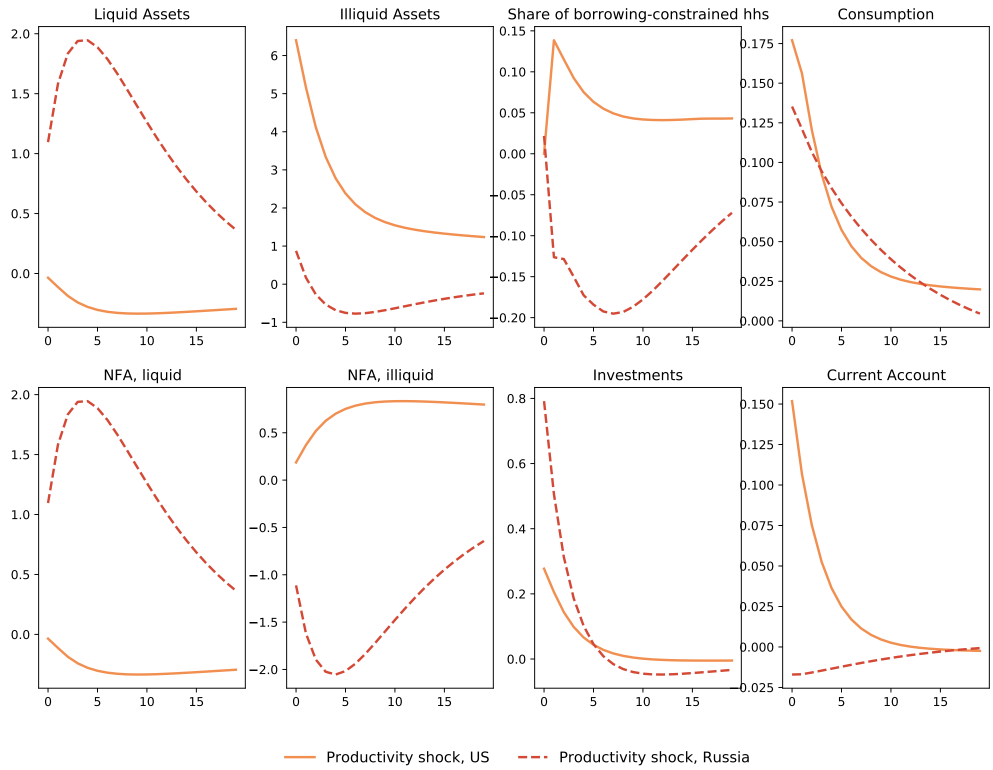


Figure 7: Impulse Responses to a TFP Shock: Country Comparison. The figure shows the percentage deviations of the specified variables from the steady state in response to a TFP shock. The shock is a 1% increase in total factor productivity; it follows an AR(1) process with persistence parameter 0.7, such that the shock mostly dissipates by the 13th quarter. The figure shows the impulse responses for the model calibrated to the US economy (solid orange lines) and to the Russian economy (dashed red lines). The X-axis shows time in quarters.

in Figure 8. First, parameters related to the intermediate-good firm's problem are changed (dash-dotted responses in burgundy). They change the cyclicality of the current account but do impact neither households' liquid and illiquid holdings, nor gross international positions.

Second, wealth level in Russia is set to the calibrated value in the US by changing the discount factor of the households (dotted lines in black). This substantially increases the responses of illiquid assets and brings them very close to those for the US. The international net illiquid position turns less negative in response to the shock. However, the impact on liquid savings and the international net liquid position is minute. Furthermore, setting parameters of the idiosyncratic risk process in Russia to US parameters largely decreases precautionary savings. The gross position in liquid assets in this counterfactual drastically declines, while the illiquid position turns positive in later periods (solid responses in dark blue). Finally, increasing the supply of bonds in Russia to US levels brings the responses of liquid and illiquid savings and US gross positions and the counterfactual economy even closer together.

Therefore, both wealth and idiosyncratic income risk contribute to the different responses in the model calibrated to the US and Russia, respectively. Wealth contributes more to the dynamics of the illiquid position, whereas idiosyncratic risk plays a more significant role in the dynamics of the liquid position.

On the other hand, differential behavior of the shares of borrowing-constrained households in the two models is mainly due to the idiosyncratic risk and liquid assets supply. Wealth differences in the two countries drive responses even more apart from each other.

4.3.4. Current Account Decomposition

An alternative method to assess the role of uninsurable idiosyncratic risk in capital flows dynamics is to decompose impulse responses into two components: consumption-smoothing of aggregate risk and consumption-smoothing of idiosyncratic risk.

The counterfactual responses for the case with only aggregate risk smoothing are obtained by setting the standard deviation of the idiosyncratic income shocks to zero when calculating IRFs. This way, the same distribution of households as in the baseline model faces an

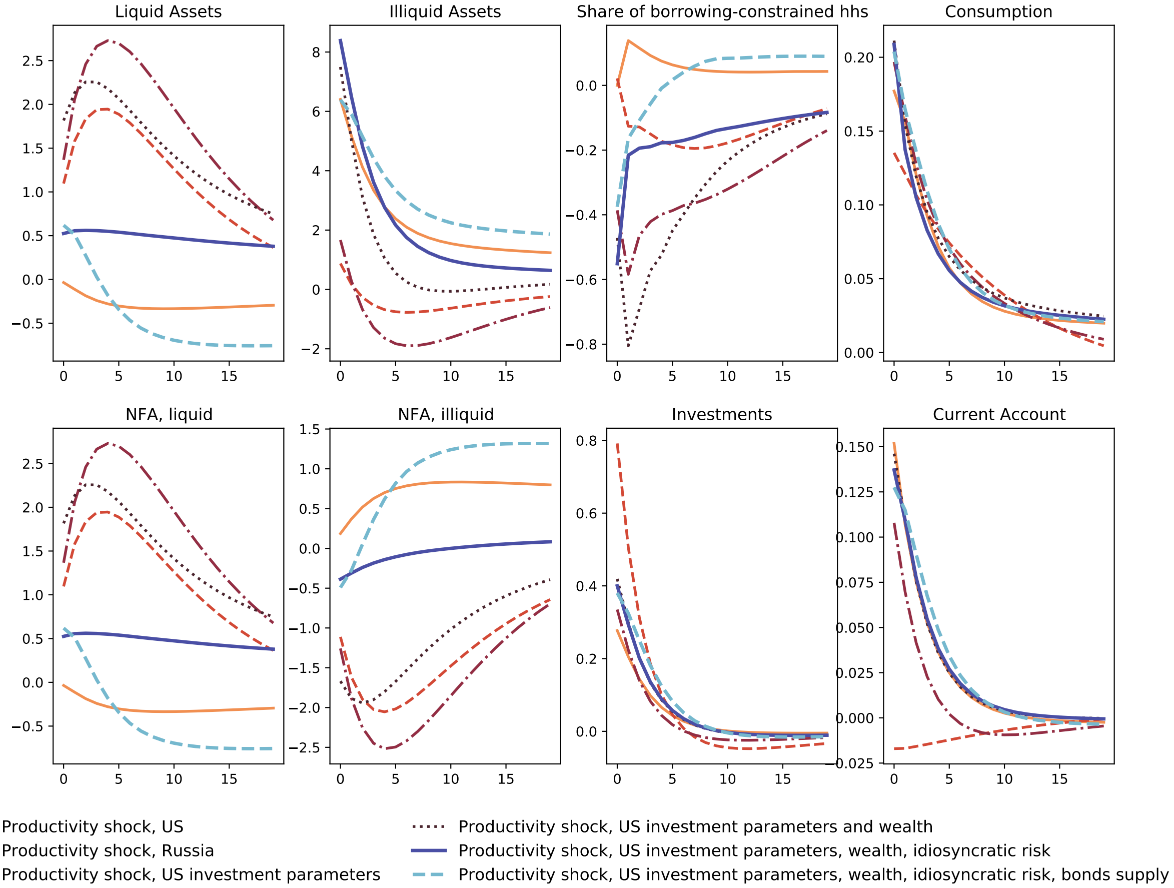


Figure 8: Impulse Responses to a TFP Shock: Counterfactual Analysis. The figure shows the percentage deviations of the specified variables from the steady state in response to a TFP shock. The shock is a 1% increase in total factor productivity; it follows an AR(1) process with persistence parameter 0.7, such that the shock mostly dissipates by the 13th quarter. The figure shows the impulse responses for the model calibrated to the US economy (solid orange lines) and to the Russian economy (dashed red lines); for the model calibrated to Russia but with the capital depreciation rate, the capital adjustment costs and the elasticity of the demand for export set to the US values (dash-dotted burgundy lines); for the model calibrated to Russia but with all investment parameters and wealth target level set as in the US (dotted black lines); for the model calibrated to Russia but with all investment parameters, wealth target level and idiosyncratic process parameters set as in the US (solid dark-blue lines); for the model calibrated to Russia but with all investment parameters, wealth target level, idiosyncratic process parameters and the supply of bonds set as in the US (dashed light-blue lines). The X-axis shows time in quarters.

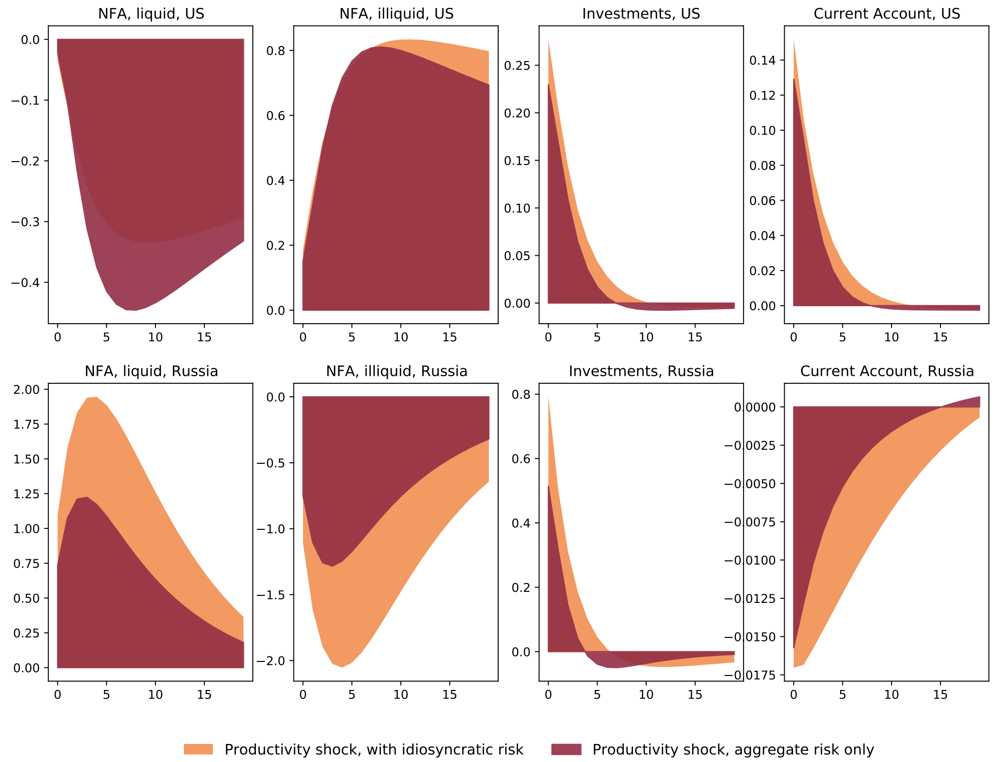


Figure 9: Decomposition of the Dynamics into Aggregate and Idiosyncratic Risk Smoothing Components. The figure shows the percentage deviations of the specified variables from the steady state in response to a TFP shock. The shock is a 1% increase in total factor productivity; it follows an AR(1) process with persistence parameter 0.7, such that the shock mostly dissipates by the 13th quarter. The figure shows the impulse responses for the model without idiosyncratic income shocks (in burgundy) and the model with idiosyncratic income shocks (in orange). The X-axis shows time in quarters.

aggregate TFP shock, as the same steady state is used. However, households no longer take into account idiosyncratic risk when optimizing their consumption paths and deciding on the amount of asset holdings. The resulting decomposition is shown in Figure 9 and in Table 9.

