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SONOMA:
a Small Open ecoNOmy for MAcrofinance

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Abstract

We develop a new small open economy model (SONOMA) in which domestic corporate debt and equities are affected by shocks to both external credit and equity markets. In a novel empirical analysis of several small-but-developed economies, we show that both external debt and equity shocks are important determinants of domestic economic fluctuations, corporate leverage, and net foreign asset positions. SONOMA replicates our empirical facts about asset prices, financial flows, and economic activity.

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Key Words: External Positions, Credit and Equity Shocks, Asset Pricing.
JEL classification: F3, F4, G15

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1 Introduction

Focusing on small-but-developed open economies, we ask the following question: how important are financial shocks to both internal and external equity and bond markets for the determination of domestic economic fluctuations and corporate financial dynamics? We address this question by developing a new macro-finance small open economy (SOE) model whose analysis requires the collection and investigation of new data. We find that shocks to the cost of external debt and equities explain a prominent share of the medium- and long-run variance of investment, consumption, net external debt and net external equities. In addition, adverse realizations of these shocks are followed by sluggish long-run growth. Domestic credit shocks are important as well, mainly for output growth, domestic leverage, and external debt.

Previous studies have focused on either large-and-developed countries or emerging economies and have reached quite different conclusions. Focusing on a large and developed country such as the U.S., the literature has found mixed results regarding the relevance of credit frictions (among others, Chari et al., 2007, and Jermann and Quadrini, 2012). However, there is consensus about borrowing shocks being a key determinant of economic fluctuations, financial flows (Coppola et al., 2021, Maggiori et al., 2020, Kalemli-Özcan and Varela, 2019), exchange rates (Itskhoki and Mukhin, 2021a, b), and sudden stops in emerging economies (see, e.g., Chari et al., 2005). In addition, the literature has often abstracted away from shocks to external equity markets. We propose a new perspective by (i) focusing on small-and-developed economies (as an exception, see Chodorow-Reich et al., 2019), and (ii) addressing the relevance of shocks to both external credit and equity markets.

We develop a new production-based equilibrium model, SONOMA, that can reproduce key properties of small-and-developed economies in terms of macroeconomic aggregates, external balances, and cost of capital. We start from a benchmark SOE model (see, among others, Mendoza, 1991, Schmitt-Grohé and Uribe, 2003, and Mendoza, 2006) and modify it in three dimensions. First, we introduce recursive preferences and productivity growth news shocks in the spirit of the long-run risk literature (among others, see Bansal and Yaron, 2004, Kaltenbrunner and Lochstoer, 2010 and Croce, 2014). Growth news shocks are important sources of macroeconomic fluctuations, risk premia and, more broadly, the cost of capital for private firms. Recursive preferences are important so that news shocks are directly priced by investors. We consider this step essential to properly address uncertainty about the long-term growth of economies in distress.

Second, we decompose net foreign asset positions into their debt and equity components. External debt is subject to exogenous external interest rate shocks. External equities are subject to two distinct types of shocks: risk premium and realized return shocks. This shock structure is consistent with our empirical evidence on the returns to external debt and equity positions. Furthermore, external equities and debt allow for different margins of adjustment in the domestic household's balance sheet. While analyzing the role of external shocks is standard in the SOE literature, the decomposition of net foreign assets into debt and equity components is a unique aspect of our model.

Third, we introduce financial frictions to create a dynamic trade-off between equity and debt financing for domestic firms. In our model, a corporate tax shield on the cost of debt makes debt-financing more appealing than equity. On the other hand, an enforcement constraint limits debt-financing exactly as in Jermann and Quadrini (2012). The tightness of this constraint fluctuates with exogenous shocks that we interpret as domestic credit shocks. Even though there is no default at the equilibrium, these shocks distort labor demand and disrupt production.

Our new insights are produced from the interplay of three elements: (i) persistent credit shocks are priced because of recursive preferences; (ii) domestic financial frictions make corporate leverage important for economic dynamics; and (iii) domestic financial flows interact with external shocks to the cost of equity and debt.

An analysis of our SONOMA model requires the collection and investigation of new data. We begin by taking seriously a subset of the restrictions imposed by our model. By doing so, we are able to measure both domestic and external borrowing conditions as well as shocks to the net external equity positions for a sizable cross section of countries. We find that adverse shocks to either external equities or external bonds are followed by lower expected productivity growth (negative growth news shocks). In addition, adverse shocks to the expected return of external equities are correlated with adverse domestic credit shocks. That is, when domestic credit conditions are tight, financing capital with equities becomes more costly as well.

We enrich our empirical investigation by studying the variance decomposition of several financial and macroeconomic variables of interest over long horizons. In the data, the cost of external debt and equities explain a prominent share of the medium- and long-run variance of investment, consumption, net external debt, and net external equities. Domestic credit shocks are important as well, mainly for output growth, domestic leverage, and net external debt.

In addition to fueling our empirical investigation, we rely on the same data and measurements to calibrate our model and show that SONOMA reproduces many empirical unconditional moments. The model inherits the success of a standard macroeconomic model in replicating the fluctuations of macroeconomic aggregates. At the equilibrium, the annualized equity premium is almost 6%, despite the ability of agents to hedge shocks through labor, domestic investment, and external debt and equity positions. Our model replicates the dynamics of corporate leverage and, most importantly, those of both the net foreign asset positions and its subcomponents. Both net external debt positions and net external equity positions are countercyclical, as in the data. In addition, the contemporaneous correlation of these components is moderate. This implies that external debt and equity positions provide distinct hedging benefits.

SONOMA is also able to replicate conditional responses documented in the data. The model reproduces key patterns of the impulse responses of both domestic and external financial aggregates with respect to shocks to external debt and equity positions. Furthermore, in the model as in the data, adverse shocks to external equity and debt markets are as disruptive as adverse productivity shocks. We find similar successes in terms of variance decompositions. The main departure between model and data concerns the variance of the investment-output ratio. In the data, this variance is mainly driven by external financial shocks, whereas in the model productivity shocks are just as important.

We complete our analysis by inspecting the mechanism, i.e., by removing features from our model one at a time. When we compare our open economy to an otherwise equivalent closed one, we find two important results. First, domestic credit shocks are less disruptive in an open economy than in a closed economy because the household can finance from abroad in order to recapitalize the domestic firm. Second, shocks to external financing conditions can have a first-order impact on economic activity and they are priced, i.e., they are relevant for the determination of the equity risk premium. We also compare our results with and without financial frictions and financial shocks. We find that both dimensions are essential for SONOMA to replicate the data.