Larger idiosyncratic labor income risk in the emerging economy (smaller persistence of the shock and a larger standard deviation) manifests itself through a larger share of the dynamics of the net and gross capital flows attributed to idiosyncratic risk smoothing. When idiosyncratic risk is present, Russian households save more in the form of liquid assets. The illiquid position of the country in a boom is more negative (second row, first and the second panels). Gross positions in the US are also affected by the idiosyncratic risk, but to a lesser extent (the first and the second panels in the first row). The increase in liquid asset demand through downward pressure on the real interest rate also impacts investments (third panel in both rows). Finally, more than half of the current account response to the TFP shock in

Table 9: Decomposition of the Cumulative Responses to a Productivity Shock. The table shows contributions of aggregate and idiosyncratic risks to, respectively, the dynamics of the current account and illiquid and liquid net foreign asset positions evaluated over a 4-year time horizon for the US and Russia. The shock is a 1% TFP shock with a 0.7 persistence. Negative contribution is calculated as an absolute value of the response divided by the sum of the absolute values of all responses.

Country	**Current Account**		**NFA, illiquid**		**NFA, liquid**	
	aggregate	**idiosyncratic**	**aggregate**	**idiosyncratic**	**aggregate**	**idiosyncratic**
US	70%	30%	96%	4%	128%	-28%
Russia	48%	52%	57%	43%	57%	43%

the emerging economy results from households' demand for insurance against idiosyncratic income risk (second row, fourth panel). For the developed country, only a third of the current account response is due to precautionary saving motives (first row, fourth panel).

In Appendix B a decomposition for the model calibrated to the US, which has not only idiosyncratic labor income risk but also idiosyncratic return risk, is performed. The return risk is calibrated using estimates from Xavier (2021). Due to low persistence and minor variances of return risks, this model extension does not affect dynamics of gross and net capital flows.

5. Conclusion

This paper evaluates the role of heterogeneous marginal propensities to save in shaping net and gross international capital flows. This assessment is done by extending the intertemporal approach to the current account to include heterogeneous households differing in their levels of wealth and facing aggregate and idiosyncratic risks. Three novel effects are revealed: (i) borrowing-constrained households do not directly impact current account since they have a low ability to smooth their consumption; (ii) the savings of unconstrained households are determined by their levels of wealth and the amount of idiosyncratic risk in the economy. Additionally, (iii) levels of idiosyncratic risk and wealth determine endogenous changes in the distribution of the households in response to shocks, which amplify savings responses when the wealth level is low and idiosyncratic risk high. In the reverse case, responses are dampened.

An important finding is that idiosyncratic risk and wealth affect countries' international portfolios. This finding has broad implications for understanding the role of within-country risk and endogenous changes in investors' risk aversion following changes in wealth, in the formation of the gross capital flows between countries.

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A. Data Appendix

Data Cleaning, RLMS. I use only households who are complete income reporters, whose real income is larger than 0 and smaller than 99.9 percentile of the distribution of income.[24] As households report not only income and consumption but also savings, I use only those responses where deviations from the budget constraint are smaller than half of the income. Also, I use only those responses where expenditure on each category is smaller than half of the total expenditures (except for durables).

Variable Construction. In constructing income and wealth variables using PSID dataset I follow Kaplan et al. (2014). Labor income is obtained by subtracting asset income from total family income. Asset income includes income from rent, income from dividends, income from earned interest, income from trust funds and royalties, asset part of the business income and income from farming (of the head and wife). Liquid assets are obtained by subtracting credit card charges, student loans, medical or legal bills, and loans from relatives from money in checking or savings accounts, money market funds, certificates of deposit, government savings bonds, or Treasury bills, not including assets held in employer-based pensions or IRA's. Illiquid assets are obtained by subtracting housing loans from value of the real estate owned, money in IRA and other illiquid assets owned (bonds, life insurance, etc.).

Those who had intermittent "headship", appeared only once, whose income grows more than 500%, falls by more than 80%, or is below \$100, who have missing observations on race, education, or state of residence were dropped.

24 Aguiar and Bils (2015) use 5% and 95% of the income distribution. However, as is explained later, the survey lacks high-income households, thus, I have cut only the most unreliable observations.

Table 10: Data Cleaning. The table shows how many responses were excluded by each restriction. The first row reports the original sample size. The final row represents the sample used in the analysis.

Restriction	Number of responses left	Percentage of responses left
Total number of responses	138 371	100%
Complete income reporters	129 394	94%
Income > 0	128 477	93%
Income < 99.9 percentile of income distribution	128 348	93%
(Exp + Savings - Income) / Income < 0.5 Income	121 730	88%
Exp. each category (except durables) < 0.5 Total Exp.	109 012	79%

In RLMS total income is taken from constructed variables file. It includes wages, pensions, stipends, alimony, insurance payments, subsidies, transfers, income from rent, income from farming, etc. Illiquid assets is the value of the housing owned less credits and net loans. In Russia retirement accounts are not accessable. Non-durable consumption includes fridge, washer, freezer, microwave, TV, hairdryer, VCR, DVD player, computers, camera, mp3 player, cars, trucks, motorcycles, boats and lawn mowers. Total consumption is also taken from constructed variables file.

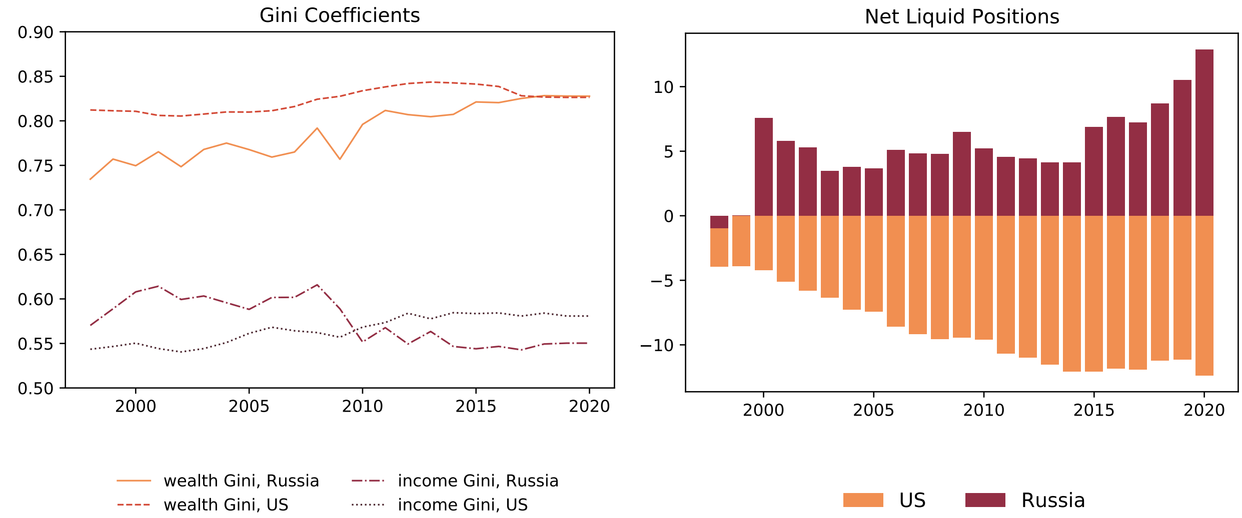
Estimation of the Income Process for Russia. I use only males from 25 to 60 years old who have earnings above the minimum income threshold, equivalent to earnings from one quarter of full-time work (13 weeks at 40 hours per week) at half of the legal minimum wage in year t. Additionally, I drop observations that report less than 270 russian rubles in 2003 prices (equivalent to $1500 used by Guvenen et al. (2021)). I also drop individuals who are observed in less than three waves or those who do not report race, age or education. Education is adjusted as in Guvenen et al. (2021).

Moments of wage residuals obtained from the regression of wage logarithm on age, age squared, race and education variables are used as data moments. Simulated moments of the AR(1) process with normally distributed residuals are used as theoretical moments.

Wealth Moments in Russia. All data needed to calculate wealth ratios is only available since 2018. Therefore, all ratios are calculated as averages for the years 2018 and 2019. The volume of government bonds in circulation is taken from the website of the russian Ministry of Finance (see OFZ volume there). Amount of liquid and illiquid holdings of households is calculated using RLMS and Household Savings database of the russian central bank. Following Kaplan et al. (2018) liquid holdings consist of deposits, bonds, money in brokers' accounts and cash taken from Household Savings database. Illiquid assets are calculated as a sum of net housing and net durables, calculated using average net housing and net durables from RLMS, and the value of equity holdings taken from the Household Savings database.

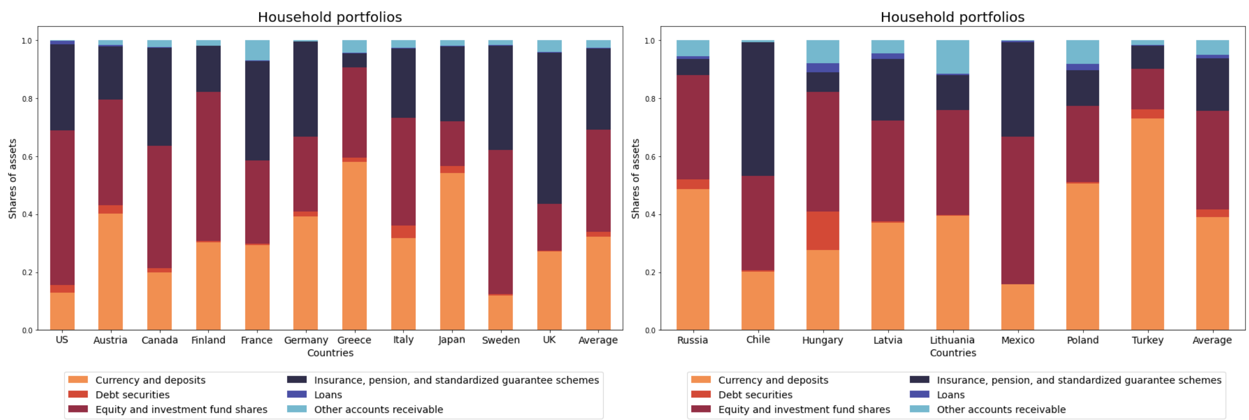
B. Additional Graphs

B.1. Data summary graphs



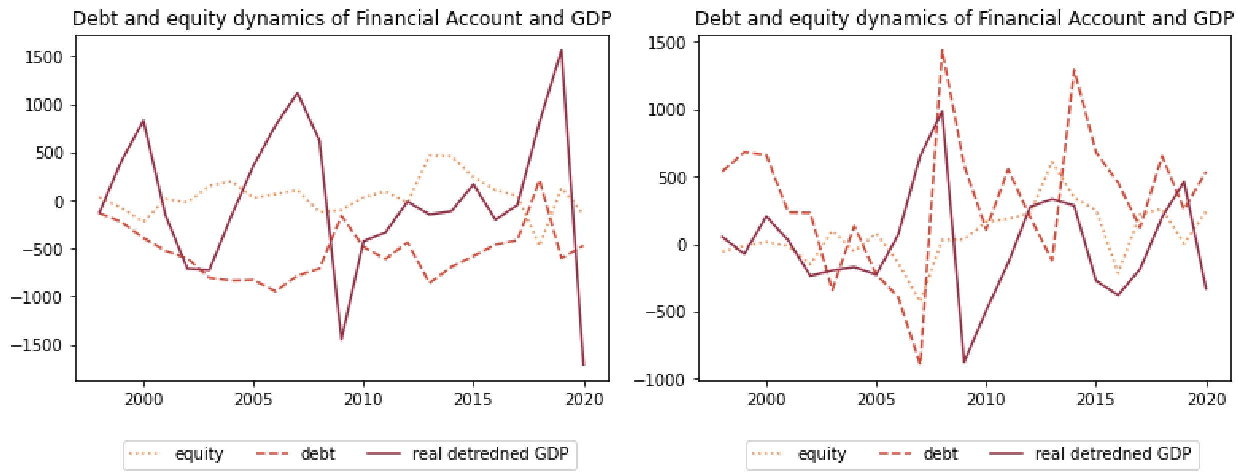
(a) **Russia** (b) **US**

Figure 10: Gini Coefficients and Liquid Positions. The left-hand side figure shows Gini coefficients for the US and Russia. Data is obtained from World Inequality Database. The right-hand side figure shows net liquid asset holdings as a percentage share of GDP for Russia and for the US. Net liquid holdings are calculated as a sum of Official Reserves (minus Gold), Portfolio Assets and Other Assets, minus Portfolio Debt and Other Liabilities. Data is obtained from Lane and Milesi-Ferretti (2017). X-axis shows time in years.



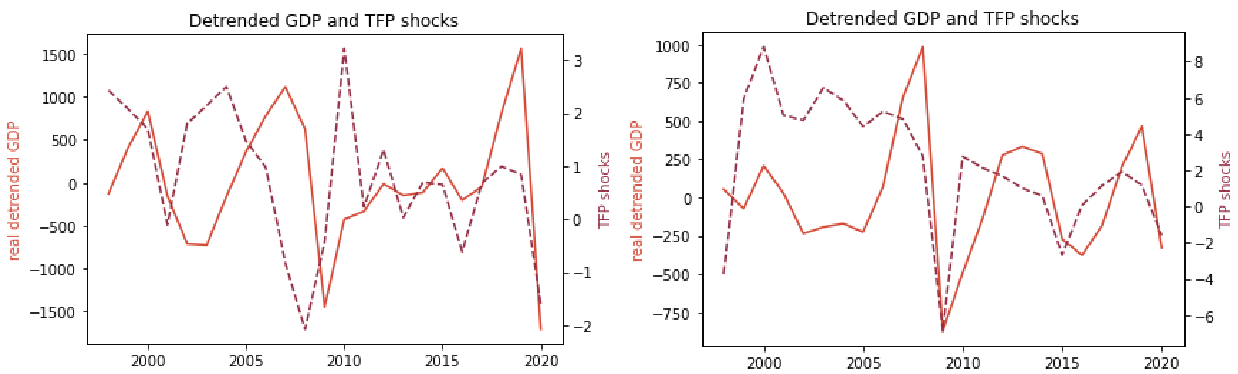
(a) **Developed countries** (b) **Emerging countries**

Figure 11: Household portfolios. The left-hand side graph shows household portfolios for the developed countries and the right-hand side shows portfolios of the emerging countries. Each asset is presented as a share from the total portfolio. X-axis shows countries. Data is taken from OECD and Russian Central Bank database. Portfolios are presented for the last available year (2021).



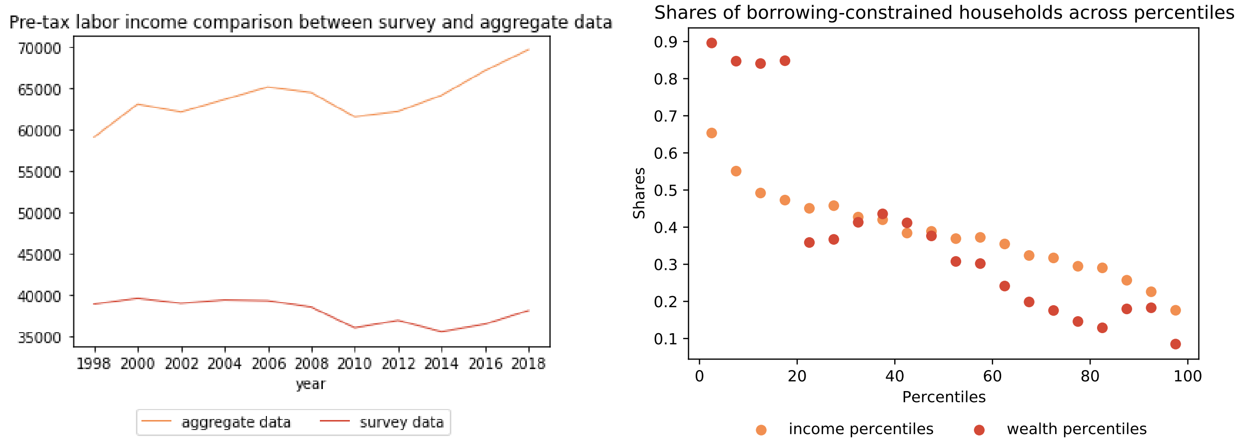
(a) **US** (b) **Russia**

Figure 12: Cyclicality of equity and debt. The left-hand side graph shows series for the US and the right-hand side graph shows time series for Russia. Equity and debt are aggregated across foreign direct investment, portfolio investment and other investment. HP filter was used to detrend GDP series. GDP deflator was used to convert nominal to real values. Series for the US are presented in billions of 2012 US dollars. Series for Russia are presented in billions of 2003 rubles. X-axis shows time in years. Data for equity and debt is taken from the IMF database (BPM6). GDP data is taken from Rosstat and FRED.



(a) **US** (b) **Russia**

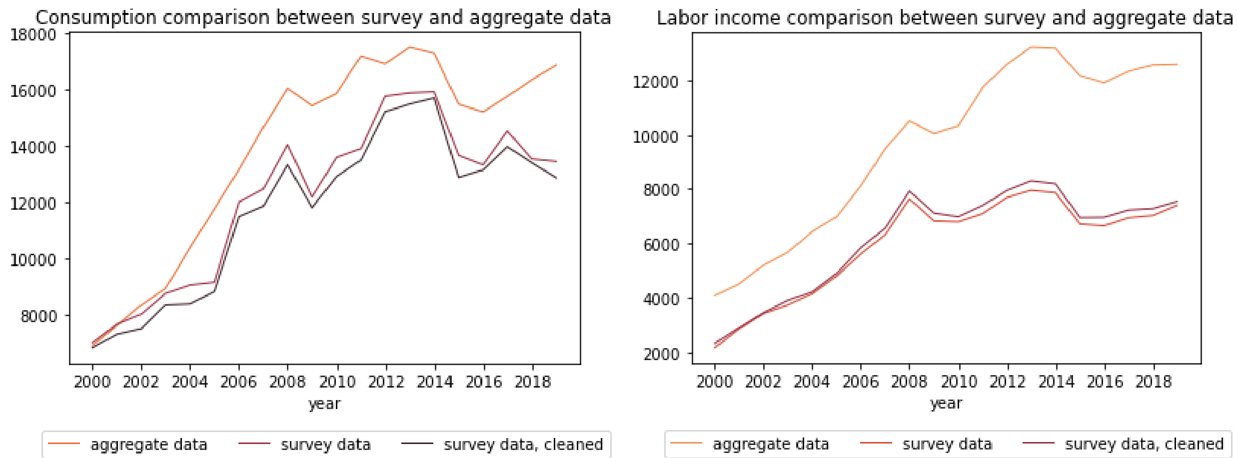
Figure 13: Detrended GDP vs. TFP series. The left-hand side graph shows series for the US and the right-hand side graph shows time series for Russia. HP filter was used to detrend GDP series. GDP deflator was used to convert nominal to real values. TFP series was taken from Penn World Table 10.0. Series for the US are presented in billions of 2012 US dollars. Series for Russia are presented in billions of 2003 rubles. X-axis shows time in years. GDP data is taken from Rosstat and FRED.



(a) Dynamics of labor income

(b) Shares of borrowing-constrained households

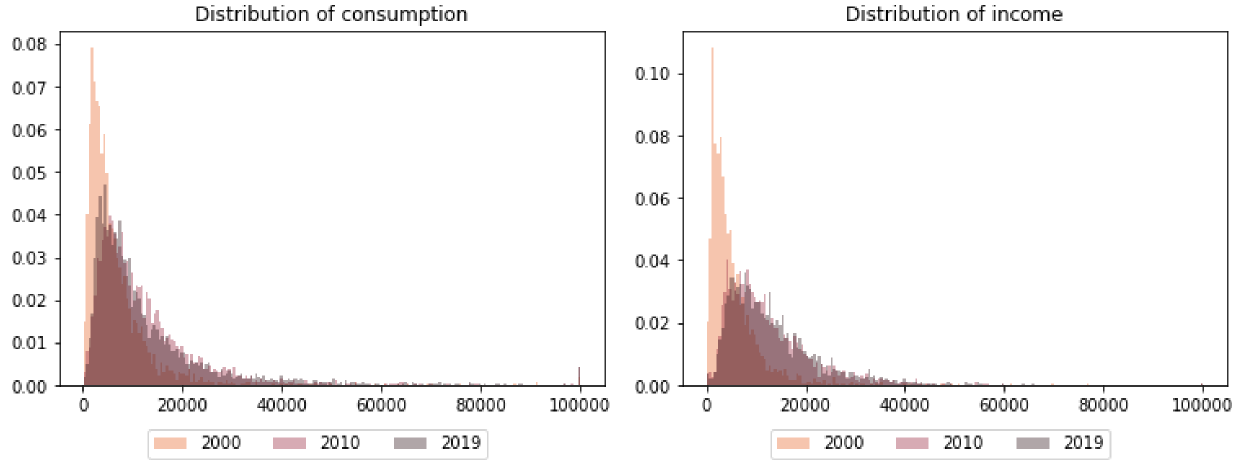
Figure 14: Labor Income and Share of Borrowing-constrained Households. The left-hand side figure shows a comparison between per household real labor income constructed from PSID and taken from NIPA. The right-hand side figure shows shares of borrowing-constrained households across income and wealth percentiles in the US averaged across 1998-2018 years.



(a) Consumption

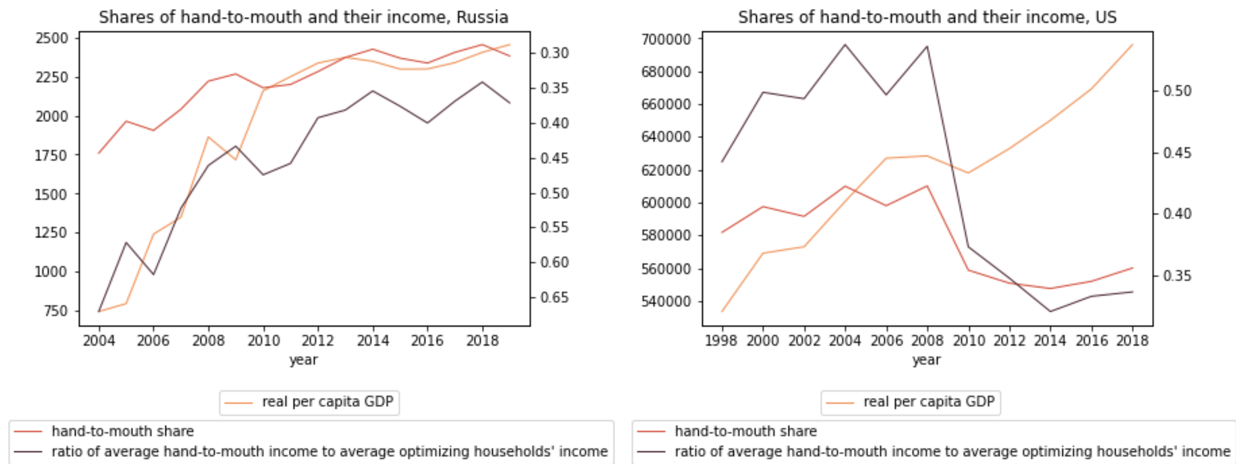
(b) Labor Income

Figure 15: Comparison Between Aggregate Statistics and Survey Data. The figures show consumption and labor income per household calculated from aggregate statistics (Rosstat) and from survey data (RLMS). All variables are real 2003 rubles and expressed in per month values. X-axis shows the time in years.



(a) **Consumption Histograms** (b) **Income Histograms**

Figure 16: Distributions of Consumption and Income, Russia. The figures show the consumption and income distributions for years 2000, 2010 and 2019. Peak at 100 000 for consumption represents the mass of all households that have consumption larger than 100 000, which was capped only for illustration purposes.