Related literature. In this paper, we relate to both the macroeconomics and finance literatures. The literature on SOEs (see, among many others, Mendoza, 1991; Schmitt-Grohé and Uribe, 2003; and Mendoza, 2006) focuses mostly on developing or emerging markets and it devotes a lot of attention to sudden stops or exchange rate regimes (among many others, see Mendoza and Smith, 2006; Chari et al., 2005; Aghion et al., 2001; and Mendoza and Uribe, 2000). Other studies focus on sovereign default (see, for example, Uribe and Yue, 2006; Aguiar and Gopinath, 2007; and Arellano, 2008). In this study, we focus on smaller-but-developed countries. While they still qualify as SOEs, they typically do not face the same type of currency problems that emerging markets face. In addition, we view the countries in our sample as being subject to frequent regular financing shocks instead of being subject to sudden stops or occasionally binding constraints.

Recently, there has been more attention to production-based asset pricing in SOEs. For example, Jahan-Parvar et al. (2013) is a SOE production-based asset pricing model featuring Greenwood et al. (1988) preferences, which builds on earlier production-based studies such as Jermann (1998) and Boldrin et al. (2001). We differ from these studies for our adoption of Epstein and Zin (1989) preferences and growth news shocks as in Bansal and Yaron (2004) (see also Bansal et al., 2007; Bansal et al., 2012, 2016; and Schorfheide et al., 2018). In one of our model extensions, we consider also downside risk, i.e., adverse co-skewness across financial shocks and growth news shocks. In this sense, we related to the disaster risk literature (Rietz, 1988; Barro, 2006; Gabaix, 2012; Barro and Jin, 2011; Nakamura et al., 2013; Gourio, 2012; and Wachter, 2013).

Colacito et al. (2018) explore long-run productivity risks in a general equilibrium production-based international setting. Our study differs from this work in two dimensions: (i) we propose a flexible and tractable partial equilibrium approach; and (ii) we study the interplay of corporate capital structure adjustments, labor and investment distortions, and external balances.

Our study is closely tied to the growing literature on financially constrained firms and the implications of credit shocks in a dynamic stochastic general equilibrium macroeconomic framework (see, for example, Gertler and Karadi, 2011; Khan and Thomas, 2013; Guerrieri and Lorenzoni, 2017; and Guerrieri and Iacoviello, 2017). In contrast to our setting, these models feature closed economies. As stated earlier, our work is closely related to Jermann and Quadrini (2012). Similarly to us, Mendoza (2010) uses a working capital constraint with two important differences: (i) there is an occasionally binding constraint in order to produce sudden stops; and (ii) imports are included in working capital. In our economy, the constraint is always binding and subject to small-and-persistent fluctuations.

Coeurdacier et al. (2015) considers financial frictions in a SOE to assess three prominent global trends: a divergence in private saving rates between advanced and emerging economies, large net capital outflows from the latter, and a sustained decline in the world interest rate. We focus on smaller developed countries in which (i) sources of long-run growth risk are directly priced, and (ii) the interplay of corporate financing decisions and external balances has a first-order impact on macro aggregates.

In contrast to the literature that considers frictionless environments (see, among others, Gourio et al., 2013; and Stathopoulos, 2016), we pay more attention to the relevance of financing frictions, financial flows and cycles, and country risks (see, for example, Atkeson et al., 2022; Borri and Verdelhan, 2012; Hassan et al., 2021; Miranda-Agrippino and Rey, 2020; Avdjiev et al., forthcoming; and di Giovanni et al., 2021). For a broader review of the international literature with financial frictions and segmentation see Maggiori (2022).

The remainder of this manuscript is organized as follows. We detail our model in section 2. We describe our empirical investigation in 3. In section 4, we discuss our calibration and main results. Section 5 concludes.

2 The Economy

In the introduction, we describe SONOMA as a benchmark small open economy model modified in three dimensions. Alternatively, we can describe SONOMA as an augmented open economy version of Jermann and Quadrini (2012) (henceforth, JQ). The original JQ model is not intended for production-based asset pricing hence we modify it to price both risky and risk-free assets in a SOE environment. To this end, we first embed recursive preferences (Kreps and Porteus 1978; Epstein and Zin 1989) and long-run risks (Bansal and Yaron 2004) in the JQ model. We then open the economy and expose it to exogenous financing shocks.

As in the JQ economy, firms need to decide the optimal mix of equity- and corporate debt-financing. Firms issue debt because of the existence of a tax shield on corporate interest payments. A borrowing constraint limits the amount of corporate debt and introduces a wedge in the labor market. Our economy differs from JQ's along two important dimensions. First, households can borrow from or lend to the rest of the world. Second, households can go long or short in foreign equities.

The model features six sources of risk. Similar to traditional real business cycle models, there are shocks to the level of the productivity growth rate. We follow Croce (2014) and introduce long-run productivity growth risk. As in JQ, there are domestic credit condition shocks, i.e., shocks to the firm's borrowing collateral constraint. We also consider a shock to external credit conditions, i.e., a shock to the cost of borrowing from abroad (see, among others, Jahan-Parvar et al. 2013; Aguiar and Gopinath 2007; and Uribe and Yue 2006). Importantly, our agent faces also shocks to external equity returns. We consider shocks to both the unexpected component of the returns and to their expected value (Sharpe ratio shocks). To the best of our knowledge, this is the first study that explores all of these financing margins simultaneously. One of our goals is to explore the relevance of these shocks for the dynamics of the components of net foreign assets (NFA).

2.1 Households' Problem

Preferences. There is a continuum of homogeneous households endowed with Kreps and Porteus (1978) recursive preferences as specified in Epstein and Zin (1989):

$$U_t = \left[(1-\beta)\widetilde{C}(C_t,\ell_t)^{1-\frac{1}{\psi}} + \beta(\mathbb{E}_t U_{t+1}^{1-\gamma})^{\frac{1-\frac{1}{\psi}}{1-\gamma}}\right]^{\frac{1}{1-\frac{1}{\psi}}}, \tag{1}$$

where $\widetilde{C}(C_t,\ell_t)$ is a consumption bundle defined over consumption (C_t) and leisure (ℓ_t), γ is a determinant of the coefficient of relative risk aversion, and ψ drives the elasticity of intertemporal substitution (IES). We define leisure as the portion of time not worked $\ell_t \leq 1 - H_t^s$, where H_t^s is the household supply of labor. We define the consumption bundle as

$$\widetilde{C}_t = \left(\varphi C_t^{1-\frac{1}{f}} + (1-\varphi)\left(SL_t\ell_t\right)^{1-\frac{1}{f}}\right)^{\frac{1}{1-\frac{1}{f}}}.$$

We set the weight φ so that steady state labor supply is equal to 0.3. To ensure balanced growth with these preferences, we introduce an exogenous preference shock process, SL_t, cointegrated with measured productivity, A_t. Specifically, we define $e^{sla_t} := \frac{SL_t}{A_t}$ and assume that:

$$sla_t = (1-\theta)(sla_{t-1} - (\Delta \ln A_t - \mu)).$$

We set θ to a moderate value so that SL_t mimics an exogenous linear trend. The parameter μ determines the average growth of the economy.

The stochastic discount factor (SDF) of the household is

$$M_{t+1} = \beta \left(\frac{\widetilde{C}_{t+1}}{\widetilde{C}_t} \right)^{-\frac{1}{\psi}} \left(\frac{U_{t+1}}{E_t \left[U_{t+1}^{1-\gamma} \right]^{\frac{1}{1-\gamma}}} \right)^{\frac{1}{\psi}-\gamma} \frac{\partial \widetilde{C}_{t+1} / \partial C_{t+1}}{\partial \widetilde{C}_t / \partial C_t}. \tag{2}$$

Since the consumption bundle is a composite of both leisure and consumption, the last term in equation (2) reflects marginal variations due to the consumption good. The second term captures aversion to long-run risks.

Budget constraint. The household maximizes lifetime utility by choosing the levels of consumption and leisure and a portfolio of financial assets, subject to the following constraints:

$$\begin{aligned} C_t &\leq \overbrace{w_t H_t + (S_t - S_{t+1}) V_t^{ex} + S_t \cdot d_t + (1 + r_t) D_t - D_{t+1} - T_t^H}^{\text{Domestic variables}} \\ &\quad \underbrace{+ \left(NED_{t+1} - \left(1 + r_t^{ED} \right) NED_t \right) - \left(NEE_{t+1} - (1 + r_t^{EE}) NEE_t \right)}_{-\Delta \text{Net Foreign Assets}} \\ 1 &\geq H_t^s + \ell_t \end{aligned}$$

where w_t represents wages earned; S_t (D_t) measures domestic equities (corporate bonds) owned by the household at the beginning of the period (predetermined variables); V_t^{ex} is the ex-dividend share price; d_t and r_t, are net equity payout and domestic corporate bond interest rate, respectively. The government rebates corporate taxes, T_t^H, to the households. Given this notation, the net domestic corporate debt payout (NDP) is $NDP_t = (1 + r_t) D_t - D_{t+1}$.

Net foreign assets. Turning our attention to the international side of the budget constraint, NED_t and NEE_t are net external debt owed and net external equity held by the household at time t, respectively. We define net foreign assets (NFA_t) in the economy as:

$$NFA_t = NEE_t - NED_t.$$

Let r_t^{ED} be the interest rate paid to external, i.e., foreign lenders. Since our model does not admit sovereign default, we will have $r_t = r_t^{ED}$ at equilibrium. The return on the household's net external equity position is denoted by r_t^{EE}, and the changes in net foreign assets (ΔNFA) are:

$$\Delta NFA_{t+1} = \big(NEE_{t+1} - (1 + r_t^{EE})NEE_t\big) - (NED_{t+1} - \big(1 + r_t^{ED}\big)\, NED_t).$$

In this model, only households can borrow from abroad (lend to the rest of the world) by increasing (decreasing) their foreign debt position. Similarly, households can adjust their net external equity position. Proceeds from these activities can then be used for domestic investment. This assumption is not crucial, but it is useful when comparing our open economy model with its closed-economy counterpart as the domestic asset holdings are concentrated in the domestic households' portfolios in both configurations.

Cost of external financing. Following Schmitt-Grohé and Uribe (2003), Jahan-Parvar et al. (2013), and numerous other studies in international finance, we posit that the interest paid to external lenders, r_t^{ED}, is a function of the predetermined world financing rate, r_{t-1}^{w}, and a predetermined country-specific spread, P_t^{ED}. The country spread increases when the external debt position of the country goes above its steady-state value, $\overline{NEDY}$:

$$\begin{aligned} r_t^{ED} &= r_{t-1}^{w} + P_t^{ED} && (3) \\ P_t^{ED} &= p_{ED,2} e^{p_{ED,1}\left(NED_t/Y_t - \overline{NEDY}\right)}. && (4) \end{aligned}$$

Neumeyer and Perri (2005) argue that country spreads have both endogenous and exogenous components. In this study, the spread (P^{ED}) is defined to be endogenous, but exogenous random factors can affect the external interest rate (r_t^{w}) as follows:

$$r_t^w = (1 - \rho_{rw})\,\mu_{rw} + \rho_{rw} r_{t-1}^w + \sigma_{rw}\epsilon_{rw,t}. \tag{5}$$

These shocks must be interpreted broadly, as they capture both changes in the world risk-free rate and changes in the sentiment of external lenders toward a specific SOE. Hence we refer to them as external credit condition shocks.

The returns on the net external equity position require more attention, as they represent a new dimension in our study. Since this position equals the difference between global equities held by the country i's residents and country i's equities held by the rest of the world, the returns of the NEE portfolio are identical to those of an investment strategy long in global equities and short in domestic equities (for a detailed discussion, see Section 3.1). We model the log returns on the NEE portfolio, $\log R^{EE}$, as having three components:

$$\log R_t^{EE} = \eta_{t-1} + P_t^{EE} + \sigma_{ee} \cdot \epsilon_{ee,t} \tag{6}$$

$$P_t^{EE} = p_{EE} \cdot \left(\overline{NEEY} - NEE_t/Y_t\right), \tag{7}$$

where η_{t-1} is an exogenous and persistent process, P_t^{EE} is an endogenous wedge that depends on the predetermined NEE_t position, and $\epsilon_{ee,t}$ is a pure unexpected *i.i.d.* shock which generates changes in the market value of the NEE portfolio (valuation channel). Because of $\epsilon_{ee,t}$, the return to external equities is ex-ante uncertain, in contrast to the cost of external debt financing. This shock captures unexpected variation to both exchange rates and foreign equity returns.

To guarantee the existence of an equilibrium, we impose $p_{EE} > 0$ so that the expected return from investing in foreign equity declines as NEE increases and hence there is no incentive to take infinitely long (or short) positions in external equities. We model the exogenous part of the expected log returns of the NEE portfolio as:

$$\eta_t = (1 - \rho_\eta)(\mu_{rw} + s_{rw}) + \rho_\eta \eta_{t-1} + \sigma_\eta \epsilon_{\eta,t}. \tag{8}$$

Given our formulation, when the net external equity position is zero, the expected foreign cost of equity equals exactly η_t. The parameter s_{rw} is computed as a residual adjustment such that the return on the NEE is equal to the cost of external debt at the deterministic steady state. Equivalently, absent risk, all assets pay the same risk-free return and no arbitrage exists. Since in our model we abstract away from time-varying volatility shocks, $\epsilon_{\eta,t}$ must be interpreted as generating small but long-lived fluctuations in the foreign equity Sharpe ratio. In our empirical analysis, we recover these shocks by working with returns adjusted by their ex-ante time-varying volatility.