(a) **Russia** (b) **US**

Figure 17: Cyclicality of borrowing-constrained shares. The figures show shares of borrowing-constrained households (λ) and ratios of average income of borrowing-constrained households and optimizing households. GDP is presented on the left Y-axis. Shares are presented on the right and inversed Y-axis. Data for real per capita GDP was from Rosstat (Russia, 2003 rubles) and FRED (US, 2012 dollars). Shares were calculated using RLMS (Russia) and PSID (US) households' surveys. X-axis shows years.

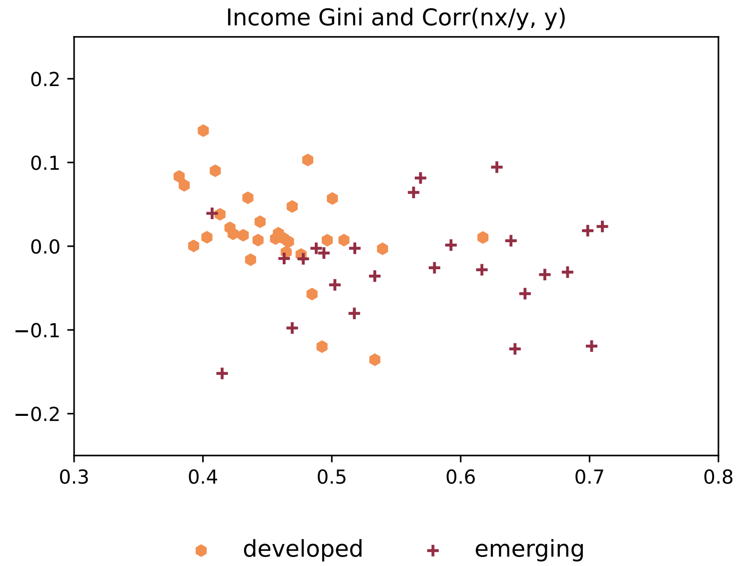


Figure 18: Income Inequality and Cyclicality of Net Export The figure shows income Gini coefficients (obtained from the World Inequality Database) and cyclicality of the net export (calculated based on the data from the IMF database, GDP was detrended using HP filter) for a sample of countries. For each country the inequality and cyclicality was obtained for the same periods of time, with the starting year not earlier than 1980 and ending year not later than 2020. The exact time span for each country depends on the data availability.

B.2. Estimation graphs

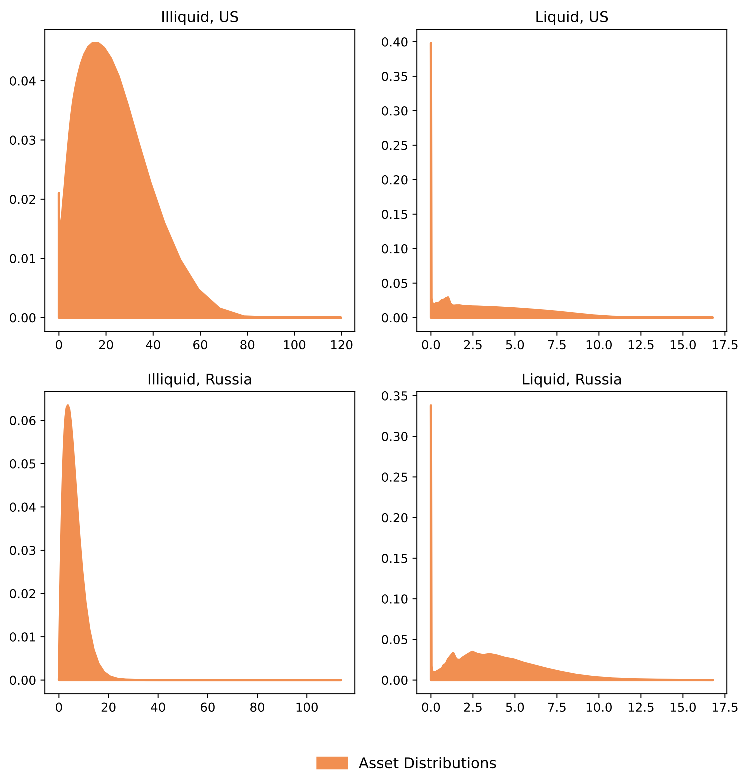


Figure 19: Distribution of Assets in the HANK models calibrated to the US and Russian Economies. The figure shows steady state liquid and illiquid distributions.

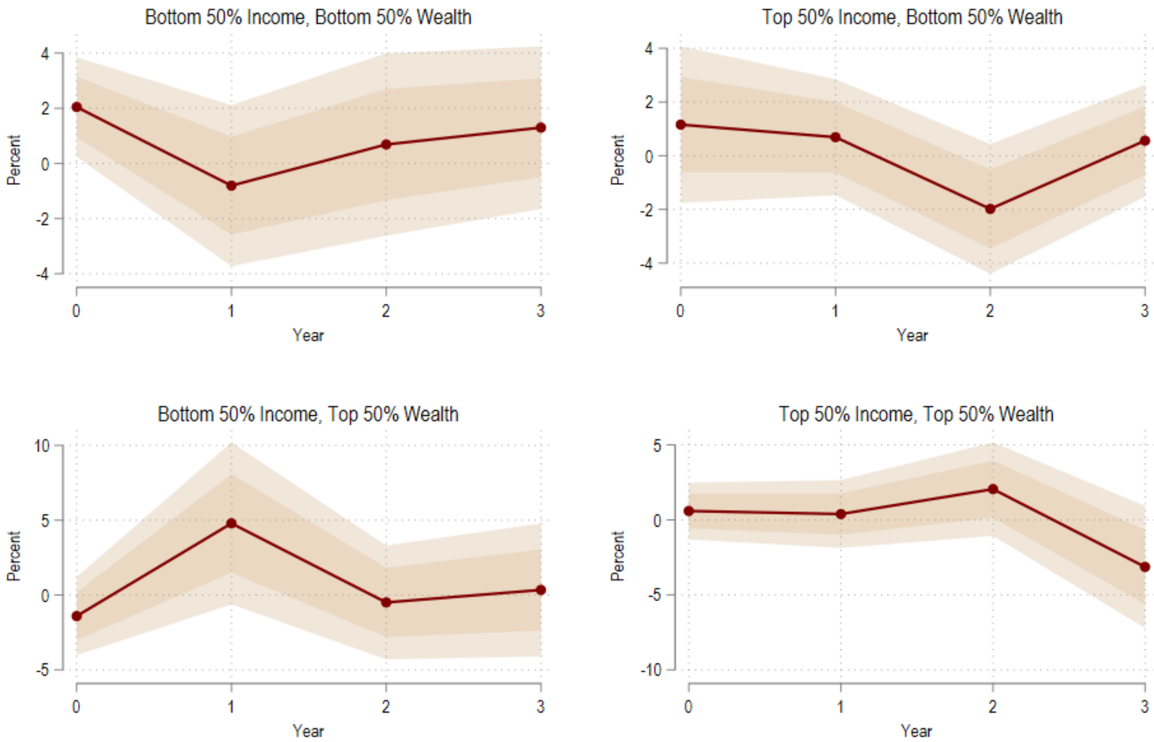


Figure 20: Empirical Impulse Responses of Liquid Assets to Income Shocks, US. The figures show impulse-responses for four groups of households (income poor/rich, wealth poor/rich). Red lines correspond to mean IRFs, inner shaded areas show one standard deviation around the mean responses, outer shaded areas show 90% confidence intervals. X-axis shows years. Liquid Assets are shown in log-differences.

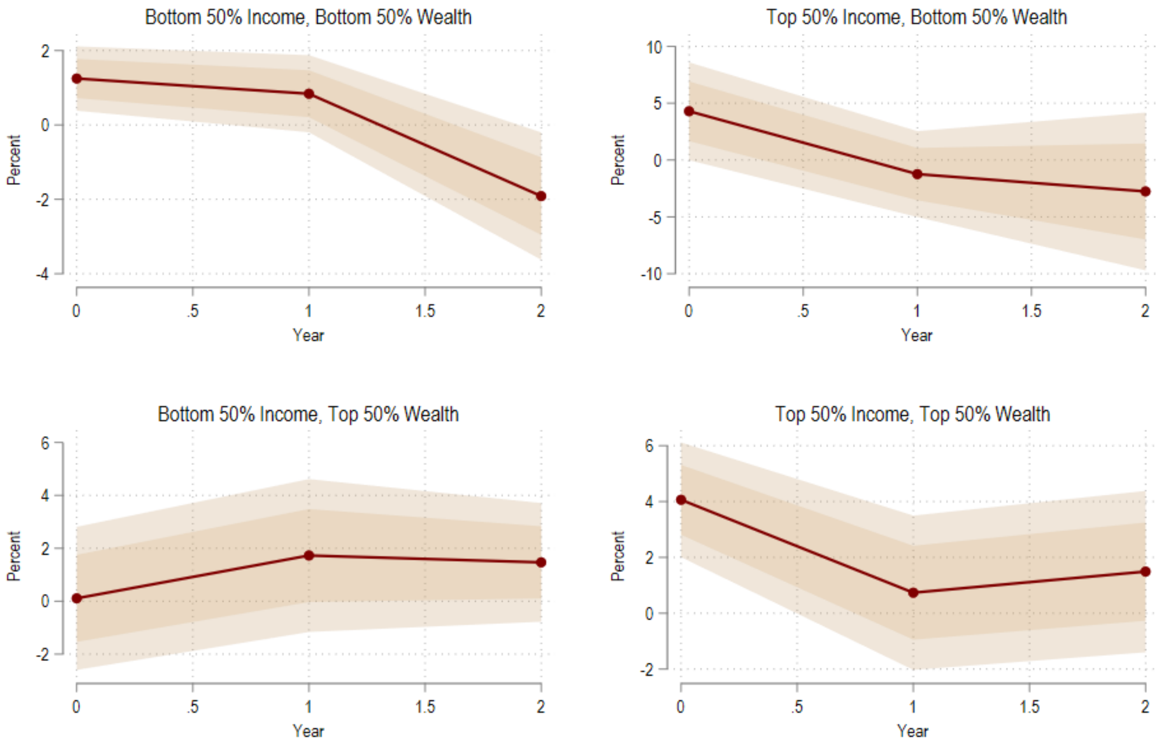


Figure 21: Empirical Impulse Responses of Illiquid Assets to Income Shocks, US. The figures show impulse-responses for four groups of households (income poor/rich, wealth poor/rich). Red lines correspond to mean IRFs, inner shaded areas show one standard deviation around the mean responses, outer shaded areas show 90% confidence intervals. X-axis shows years. Illiquid Assets are shown in log-differences.

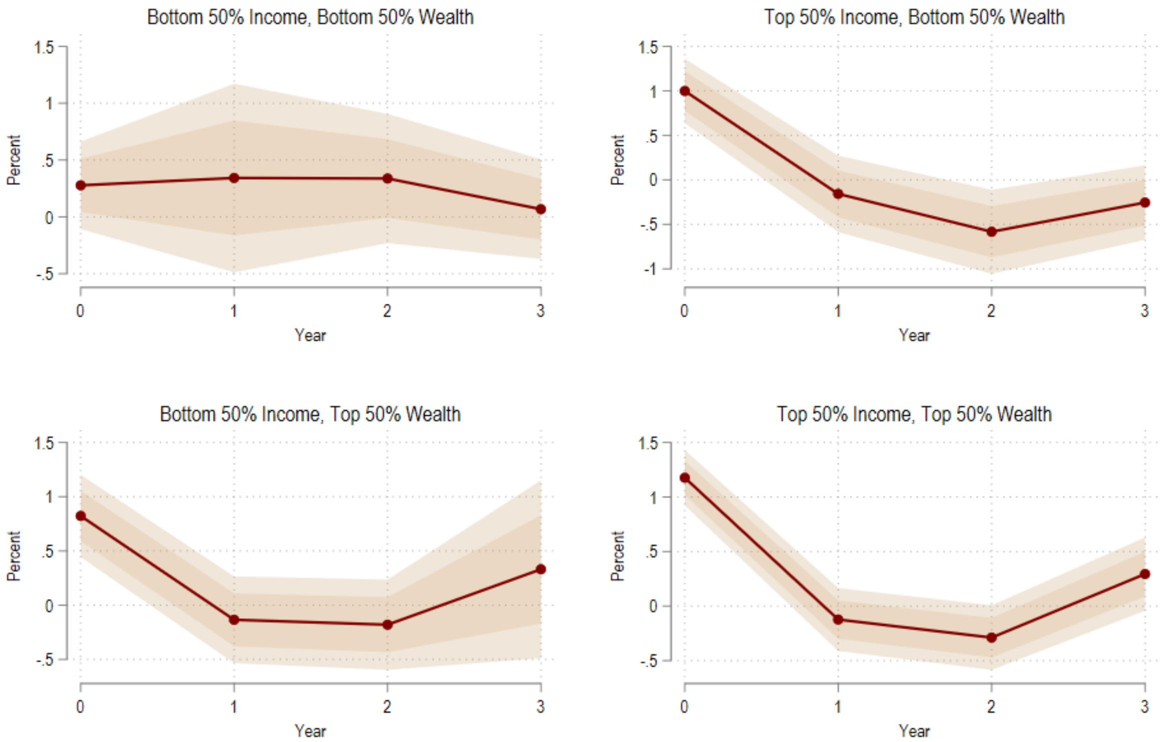


Figure 22: Empirical Impulse Responses of Consumption to Income Shocks, Russia. The figures show impulse-responses for four groups of households (income poor/rich, wealth poor/rich). Red lines correspond to mean IRFs, inner shaded areas show one standard deviation around the mean responses, outer shaded areas show 90% confidence intervals. X-axis shows years. Consumption is shown in log-differences.

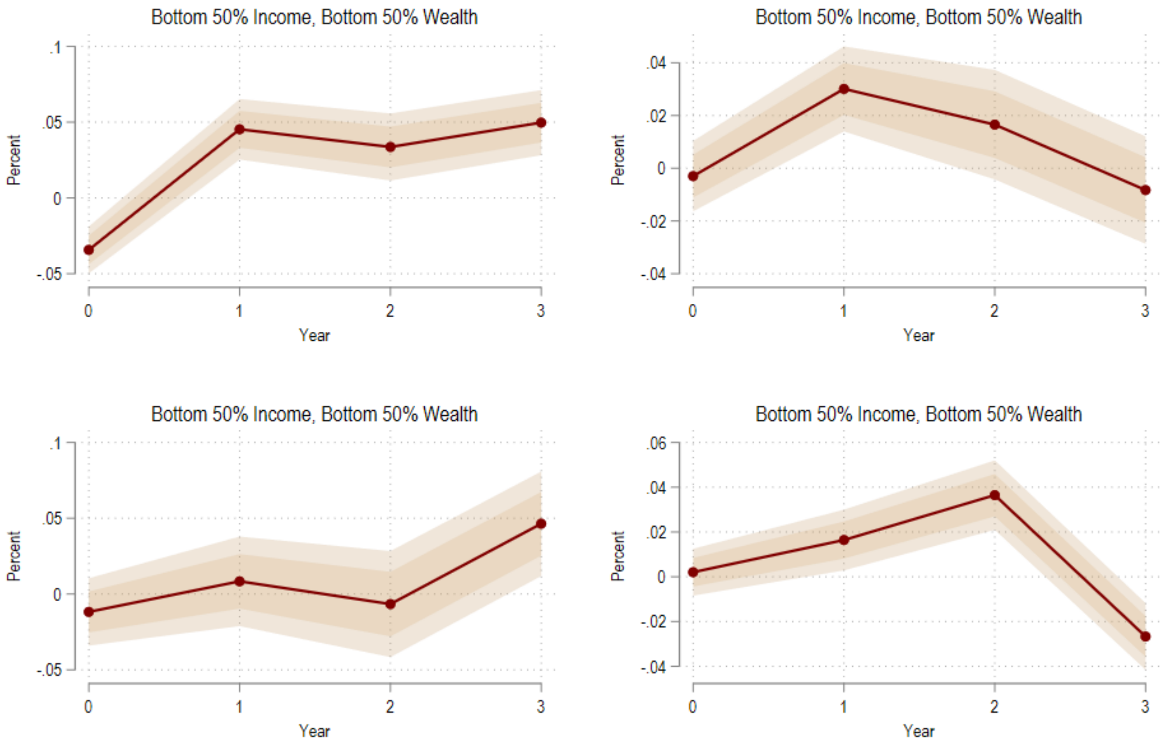


Figure 23: Empirical Impulse Responses of Income to TFP Shocks, US. The figures show impulse-responses for four groups of households (income poor/rich, wealth poor/rich). Red lines correspond to mean IRFs, inner shaded areas show one standard deviation around the mean responses, outer shaded areas show 90% confidence intervals. X-axis shows years. Income is shown in log-differences.

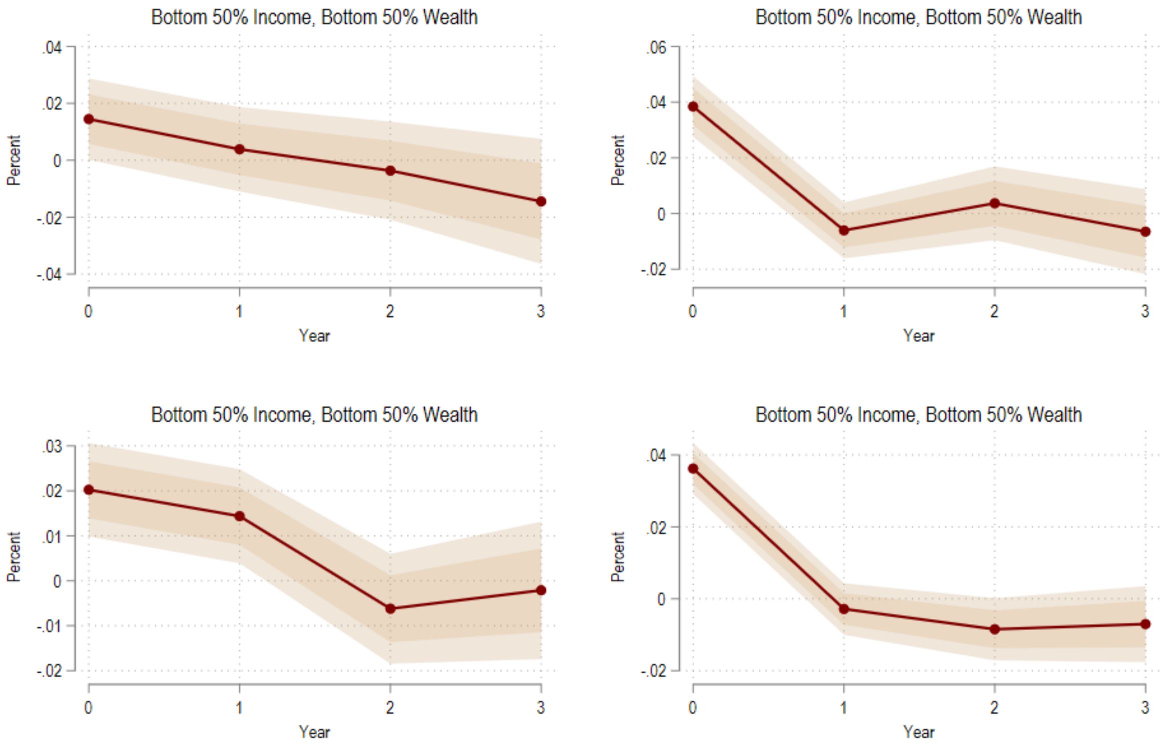


Figure 24: Empirical Impulse Responses of Income to TFP Shocks, Russia. The figures show impulse-responses for four groups of households (income poor/rich, wealth poor/rich). Red lines correspond to mean IRFs, inner shaded areas show one standard deviation around the mean responses, outer shaded areas show 90% confidence intervals. X-axis shows years. Income is shown in log-differences.

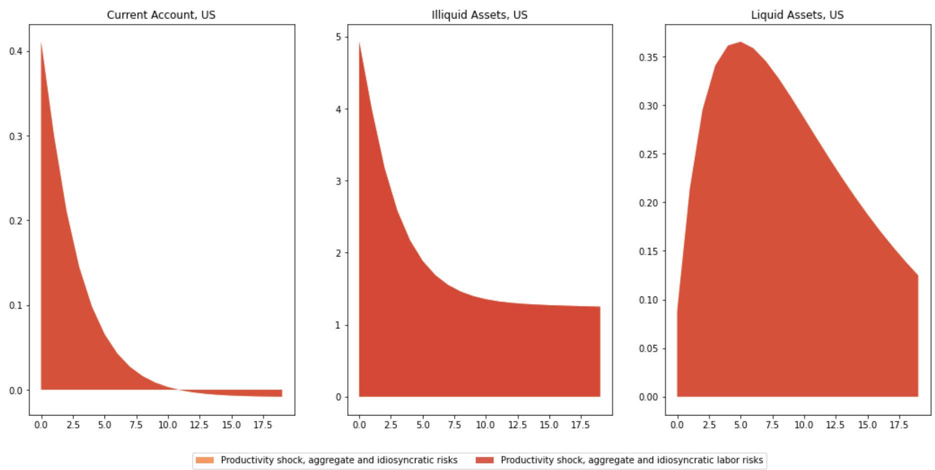


Figure 25: 1% TFP shock with 0.7 persistence. The figure shows a decomposition for a model with heterogeneous return risk calibrated to the values found in Xavier (2021). All variables are expressed in deviations from their steady state levels. X-axis shows time in quarters.

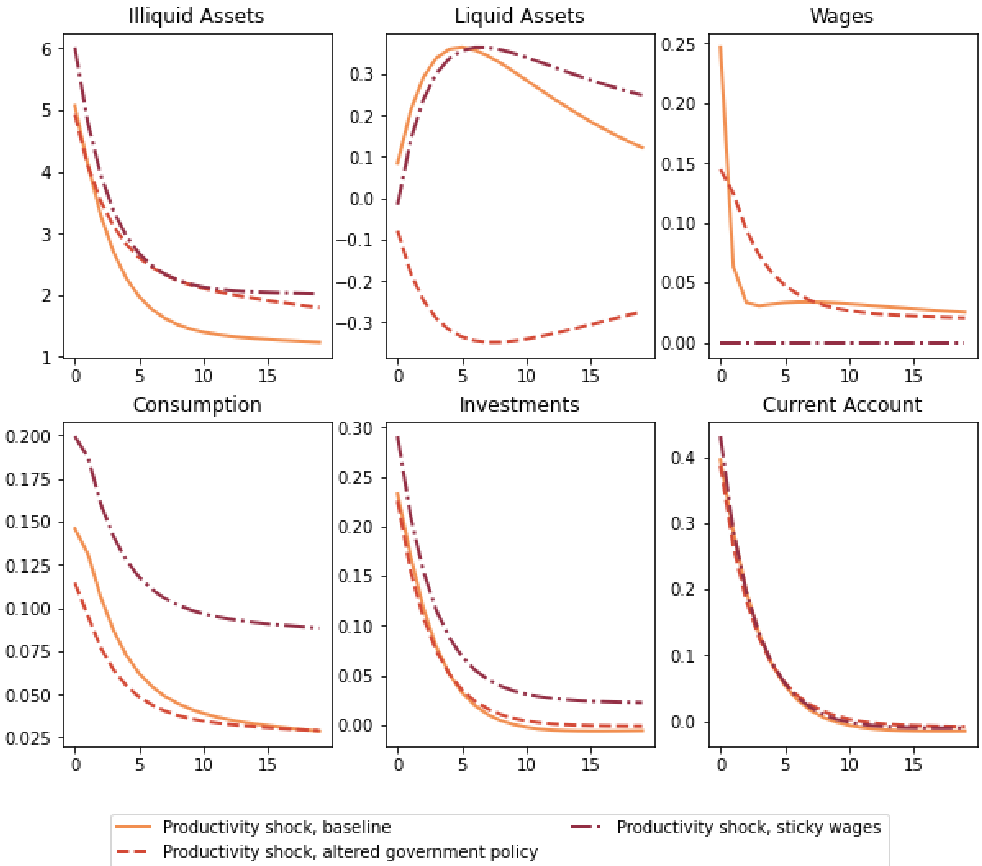


Figure 26: Impulse Responses to a TFP Shock with Different Distributions of the TFP Proceeds, US. The figure shows the percentage deviations of the specified series from the steady state in response to a TFP shock. The shock is a 1% increase in the total factor productivity; the shock follows an AR(1) process with the persistence parameter 0.7, such that the shock almost dissipates by the 13th quarter. The figure shows the impulse responses for the baseline model (solid orange lines), for the model with different government policy specification (dashed red lines) and for the model with flat wages (dash-dotted burgundy lines). X-axis shows time in quarters.