Optimality. All first order conditions are standard and are detailed in Appendix A.

2.2 Firms' Problem

Technology. There is a continuum of identical firms with production function

$$F_t = F(A_t, K_t, H_t) = K_t^\alpha (A_t H_t)^{1-\alpha},$$

where K_t, H_t and A_t represent capital, labor, and the stochastic level of productivity, respectively. K_t is predetermined at time $t-1$ whereas labor is determined flexibly at time t. Capital evolves according to

$$K_{t+1} \leq (1-\delta)K_t + I_t - \Phi\left(\frac{I_t}{K_t}\right)K_t, \quad \Phi\left(\frac{I_t}{K_t}\right) = \frac{\phi_1}{1-\frac{1}{\phi_2}}\left(\frac{I_t}{K_t}\right)^{1-\frac{1}{\phi_2}} + \phi_3,$$

where δ is the depreciation rate for capital. I_t is investment at time t. $\Phi\left(\frac{I_t}{K_t}\right)$ is the capital adjustment cost defined as in Jermann (1998). The elasticity of adjustment costs is determined by ϕ_2.

In this study, we assume that productivity growth evolves as follows:

$$\begin{aligned} \Delta a_{t+1} &= \mu_a + x_t + \sigma_a \epsilon_{a,t+1}, &(9)\\ x_{t+1} &= \rho_x x_t + \sigma_x \epsilon_{x,t+1} + \rho_{rw,x} \sigma_{rw} \epsilon_{rw,t+1} + \rho_{\eta,x} \sigma_{\eta} \epsilon_{\eta,t+1}, &(10) \end{aligned}$$

where x_t is the long-run productivity risk (LRR) component (Croce 2014), and the volatility of short- and long-run risks are represented by σ_a and σ_x, respectively. The coefficients $\rho_{rw,x}$ and $\rho_{\eta,x}$ capture potential correlations of the long-run risk process with the external interest rates (equation (5)) and the Sharpe ratio shocks (equation (8)), respectively.

Financing problem. The firm finances its operations by issuing corporate debt or equities which are sold to the domestic household. The household can use foreign funds to buy local equities or debt. This convention enables us to replicate the close economy setting of JQ when we impose $NEE \equiv 0$ and $NED \equiv 0$. As in JQ and Hennessy and Whited (2005), corporate debt carries a tax advantage over equity and thus it is the preferred source of funding for the firm. The corporate capital structure is well-defined because of the existence of a working capital constraint.

More specifically, the firm chooses labor, investment, debt and equity issuance to maximize its cum-dividend value V_t,

$$V_t = d_t + \mathbb{E}_t \left[M_{t+1} V_{t+1} \right],$$

where d_t is the net equity payout, and M_t is the domestic SDF.[1] This optimization is subject to the following constraints:

$$
\begin{aligned}
d_t &\leq F(A_t, K_t, H_t) - w_t H_t - I_t - \chi(d_t) + D_{t+1} - D_t(1+r_t) - T_t^c, && (11)\\
F_t &\leq \xi_t (K_{t+1} - D_{t+1}). && (12)
\end{aligned}
$$

Equation (11) represents a standard firm's budget constraint. Following JQ, we impose a quadratic cost on the equity payout to make equities and bonds imperfect substitutes,

$$
\chi(d_t) = A_{t-1} \cdot \kappa \left(\frac{d_t}{SL_{t-1}} - \bar{d} \right)^2,
$$

where $\kappa \geq 0$, $\bar{d}$ is the steady state payout target, and SL_t mimics a time-trend that enables us to have balanced growth. The government collects a corporate revenue tax, T_t^c,

$$
T_t^c = \tau_F (F_t - w_t H_t - D_t r_t), \tag{13}
$$

where τ_F is a constant tax rate and the tax base equals corporate revenues $F_t - w_t H_t$ net of the cost of predetermined corporate debt, $D_t r_t$.

In equation (12), we impose a credit constraint subject to time-varying leverage shocks, as in JQ. The process ξ_t captures exogenous changes in domestic credit conditions and it evolves as follows:

$$
\xi_{t+1} = (1-\rho_\xi)\mu_\xi + \rho_\xi \xi_t + \epsilon_{\xi,t+1} + \rho_{rw,\xi}\sigma_{rw}\epsilon_{rw,t} + \rho_{\eta,\xi}\sigma_\eta \epsilon_{\eta,t}. \tag{14}
$$

[1] Given our assumptions, the domestic household is the marginal investor and only her SDF matters.

The parameters $\rho_{rw,\xi}$ and $\rho_{\eta,\xi}$ determine the contemporaneous impact of shocks to external financing conditions on domestic credit conditions.

Optimality. Our optimality conditions are identical to the ones in JQ and are reported in Appendix A. Our financial constraint causes a wedge in the labor market such that a tighter credit constraint reduces labor demand and economic activity. In this class of models, there is a possibility that the credit constraint may not be binding in some states. In our implementation, we observe negligible instances of such an event. For robustness, we have also solved the companion convexified version of the problem, i.e., we remove the credit constraint and we introduce convex distress costs on working capital. Our results are unchanged (see Appendix B).

In what follows, the return on domestic equities is denoted as R_E, whereas the return on assets is denoted as R_K. At the equilibrium, $R_{E,t+1} = \frac{V_{t+1}}{V_t - d_t}$. The expression for the (unlevered) return on assets can be found in Appendix A, equation (A3).

2.3 Tax Policy and Market Clearing

Government. The government runs a balanced budget policy, i.e., it collects corporate taxes and rebates them lump-sum to the household. The main purpose of this margin is to generate an incentive to issue corporate debt.

Market Clearing Conditions. The recursive competitive equilibrium in this economy requires that (i) the labor market clears, (ii) all equities and corporate bonds are held domestically by the household, and (iii) the goods market clears:

$$F_t - \chi(d_t) = C_t + I_t + \Delta NFA_t.$$

3 Empirical Evidence

The goal of our empirical investigation is twofold. First, we establish important and novel empirical macro-financial regularities in advanced SOEs. Second, we use our empirical findings to provide new empirical moments that can guide both our calibration and future quantitative studies.

We start our empirical analysis by investigating the properties of the fundamental shocks that drive the economic dynamics in the SONOMA model. We then look at the contribution of our shocks to the long-run variance of relevant macro-financial variables. We focus on a cross section of 10 Western European advanced SOEs: Portugal, Italy, Spain, Finland, Sweden, Switzerland, Austria, Belgium, Denmark and the Netherlands. The main data sources that we use are reported in Appendix C. We visualize our results on this webpage: `https://sites.google.com/view/sonoma-macrofin/home`.

3.1 Country-level Measurements

For each country in our sample, we compute essential aggregate variables needed for our analysis. In what follows, we focus on the series that are necessary to compute our fundamental shocks.