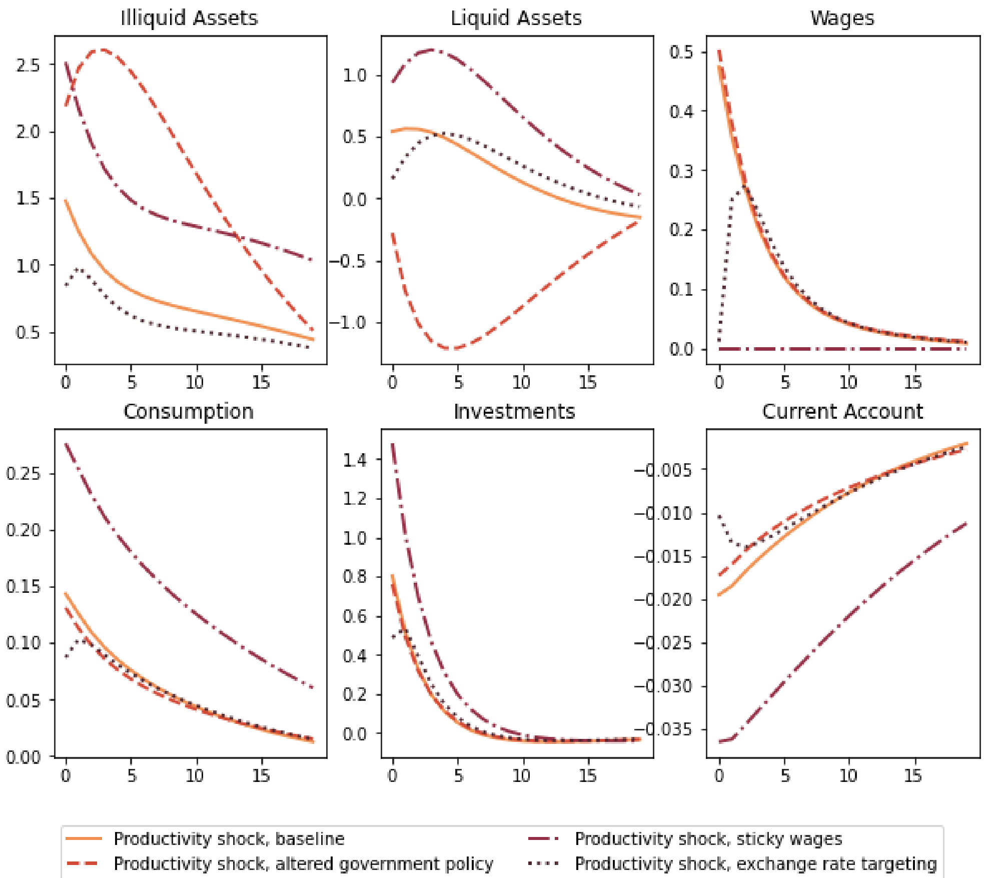


Figure 27: Impulse Responses to a TFP Shock with Different Distributions of the TFP Proceeds, Russia. The figure shows the percentage deviations of the specified series from the steady state in response to a TFP shock. The shock is a 1% increase in the total factor productivity; the shock follows an AR(1) process with the persistence parameter 0.7, such that the shock almost dissipates by the 13th quarter. The figure shows the impulse responses for the baseline model (solid orange lines), for the model with different government policy specification (dashed red lines), for the model with flat wages (dash-dotted burgundy lines) and for the model with monetary policy targeting nominal exchange rate (dotted black lines). X-axis shows time in quarters.

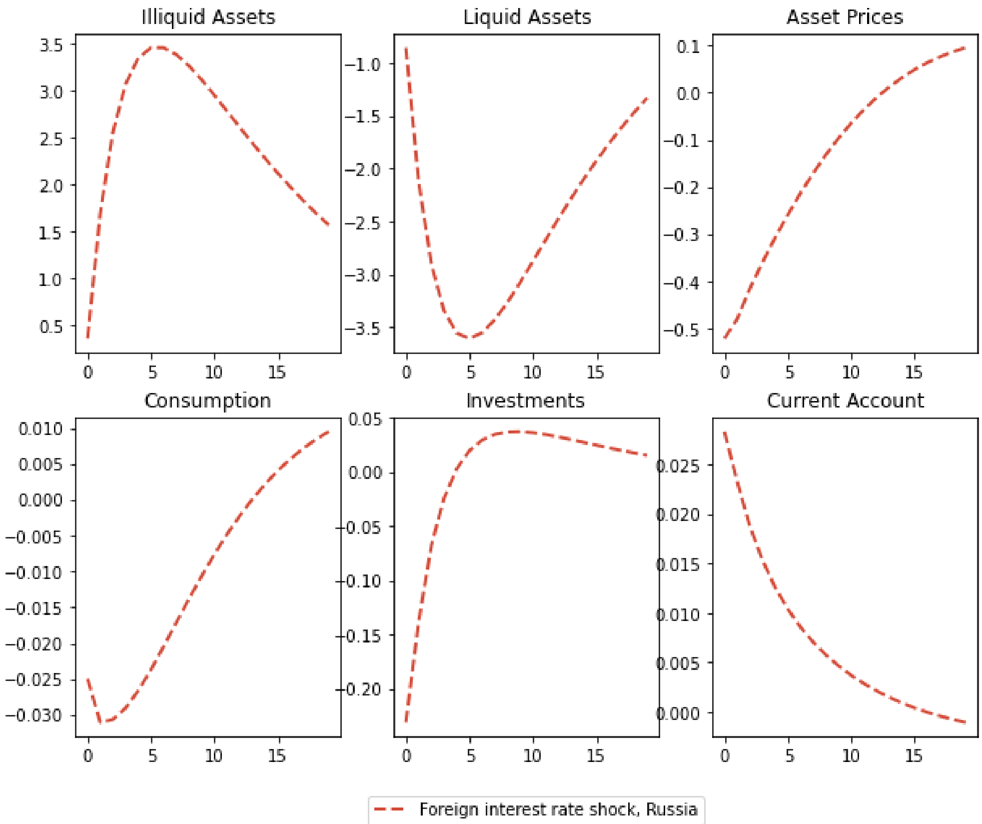


Figure 28: Impulse Responses to a Foreign Monetary Policy Shock, Russia. The figure shows the percentage deviations of the specified series from the steady state in response to a TFP shock. The shock is a 1% increase in the total factor productivity; the shock follows an AR(1) process with the persistence parameter 0.7, such that the shock almost dissipates by the 13th quarter. The figure shows the impulse responses for the model calibrated to Russian economy. X-axis shows time in quarters.

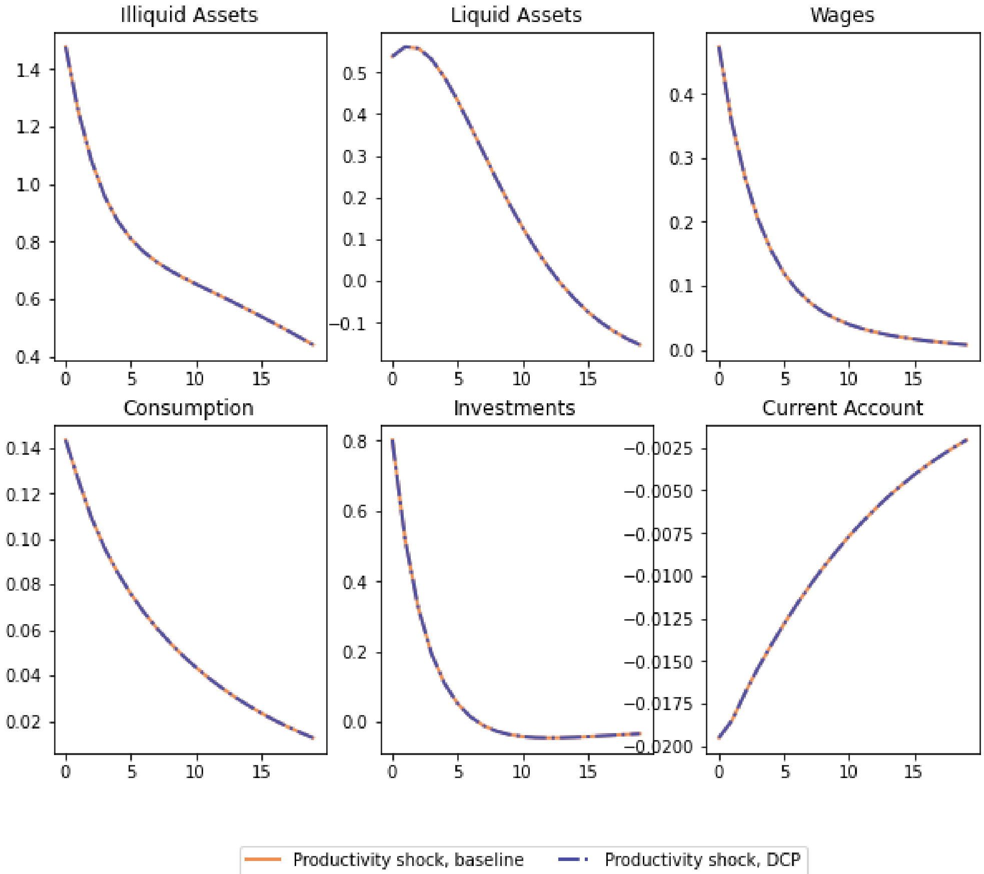


Figure 29: Impulse Responses to a TFP Shock with Different Currency Paradigms. The figure shows the percentage deviations of the specified series from the steady state in response to a TFP shock. The shock is a 1% increase in the total factor productivity; the shock follows an AR(1) process with the persistence parameter 0.7, such that the shock almost dissipates by the 13th quarter. The figure shows a comparison for model with Producer Currency Paradigm and Dollar Currency Paradigm for the model calibrated to Russia. X-axis shows time in quarters.

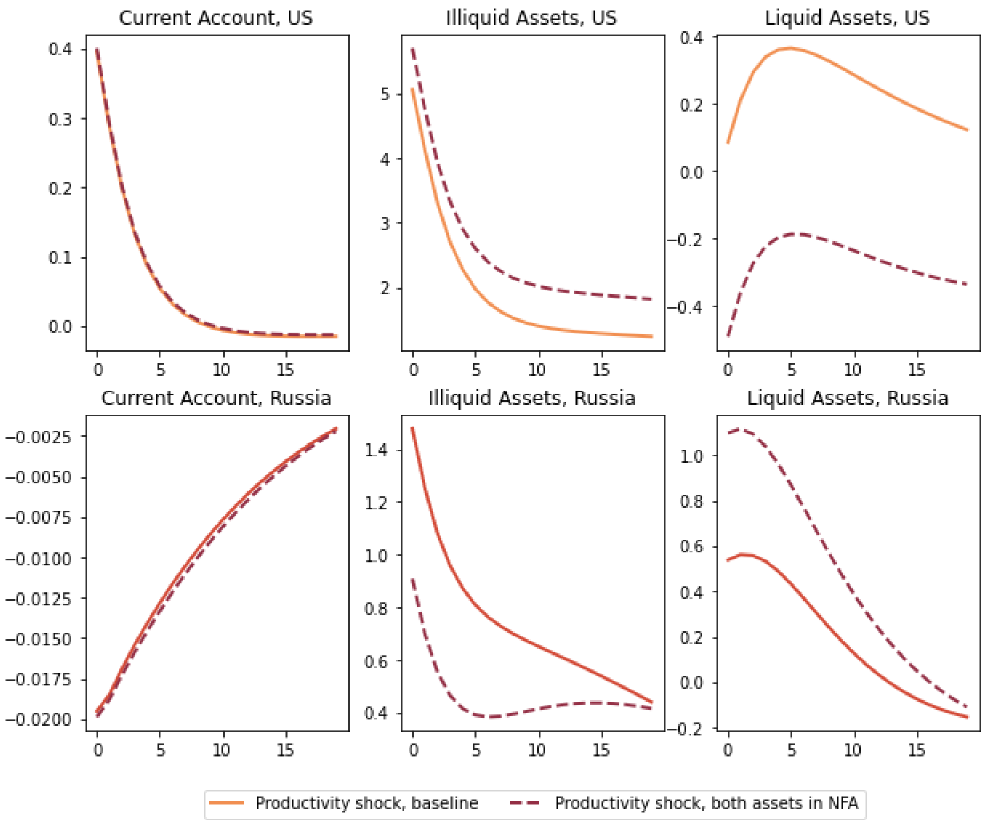


Figure 30: Impulse Responses to a TFP Shock with a Different Specification of Financial Intermediary. The figure shows the percentage deviations of the specified series from the steady state in response to a TFP shock. The shock is a 1% increase in the total factor productivity; the shock follows an AR(1) process with the persistence parameter 0.7, such that the shock almost dissipates by the 13th quarter. The figure shows the impulse responses for the model with illiquid bonds (solid lines) and for the models with liquid bonds (dashed lines). X-axis shows time in quarters.

C. Additional Tables

Table 11: Income distributions. The table shows empirical averaged across sample years income distributions for Russia and the US with income variable normalized to have the same sample mean.

	Russia	**US**
mean	0.63	0.63
std	0.52	0.59
skewness	3.1	10.0
kurtosis	22.2	279.6
1%	0.06	0.07
5%	0.13	0.13
10%	0.18	0.18
25%	0.29	0.30
50%	0.50	0.51
75%	0.80	0.80
90%	1.20	1.16
95%	1.53	1.47
99%	2.53	2.44

Table 12: Earning Process Estimation, Russia. The table shows estimation parameters for different specifications.

Parameter	**Target Only Variances,** $W = I$	**Target Variances,** $W = I$	**Target Std,** $W = I$	**Target Variances,** W **rescaled by means**	**Target Variances, two-step GMM**
Persistence	0.542	0.54	0.579	0.678	0.9
Standard deviation	2.14	2.15	2.09	1.78	2.0

D. Derivations of Current Account with Heterogeneous Households

In this section I derive current account expression that accounts for household heterogeneity. The main focus of these derivations is to understand how the presence of borrowing-constrained households affects foreign borrowing and lending. I follow Debortoli and Galí (2017) analytical framework where heterogeneity is captured by three variables, two of which are particularly important for the borrowing-constrained households. The framework is more flexible than TANK models as it also captures precautionary savings motives. Other analytical HANK models, being insightful in many dimensions, are less suitable for this paper as they either focus on precautionary savings like Acharya and Dogra (2020) or approximate models around zero liquidity steady state (see Bilbiie, 2021). The derivations are presented, firstly, for the two-period perfect foresight model to show insights in a simple framework. Then the model is extended to an infinite horizon economy. Furthermore, finally, I show how incorporating uncertainty affects the results.

D.1. Two-period model

The economy is populated by a set $\mathcal{U} \subset [0,1]$ of atomistic optimizing households. Each optimizing household i maximizes two-period CRRA utility function $U(c_1^i, c_2^i) = u(c_1^i) + \beta u(c_2^i)$ with $u(c) = \frac{c^{1-\sigma}}{1-\sigma}$ in a perfect foresight environment subject to individual budget constraint $c_1^i + \frac{c_2^i}{R} = y_1^i + \frac{y_2^i}{R}$, where R represents gross rate of return in the world capital market on date 1, which could not be affected by the small open economy. The solution to this problem is an individual Euler equation

$$(c_1^i)^{-\sigma} = \beta R (c_2^i)^{-\sigma} \tag{D.1}$$

Let $c_t^o \equiv \frac{1}{1-\lambda_t} \int_{s \in \mathcal{U}} c_t^i di$ denote average consumption of optimizing households which constitute share $1 - \lambda_t$ in the economy in period t. Borrowing-constrained households, accordingly, constitute share λ_t in the economy and consume their income $y_t^h = \gamma_t y_t^o$, which is related to the average income of the optimizing households $y_t^o = \frac{1}{1-\lambda_t} \int_{s \in \mathcal{U}} y_t^i di$ by the variable γ_t. In principal, borrowing-constrained households could be heterogeneous in income too. However, that will not affect the results for the current account.

Production function has a standard Cobb-Douglas form $Y_t = AK_t^\alpha$ where A denotes constant total factor productivity and α stands for the capital share in production. All households supply labor inelastically, and without loss of generality, the labor supply is normalized to 1. In the first period economy is endowed with capital stock K_0. Production in the second period depends on the (dis)investments in the first period I_1, and, for simplicity, capital has zero depreciation rate such that $K_1 = K_0 + I_1$. After production in the first period, the households eat all capital stock, thus $I_2 = -K_1$.

There is no government policy, therefore, aggregate resource constraint is

$$(1-\lambda_1)c_1^o + \lambda_1\gamma_1 y_1^o + I_1 + \frac{(1-\lambda_2)c_2^o + \lambda_2\gamma_2 y_2^o - (K_0+I_1)}{R} = AK_0^\alpha + \frac{A(K_0+I_1)^\alpha}{R} \tag{D.2}$$

where consumption of the borrowing-constrained households is substituted by their income and K_1 is substituted from the capital accumulation equation. Aggregating eq. (D.1) across optimizing households delivers

$$c_1^o = \frac{1}{1-\lambda_1}\int_{s\in\mathcal{U}} c_1^i di = \frac{1}{1-\lambda_1}\int_{s\in\mathcal{U}} (\beta R)^{-\frac{1}{\sigma}} c_2^i di = (\beta R)^{-\frac{1}{\sigma}} \frac{1-\lambda_2}{1-\lambda_1} c_2^o \tag{D.3}$$

which relates the average consumption of optimizing households across periods. Notice, that if $\beta = R$ in this setting aggregate consumption of optimizing households, i.e. $(1-\lambda_t)c_t^o$, is equalized across periods.

Let the investment decision be given to a representative firm that optimizes her discounted sum of profits and rebates them as dividends to households (the distribution of profits across households is governed by γ_t). Then her maximization problem is solved by equalizing the marginal return on capital to the net world interest rate.

$$\max_{I_1} d = AK_0^\alpha - I_1 + \frac{A(K_0+I_1)^\alpha}{R} + \frac{K_0+I_1}{R} \tag{D.4}$$

$$R - 1 = \alpha A(K_0+I_1)^{\alpha-1} \tag{D.5}$$

Substituting eq. (D.3) and eq. (D.5) into the eq. (D.2) the equation could be solved for aggregate consumption of optimizing households $(1-\lambda_1)c_1^o$

$$(1-\lambda_1)c_1^o = \frac{1}{1+\frac{(\beta R)^{\frac{1}{\sigma}}}{R}}\left[(Y_1^* - I_1^*)\left(1 - \frac{\lambda_1\gamma_1}{1-\lambda_1(1-\gamma_1)}\right) + \frac{1}{R}(Y_2^* + K_1^*)\left(1 - \frac{\lambda_2\gamma_2}{1-\lambda_2(1-\gamma_2)}\right)\right] \tag{D.6}$$

where for the sake of intuitive representation, optimal investments I_1^* are not substituted with their value from eq. (D.5) (the same applies to optimal outputs Y_1^* and Y_2^*).

Competitive equilibrium. From eq. (D.6) we infer that aggregate consumption of optimizing households depends on their lifetime income which is the total income available for consumption less the share that is consumed by the borrowing-constrained households (these households constitute share λ_t, γ_t governs the share of the their income out of total households' income).

The current account follows from the solution for optimal consumption.

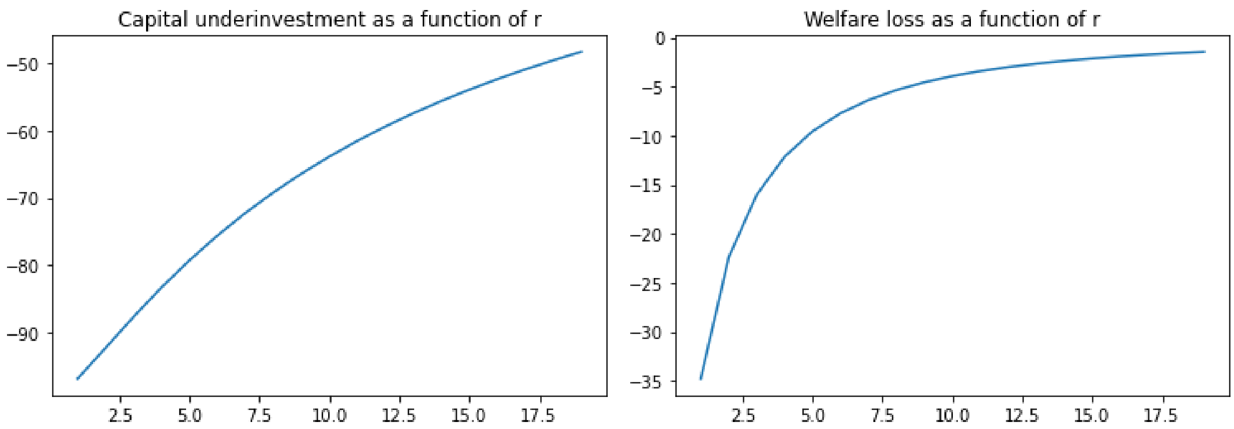
$$CA_1 = Y_1 - I_1 - (1-\lambda_1)c_1^o - \lambda_1 y_1^h =$$
$$= \frac{\tilde{\beta}}{1+\tilde{\beta}}\left(1 - \frac{\lambda_1\gamma_1}{1-\lambda_1(1-\gamma_1)}\right)(Y_1^* - I_1^*) - \frac{1}{1+\tilde{\beta}}\frac{1}{R}\left(1 - \frac{\lambda_2\gamma_2}{1-\lambda_2(1-\gamma_2)}\right)(Y_2^* + K_1^*) \tag{D.7}$$

where $\tilde{\beta} = \frac{(\beta R)^{\frac{1}{\sigma}}}{R}$. Equation (D.7) shows that the current account depends only on the income of optimizing households. In contrast, the income of borrowing-constrained households does not play any role in current account determination. There is a parallel of this result with the result that the production of non-tradable goods does not enter current account expression. The larger the share of borrowing-constrained households λ_t and the share of income that goes into their pockets γ_t, the less is the share of output that plays a role in the determination of between countries' capital flows. [25]

In this setting λ_t and γ_t are exogenous but in the quantitative model they evolve endogenously.