Capital stock. In each country j, we measure the capital stock as in JQ by capitalizing quarterly investment net of depreciation,

$$K_{t+1}^{j} = K_t^{j}(1 - \delta_t^{j}) + I_t^{j}.$$

Quarterly investment (I^j) data are from the OECD dataset whereas the depreciation rate (δ^j) is from the Penn World Table (PWT).[2]

[2]For each country, we initialize the recursion above by ensuring that (i) the initial and the final values of capital-to-output have the same value (as in Jermann and Quadrini (2012)); and (ii) the average capital-to-output ratio is equal to that computed from the annual data from PWT.

Productivity. For each country j, we compute total factor productivity A_t^j by postulating the Cobb-Douglas production function $Y_t^j = A_t^j K_t^{j\alpha_{j,t}} H_t^{j\ 1-\alpha_{j,t}}$, in which K_t^j measures beginning-of-the-quarter aggregate capital, H_t^j refers to total labor hours, and $\alpha_{j,t}$ is a moving average of the labor income share of GDP as reported in the PWT. Jermann and Quadrini (2012) recommend using business value added to measure Y_t^j. We believe that GDP is a more appropriate measure in our case since capital stock and labor series are total measures, i.e., they include all sectors and economic activities. In some of the countries in our sample non-profit and government sector activities are sizeable and should be accounted for in our empirical exercise.

Long-run productivity shocks. As in Croce (2014), we estimate the long-run component of productivity growth by forecasting the demeaned productivity growth rate $(\Delta a_{t+1}^j - \mu_a^j)$ using a set of lagged variables as predictors,

$$\Delta a_{t+1}^j - \mu_a^j = \overbrace{b_x^j X_t^{j,dm}}^{x_t^j} + \epsilon_{a,t+1}^j \tag{15}$$

$$x_t^j = \rho^j x_{t-1}^j + \epsilon_{x,t}^j. \tag{16}$$

Specifically, the vector $X_t^{j,dm}$ includes the demeaned lagged values of the log price-dividend ratio, inflation, and risk-free rate. This approach is common in the long-run growth news shock literature. See Appendix D for more details.

Domestic credit conditions. We take seriously the JQ approach and measure credit tightness, ξ_t^j, directly from the following ratio derived from equation (12),

$$\xi_t^j = \frac{Y_t^j}{K_{t+1}^j - B_{t+1}^{j,end}},$$

where K_{t+1}^{j} ($B_{t+1}^{j,end}$) measures the end-of-the-quarter capital stock (corporate debt, provided by the BIS). In contrast to JQ, we do not focus on detrended variables, i.e., on deviations from a long-run trend. Given our attention to long-run dynamics and expectations, we extract our measures of domestic credit conditions, ξ_t^j, using raw aggregate variables in levels.

External credit conditions. We model the external interest rates as specified in equations (3) and (4). To identify the country-specific spread, $P_t^{ED,j}$, we proceed as follows. We compute the difference between the real interest rate of country j, $r_t^{ED,j}$, and the real German rate, i.e., our measure for the world risk-free interest rate. These data are obtained from the OECD and refer to long-term debt. We measure the demeaned country-level net external debt ratio, $(NED/Y^j - \overline{NEDY}^j)$, using data from the IMF IIP/BOP database (see the methods in Lane and Milesi-Ferretti, 2007). We assume that the parameters $p_{ED,1}$ and $p_{ED,2}$ are common across countries and estimate them through a panel regression that enables us to isolate the country-specific spread:

$$\ln\left(1+\widehat{P}_t^{ED,j}\right) = \underbrace{\alpha}_{\substack{0.0008\\(0.0003)}} + \underbrace{\beta}_{\substack{0.0025\\(0.0005)}} \left(NED_t^j/Y_t^j - \overline{NEDY}^j\right) \quad j = 1, 2, \cdots, 10. \tag{17}$$

HAC-adjusted standard errors are reported in parentheses. We derive the exogenous component of the external interest rate for each country, $\hat{r}_t^{j,w}$, in the following residual way:

$$\hat{r}_t^{j,w} = \frac{1 + r_t^{ED,j}}{1 + \widehat{P}_t^{ED,j}} - 1.$$

Consistent with our model description, we refer to $r_t^{j,w}$ as a measure of external credit conditions throughout the remainder of our paper. This process embodies both changes to the world risk-free rate and changes to the external credit sentiment about country j. Additional details and results are available in Appendix D.

External cost of equity. In our model, $R_t^{EE,j}$ is the gross return on the *net* external equity (NEE) position of country j, which is measured as in Lane and Milesi-Ferretti (2007). We construct this return using gross positions. Specifically, in each country j the time-t value of the local NEE portfolio is

$$NEE_t^j = A_{t-1}^{EE,j} R_t^{E,w} - L_{t-1}^{EE,j} R_t^{E,j}$$

where $R_t^{E,w}$ is the return on the rest-of-the-world equity asset; $R_t^{E,j}$ is the return on equity in country j; $A_{t-1}^{EE,j}$ and $L_{t-1}^{EE,j}$ are the time-$t-1$ balances of external equity assets and liabilities, respectively. Divide and multiply by $NEE_{t-1}^j \equiv A_{t-1}^{EE,j} - L_{t-1}^{EE,j}$ to find

$$NEE_t^j = \left(\underbrace{\frac{A_{t-1}^{EE,j}}{A_{t-1}^{EE,j} - L_{t-1}^{EE,j}} R_t^{E,w} - \frac{L_{t-1}^{EE,j}}{A_{t-1}^{EE,j} - L_{t-1}^{EE,j}} R_t^{E,j}}_{R_t^{EE,j}} \right) NEE_{t-1}^j.$$[3]

In our analysis, we use the Major Markets International Index Portfolio provided by Kenneth French to measure the world returns. Kenneth French's Data Library also provides country-specific equity market returns to measure the cost of external equity liabilities. All returns are real and expressed in common units, i.e., they are both inflation- and exchange rate-adjusted.

[3] If the country holds foreign equities but has no international equity liability (i.e., $L_{t-1}^{EE} = 0$) then $R_t^{EE} = 1 + r_t^{E,w}$ and $NNE_t = R_t^{EE} A_{t-1}^{EE}$. If the country holds no foreign equity asset (i.e., $A_{t-1}^{EE} = 0$) then $R_t^{EE} = 1 + r_t^{E,j}$ and the external position would be $NEE_t = -R_t^{EE} L_{t-1}^{EE}$. If $A^{EE} = L^{EE}$, R_t^{EE} is undefined, but the NEE evolution can still be computed as $NEE_t = (R_t^{E,w} - R_t^{E,j}) A_{t-1}^{EE}$.