Household head for optimizing households. Suppose that investment decision is in the hands of optimizing agents. For them to make this decision, I have to impose a household head for optimizing households such that aggregate resource constraint becomes his budget constraint. The result is that this household head (who now chooses the level of consumption and investment as if he is a representative household but who realizes the presence of

25 $\frac{\partial CA_1}{\partial \lambda_1} = -\frac{\tilde{\beta}}{1+\tilde{\beta}}(Y^* - I^*)\frac{\gamma_1}{(1-\lambda_1(1-\gamma_1))^2}$ and $\frac{\partial CA_1}{\partial \gamma_1} = -\frac{\tilde{\beta}}{1+\tilde{\beta}}(Y^* - I^*)\frac{\lambda_1(1-\lambda_1)}{(1-\lambda_1(1-\gamma_1))^2}$



(a) Capital underinvestment in two-period model

(b) Welfare losses from underinvestment in two-period model

Figure 31: Capital Underinvestment and Welfare Losses. The left-hand side figure shows in percentage points how much less household head invests compared to the competitive equilibrium case ($\frac{K_1^{hh}-K_1^{CE}}{K_1^{CE}}$) as a function of interest rate. The right-hand side figure shows welfare losses calculated as percentage loss in per period consumption of optimizing households. The X-axis shows the interest rate in percentage points. Calibration: $\lambda_2 = 0.1$, $\gamma_2 = 0.8$, $\alpha = 0.33$, $Y_1 = 1$.

borrowing-constrained households) underinvests compared to the competitive equilibrium case. He anticipates that some of the next period's income will go to borrowing-constrained households. On the other hand, the cost of investment encounter only optimizing households. This reduces his incentives to invest, and he charges a premium on his investments. F.O.C. for investments transforms into

$$\alpha A(K_0 + I_1)^{\alpha-1} = \frac{R}{1 - \frac{\lambda_2\gamma_2}{1-\lambda_2(1-\gamma_2)}} - 1 \tag{D.8}$$

This underinvestment could be quite substantial (see fig. 31, for example, for the rate of return at 2.5% household head chooses the level of capital which is 90% less than the capital level in competitive equilibrium case). Welfare loss from this decision induces per period consumption which is 19% less than in the competitive equilibrium case. These results, however, are for the two-period model, thus, quantitative magnitudes should not be taken too seriously but should be instead considered indicative. This could also be a source of differential marginal products across countries.

D.2. Multi-period model with uncertainty

Moving away from perfect foresight two-period model to the infinite-horizon model with uncertainty delivers atomistic individuals' Euler equation that has an expectation in front of future consumption. That makes it impossible to obtain average optimizing agents' consumption in the same simple form as it was in a perfect foresight setting, but Debortoli and Galí (2017) setting allows to obtain average optimizing agents' consumption in a compact form (see eq. (D.10) in absolute and eq. (D.11) in log-linearized terms).

$$(c_t^i)^{-\sigma} = \beta E_t {c_{t+1}^i}^{-\sigma} R_{t+1} \tag{D.9}$$

$$(c_t^o)^{-\sigma} = \beta E_t (c_{t+1}^o)^{-\sigma} R_{t+1} \left(\frac{1 - E_t \lambda_{t+1}}{1 - \lambda_t} \right)^{-\sigma} E_t \theta_{t+1} \tag{D.10}$$

$$\hat{c}_t^o = E_t \hat{c}_{t+1}^o + \frac{\lambda}{1-\lambda} (\hat{\lambda}_t - E_t \hat{\lambda}_{t+1}) - \frac{1}{\sigma} E_t \hat{\theta}_{t+1} - \frac{1}{\sigma} E_t \hat{R}_{t+1} \tag{D.11}$$

where $E_t \theta_{t+1} = \frac{\left(\int c_t^i di\right)^{-\sigma}}{\int (c_t^i)^{-\sigma} di} \frac{E_t R_{t+1} \int (c_{t+1}^i)^{-\sigma} di}{E_t R_{t+1} \left(\frac{1 - E_t \lambda_{t+1}}{1 - \lambda_{t+1}} \int c_{t+1}^i di \right)^{-\sigma}}$ and captures dispersion of consumption among optimizing households and thus is a measure of precautionary savings.[26] The ˆ denotes log-deviations from the steady state.

The log-linearized aggregate consumption could be directly obtained from the aggregate consumption definition and using the distribution rule of income governed by γ.

$$\hat{c}_t = \frac{1-\lambda}{1-\lambda+\lambda\gamma} \hat{c}_t^o + \frac{\lambda\gamma}{1-\lambda+\lambda\gamma} \hat{no}_t + \frac{\lambda\gamma(1-\lambda)}{(1-\lambda+\lambda\gamma)^2} \hat{\gamma}_t - \frac{(1-\lambda)\lambda(1-\gamma)}{(1-\lambda+\lambda\gamma)^2} \hat{\lambda}_t \tag{D.12}$$

The aggregate resource constraint could be log-linearized following Campbell and Mankiw (1989) log-linearization technique, which delivers

$$\hat{ca}_t^* \equiv \hat{no}_t - \hat{c}_t = - \sum_{s=t}^{\infty} \left(\frac{1}{R} \right)^{s-t+1} (\Delta \hat{no}_{s+1} - \Delta \hat{c}_{s+1}) \tag{D.13}$$

where $NO_t = Y_t - I_t - G_t$. Plugging the log-linearization of aggregate consumption into

26 Definition of θ differs from Debortoli and Galí (2017) to separate λ from θ.

log-linearized resource constraint delivers current account expression for the infinite-horizon model with uncertainty.

$$
\begin{aligned}
\hat{ca}_t^* = & -\sum_{s=t}^{\infty}\left(\frac{1}{R}\right)^{s-t+1}(1-\frac{\lambda\gamma}{1-\lambda+\lambda\gamma})E_t\Delta\hat{no}_{s+1} + \frac{1-\lambda}{1-\lambda+\lambda\gamma}\frac{1}{\sigma}\sum_{s=t}^{\infty}\left(\frac{1}{R}\right)^{s-t+1}E_t\left(\hat{\theta}_{s+1}+\hat{R}_{s+1}\right) \\
& + \frac{\lambda\gamma}{(1-\lambda+\lambda\gamma)^2}\sum_{s=t}^{\infty}\left(\frac{1}{R}\right)^{s-t+1}E_t(\Delta\hat{\lambda}_{s+1}+(1-\lambda)\Delta\hat{\gamma}_{s+1}) \qquad \text{(D.14)}
\end{aligned}
$$

The first term is the same as in a representative agent framework, except only the share of income that goes to the optimizing agents should be taken into account (as in the previous models). The second term represents precautionary savings and responses to changes in the world interest rate. The larger the precautionary savings, the larger the current account. The last term shows how a decrease in the share of borrowing-constrained households $\Delta\hat{\lambda}_{s+1}$ or the share of income that borrowing-constrained households get $\Delta\hat{\gamma}_{s+1}$ additionally decrease current account. This can amplify or dampen current account responses: future expected increase/decrease in $\Delta\hat{\lambda}_{s+1}$ and $\Delta\hat{\gamma}_{s+1}$ increases/decreases today's current account.

D.3. Additional log-linearizations

Log-linearization of the aggregate consumption equation

Using market clearing conditions for goods and assets markets and aggregate resource constraint for households

$$NO_t = Y_t - G_t - I_t = C_t + NX_t = C_t + B_t - (1+r_t)B_{t-1} \qquad \text{(D.15)}$$

$$A_t = K_t + B_t \qquad \text{(D.16)}$$

$$C_t + A_t - A_{t-1} = (1-\lambda_t)y_t^o + \lambda_t y_t^h \qquad \text{(D.17)}$$

assuming no depreciation of capital the relation between net output and the income of borrowing-constrained households could be obtained

$$r_t B_{t-1} + NO_t + I_t = (1 - \lambda_t + \lambda_t \gamma_t) y_t^o = \frac{1}{\gamma_t}(1 - \lambda_t + \lambda_t \gamma_t) y_t^h \tag{D.18}$$

Steady state relation of consumption of optimizing households and aggregate consumption (using $NO = C$, given $CA = 0$ in the steady state) are

$$C = (1-\lambda)c^o + \lambda y^h = (1-\lambda)c^o + \frac{\lambda\gamma}{1-\lambda+\lambda\gamma}C \tag{D.19}$$

$$c^o = \frac{1}{1-\lambda+\lambda\gamma}C \tag{D.20}$$

Below all letters without time subscripts denote steady state values, and all letters with time subscripts denote deviations from the steady state.

$$\begin{aligned} &C(1+c_t) = (1-\lambda-\lambda\lambda_t)c^o(1+c_t^o) + \lambda(1+\lambda_t)y^h(1+y_t^h) = \\ &(1-\lambda-\lambda\lambda_t)c^o(1+c_t^o) + NO(1+no_t)\frac{\lambda\gamma}{1-\lambda+\lambda\gamma}(1+\frac{1}{1-\lambda+\lambda\gamma}(\lambda_t + (1-\lambda)\gamma_t)) \end{aligned} \tag{D.21}$$

Therefore,

$$c_t = \frac{1-\lambda}{1-\lambda+\lambda\gamma}c_t^o + \frac{\lambda\gamma}{1-\lambda+\lambda\gamma}no_t + \frac{\lambda\gamma(1-\lambda)}{(1-\lambda+\lambda\gamma)^2}\gamma_t - \frac{(1-\lambda)\lambda(1-\gamma)}{(1-\lambda+\lambda\gamma)^2}\lambda_t \tag{D.22}$$

Log-linearization of the aggregate resource constraint

Equation for log-linearization

$$\sum_{s=t}^{\infty}\left(\frac{1}{R}\right)^{s-t}C_s = RB_t + \sum_{s=t}^{\infty}\left(\frac{1}{R}\right)^{s-t}NO_s \tag{D.23}$$

Let $\Phi_s = \sum_{s=t}^{\infty}\left(\frac{1}{R}\right)^{s-t}C_s$, $B_s = RB_t$, $\Psi_s = \sum_{s=t}^{\infty}\left(\frac{1}{R}\right)^{s-t}NO_s$. Then equation $\Phi_s = B_s + \Psi_s$ could be rewritten in log-terms (without time subscripts are steady state values, small letters denote logarithms of variables)

$$\begin{aligned} ln(1-\frac{B_s}{\Phi_s}) = ln(1-\frac{B}{\Phi}) - \left(1-\frac{1}{1-\frac{B}{\Phi}}\right)ln(\frac{B}{\Phi}) + \left(1-\frac{1}{1-\frac{B}{\Phi}}\right)ln(\frac{B_s}{\Phi_s}) = \\ = k_o + (1-\frac{1}{\Omega_0})(b_s-\phi_s) = \psi_s - \phi_s \end{aligned} \tag{D.24}$$

Relation between Φ_s and C_s which is $\frac{\Phi_{s+1}}{\Phi_s} = (1-\frac{C_s}{\Phi_s})R$ could be also written is log-terms

$$\begin{aligned} \phi_{s+1} - \phi_s = r + ln(1-\frac{C}{\Phi}) - \left(1-\frac{1}{1-\frac{C}{\Phi}}\right)ln(\frac{C}{\Phi}) + \left(1-\frac{1}{1-\frac{C}{\Phi}}\right)ln(\frac{C_s}{\Phi_s}) = \\ = r + k_1 + (1-\frac{1}{\Omega_1})(c_s-\phi_s) \end{aligned} \tag{D.25}$$

Using

$$\phi_{s+1} - \phi_s = \Delta c_{s+1} + (c_s - \phi_s) - (c_{s+1} - \phi_{s+1}) \tag{D.26}$$

eq. (D.25) delivers

$$c_s - \phi_s = -\sum_{j=1}^{\infty}\Omega_1^j \Delta c_{s+j} + \sum_{j=1}^{\infty}\Omega_1^j (r + k_1) \tag{D.27}$$

Analogously

$$no_s - \psi_s = -\sum_{j=1}^{\infty}\Omega_2^j \Delta no_{s+j} + \sum_{j=1}^{\infty}\Omega_2^j (r + k_2) \tag{D.28}$$

Plugging eq. (D.27) and eq. (D.28) into eq. (D.24) and using $B = 0$ thus $\Omega_0 = 1$ and $\Omega_1 = 1 - \frac{C}{\Phi} = 1 - \frac{C}{C\frac{1}{1-\frac{1}{1+r}}} = \frac{1}{1+r} = \Omega_2$, and therefore $k_1 = k_2$ delivers

$$k_0 - no_s + c_s = \sum_{j=1}^{\infty} \left(\frac{1}{1+r} \right)^j (\Delta no_{s+j} - \Delta c_{s+j}) \tag{D.29}$$

in log-terms (subtracting logarithms of steady state values delivers an equation in log-deviations used in the main derivations).