Composition of R^{EE} and link to the model. To estimate the components in equation (6), we must be able to both identify η^j_{t-1} and estimate the key parameters of the endogenous spread between internal ($R^{E,j}$) and external ($R^{E,w}$) equity expected returns. In our model, volatility is assumed to be constant. Hence when η^j_{t-1} increases, foreign stocks are relatively more appealing as they exhibit a better Sharpe ratio. In our data, by no-arbitrage, expected equity returns are driven by both volatility shocks and Sharpe ratio shocks. Empirically, we must disentangle pure volatility shocks from Sharpe-ratio shocks properly calibrate our model. We work with a volatility-adjusted spread (VAS^j_t) defined as follows:

$$VAS^j_t := \frac{E_t[R^{E,w}_{t+1} - R^{E,j}_{t+1}]}{\sigma^j_t},$$

where $\sigma^j_t := vol_t(R^{E,w}_{t+1} - R^{E,j}_{t+1})$. We recover $\hat{\sigma}^j_t$ by estimating a GARCH(1,1) model over the full sample. In the spirit of the finance literature, we use the world price-dividend ratio, pd^w, to capture variations in the global investment frontier by assuming that:

$$VAS^j_t = \alpha_{1,j} + \beta_{pd} pd^w_t \quad j = 1, ..., 10.$$

Equivalently, we allow for a country-specific constant, but we assume a common β_{pd} to have a tighter identification of this parameter. We then impose that

$$\eta^j_t := VAS^j_t \times \overline{\sigma},$$

where $\overline{\sigma} = Avg(\sigma^j_t)$ so that our empirical measure of the external equity market conditions is driven only by country-level Sharpe ratio shocks. We augment equation (7) with a country-specific constant and use an over-identified GMM to jointly estimate our key parameters.[4] Country-specific coefficients help us in capturing cross sectional heterogeneity in external equity positions ($A_t^{EE,j}$ and $L_t^{EE,j}$), i.e., the key source of difference between the return on NEE, $R_t^{EE,j}$, and the external spread, $R^{E,w} - R^{E,j}$.

For the sole sake of calibrating our model, we are interested in the following parameter estimates (HAC-adjusted standard errors in parenthesis):

$$\hat{p}_{EE} = \underset{(0.029)}{0.098}, \qquad \hat{\beta}_{pd} = \underset{(0.141)}{-0.699}. \tag{18}$$

The first coefficient confirms that countries that take longer positions in external equities accept lower expected returns. The second coefficient is useful for the identification of η_t^j and confirms that when global sentiment is high (high pd^w), foreign equities offer lower Sharpe-ratios relative to domestic equities. In what follows, we refer to our fitted η_t^j as the NEE expected equity return (NEE-ER) process.

Visual inspection. The reader can see our main exogenous time-series in Figure D1, Appendix D. Our long-run component captures the positive revision of expected growth in the late 1990s, as well as their during the global financial crisis (GFC). Our process for domestic credit conditions starts to decline in 2008 and it drops even

[4] We recover the parameters of interest using a joint GMM estimation strategy featuring the following moment conditions for each country $j = 1, ..., 10$:

$$\begin{aligned}
0 =& \mathbb{E}\left[\frac{R_{t+1}^{E,w} - R_{t+1}^{E,j}}{\hat{\sigma}_t^j} - \alpha_{1,j} - \beta_{pd} pd_t^w\right] \\
0 =& \mathbb{E}\left[\left(\frac{R_{t+1}^{E,w} - R_{t+1}^{E,j}}{\hat{\sigma}_t^j} - \alpha_{1,j} - \beta_{pd} pd_t^w\right) pd_{t-1}^w\right] \\
0 =& \mathbb{E}\left[(\ln(R_t^{EE})^j - \hat{\sigma}_t^j \times \left(\alpha_{1,j} + \beta_{pd} \times pd_{t-1}^w\right) - \alpha_{2,j} - p_{EE}\left(\overline{NEEY}^j - \frac{NEE_{t-1}^j}{Y_{t-1}^j}\right)\right] \\
0 =& \mathbb{E}\left[\left(\ln(R_t^{EE})^j - \hat{\sigma}_t^j \times \left(\alpha_{1,j} + \beta_{pd} \times pd_{t-1}^w\right) - \alpha_{2,j} - p_{EE}\left(\overline{NEEY}^j - \frac{NEE_{t-1}^j}{Y_{t-1}^j}\right)\right) \cdot \frac{NEE_{t-1}^j}{Y_{t-1}^j}\right].
\end{aligned}$$

The first two conditions pin down the country fixed-effects, $\alpha_{1,j}$, and the common slope β_{pd}, respectively; the last two conditions pin down the constant $\alpha_{2,j}$ and the cost function slope p_{EE}.

further during the European debt crisis. It starts to pick up again post-2015, i.e., in the recent period of improved credit. The external cost of debt shows a downward trend consistent with the well-known secular decline of interest rate across the globe. Our VAS picks up the increases in external Sharpe ratio that we observed post-IT bubble (post-2000), and post-GFC (post-2008).

3.2 Dynamic Properties of Exogenous Shocks

The dynamics and co-movements of macrofinancial variables in developed SOEs have been less studied than those in developing economies. In this section, we document novel salient empirical facts by estimating the following VAR:

$$Y_t = \Phi Y_{t-1} + \Sigma u_t \tag{19}$$

in which

$$Y_t = \begin{bmatrix} r_t^w & \eta_t & r_t^{EE} & \xi_t & x_t \end{bmatrix}', \tag{20}$$

and where r_t^w, η_t, r_t^{EE}, ξ_t, and x_t, denote the exogenous component of the external interest rate, the exogenous component of external expected equity returns, the returns on net external equity position, the domestic credit tightness, and the long-run productivity component, respectively. In what follows, we use a lower-triangular Cholesky decomposition to orthogonalize our shocks. As a result, external shocks are treated as 'more exogenous', in the spirit of the SOE literature.

Impulse responses. In the main text, we report the results that we obtain by estimating the VAR model in equations (19)–(20) using the time series of data av-

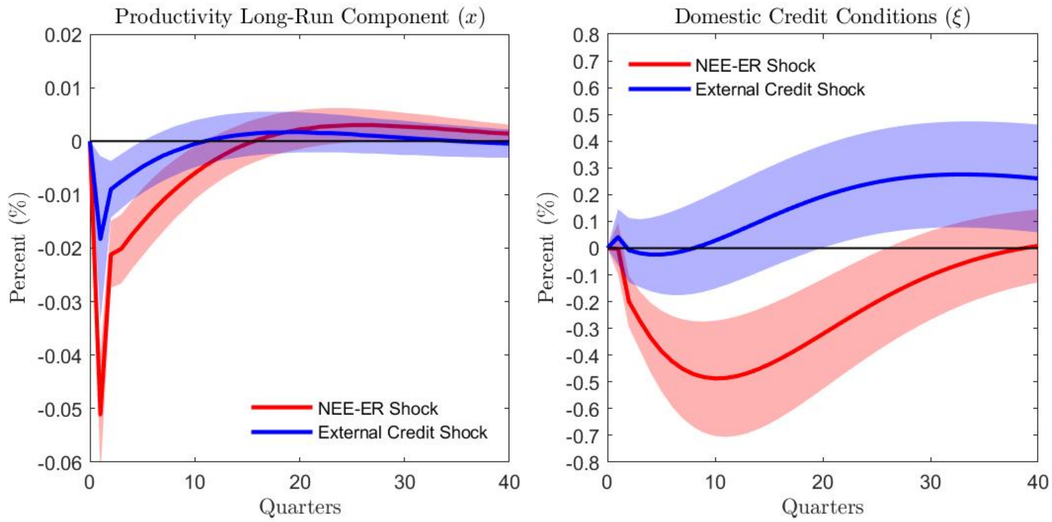


Fig. 1. **Empirical Impulse Responses to External Financial Shocks.** This figure shows the responses of the long-run component of productivity (x) and domestic credit conditions (ξ) to adverse shocks from external credit (r^w) and equity (NEE-ER, η) markets. All results are based on the VAR specified in equations (19)-(20) using data constructed from cross-country averages. Confidence intervals are HAC-adjusted. Our sources are detailed in Appendix C and our quarterly sample starts in 1995:Q1 and ends in 2018:Q4.

eraged across cross countries. We do so for two reasons. First, at the country-level we have an unbalanced panel (refer to the companion document, Croce et al., 2019) with a small cross section when we focus on a long time-series. Using cross-country averaged data enables us to work with long time-series. Second, our results could be viewed as applying to a representative developed SOE and hence they can be used to calibrate our model. Alternatively, our approach captures global components which are common to all the countries in our sample. In addition, we observe that country-level results are qualitatively similar to what we report here for the averaged variables (as shown in Appendix D). Our results are confirmed both when we use in GDP-weighted and equal-weighted data. We find these results reassuring as they confirm the robustness of our main findings.

Our VAR analysis highlights several relevant results about our fundamental processes. First, both adverse NEE-ER shocks and external credit condition shocks are correlated with negative long-run growth news, meaning that tight external markets tend to be associated with periods of lower expected long-run growth (Figure 1, left panel). Second, adverse NEE-ER shocks (η_t increases) anticipate tighter internal credit markets, i.e., the ξ_t process declines (Figure 1, right panel). These effects are long-lived. Interestingly, external credit shocks do not have a significant correlation with internal credit conditions and hence external bonds represent a hedge against domestic credit crunches.

3.3 SOE Accounting: Variance Decomposition

In this section, we expand our VAR to analyze the relevance of all of our exogenous shocks for key endogenous variables of interest. Specifically, we consider the following specification,

$$Y_t = \begin{bmatrix} r_t^w & \eta_t & r_t^{EE} & \xi_t & x_t & \epsilon_{a,t} & Z_t \end{bmatrix}', \tag{21}$$

where the sixth variable captures short-productivity shocks estimated as in equation (15), and Z_t refers to an endogenous variable of interest.[5] We focus on: net external debt-to-output ratio; net external equity-to-output ratio; investment-to-output ratio; corporate leverage, i.e., debt-to-assets ratio; consumption-to-output ratio; and output growth. We depict our results in Figure 2.

We note several interesting facts. First, credit shocks are first-order in explaining the medium- and long-run adjustments of both net external debt and equity. A substantial share of external debt variance over a 10-year horizon is explained by internal credit shocks, consistent with the fact that internal credit shocks can be hedged

[5]The results presented in the previous sections remain unchanged even if we add short-run productivity shocks as 6th variable in our VAR.

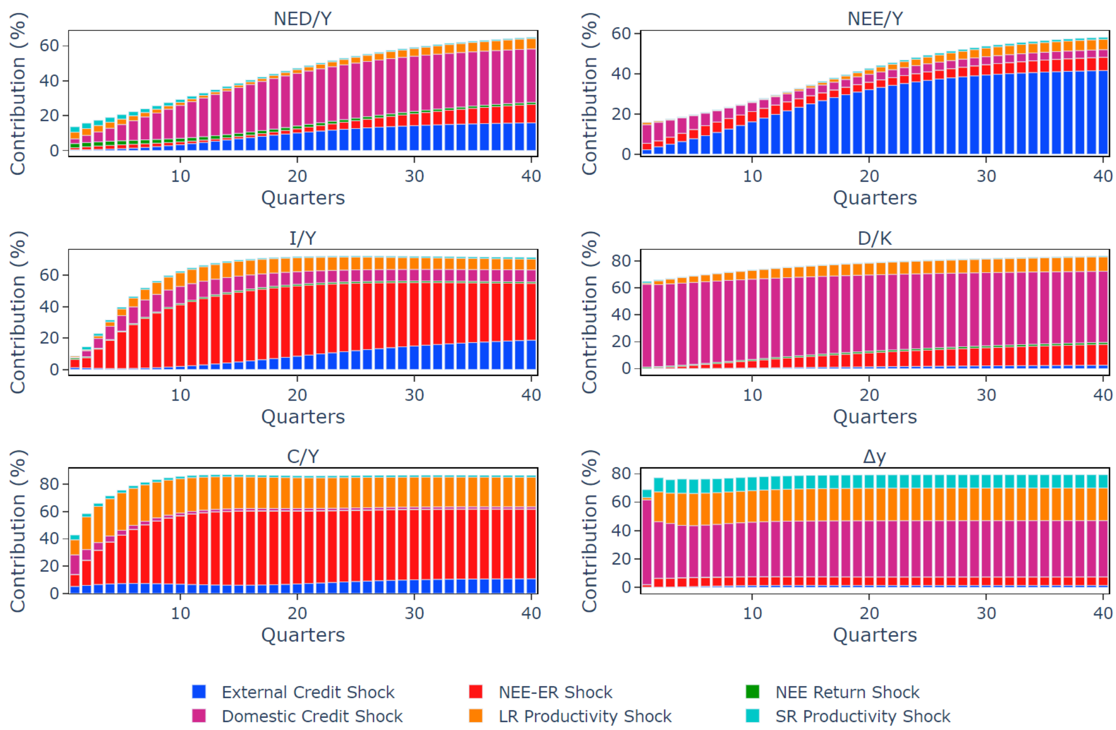


Fig. 2. **Relevance of Exogenous Shocks.** This figure shows the variance decomposition over a 40-quarter horizon for the following variables of interest: net external debt-to-output ratio (NED/Y); net external equity-to-output ratio (NEE/Y); investment-to-output ratio (I/Y); corporate leverage, i.e., debt-to-assets ratio (D/K); consumption-to-output ratio (C/Y); and output growth (Δy). All results are based on the VAR specified in equations (19) and (21) using data constructed from cross-country averages. Our sources are detailed in Appendix C and our quarterly sample starts in 1995:Q1 and ends in 2018:Q4.

by adjusting external leverage. In contrast, internal credit shocks play a minor role in explaining net external equity fluctuations. Consistent with the observation that international credit conditions are correlated with adverse external equity shocks, internal shocks are not hedged by adjusting the external equity positions. Interestingly, external credit shocks explain a large share of the fluctuations of the net external equities, implying that external credit shocks prompt a substantial reallocation across external debt and equity.

When we turn our attention to macroeconomic variables, we see that financial shocks play a dominant role in explaining the medium- and long-run fluctuations of investment, consumption, and output. This is a novel and very relevant empirical fact that goes beyond what we know about the U.S. (Jermann and Quadrini (2012)). More specifically, shocks to external equity and credit markets, as well as long-run productivity shocks, are key determinants of the composition of output, that is, the investment- and the consumption-to-output ratios. In contrast, internal credit shocks are more important than external shocks to explain output growth.

Lastly, we note that domestic corporate leverage is mainly driven by internal credit shocks. This is not surprising given the way in which we measure credit shocks. However, we find it important to note that external equity shocks explain about 20% of the fluctuations of the corporate capital structure over the long-run, i.e., a relevant portion. In our next step, we will reassess these empirical facts through the lens of our equilibrium model.

4 Calibration and Results

In this section, we discuss our calibration strategy and address our model results.

4.1 Calibration

Our medium-scale model features a total of 34 parameters. In what follows, we discuss the calibration of the parameters that are specific to SONOMA (Table 1). The remaining parameters are calibrated similarly to those in both the production-based asset pricing literature and international finance literature. Our calibrated values are broadly consistent with those reported in empirical studies of the Euro Area (among others, see Smets and Wouters 2003, Gerali et al. 2010, and Brinca et al. 2016). We discuss in detail the calibration of our canonical parameters in Appendix E.

Table 1: SONOMA Benchmark Calibration

Domestic Financial Markets			Estimate/Moment
Average Domestic Credit Conditions	(μ_ξ)	0.24	$\mathbb{E}[D/K]$
Volatility of Domestic Credit Conditions Shock	(σ_ξ)	0.4%	0.7% (0.1%)
Persistence of Domestic Credit Conditions	(ρ_ξ)	0.97	0.96 (0.02)
Loading of Domestic Credit Conditions on r^w Shock	($\rho_{rw,\xi}$)	-0.10	-0.01 (0.21)
Loading of Domestic Credit Conditions on η Shock	($\rho_{\eta,\xi}$)	-1.00	-1.01 (0.40)
Equity Adj. Cost Coefficient	(κ)	0.146	JQ(2012)
External Credit Market			
Average World Interest Rate	(μ_{rw})	0.28%	0.45% (0.17%)
Persistence of World Interest Rate	(ρ_{rw})	0.90	0.96 (0.03)
Volatility World Interest Rate Shock	(σ_{rw})	0.30%	0.36% (0.03%)
Average External Debt Ratio	($\overline{NEDY}$)	2.40	$\mathbb{E}[NED/Y]$
Country Spread (P^{ED}) Elasticity	($p_{ED,1}$)	6	3.13 (1.80)
Country Spread (P^{ED}) Coefficient	($p_{ED,2}$)	0.008	$\sigma(P^{ED})$
Loading of r^w Shock on Long-Run Component	($\rho_{rw,x}$)	-0.02	-0.03 (0.01)
External Equity Market			
Average Net External Equities Ratio	($\overline{NEEY}$)	0.20	$\mathbb{E}[NEE/Y]$
Endog. Component of Expected Return (P^{EE}) Function Exponent	(p_{EE})	0.10	0.10 (0.03)
Persistence of Exog. Component of Expected Return (η)	(ρ_η)	0.80	0.72 (0.04)
Volatility of Exog. Component of Expected Return Shock	(σ_η)	0.2%	0.2% (0.014%)
Volatility of Return Shock	(σ_{ee})	0.10	0.15 (0.02)
Corr. Return with r^w Shock	($\rho_{rw,ee}$)	-35	-49 (21)
Corr. Expected Returns with Long-Run Component	($\rho_{\eta,x}$)	-0.06	-0.14 (0.02)

Notes: This table reports our benchmark quarterly calibration for the parameters that are specific to SONOMA. The last column reports either a direct empirical estimate of the calibrated parameter (with HAC-adjusted standard errors in parentheses) or a specific moment that we target in our calibration procedure. "JQ (2012)" refers to parameter values that we get directly from Jermann and Quadrini (2012). All other parameters are reported and discussed in Appendix E.

Most parameters have a direct empirical counterpart and are set to be consistent with our empirical confidence intervals. Some parameters are set to make sure that our endogenous variables have plausible features in equilibrium.

The first block of parameters pertains to the domestic financial conditions. We choose the average domestic credit conditions parameter, μ_ξ, to target the average domestic corporate leverage in our sample, $\mathbb{E}[D/K]$. The volatility of this shock, σ_ξ, is set to a conservative level that enables us to keep the volatility of corporate leverage, $\sigma[D/K]$, consistent with the data. Our estimated results point to notable persistence in domestic financial conditions. Accordingly, we set the persistence parameter, ρ_ξ, to 0.97. The loadings of the domestic financial conditions process on two of the shocks to the external conditions (see equation 14), $\rho_{rw,\xi}$ and $\rho_{\eta,\xi}$, are recovered from our

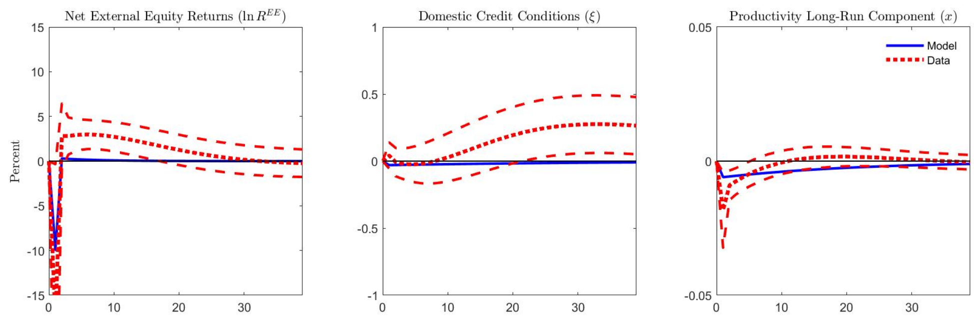
VAR estimation. Our choice for equity adjustment cost coefficient, κ, is based on Jermann and Quadrini (2012).

The external exogenous interest rate process (equation (5)) features three parameters, μ_{rw}, σ_{rw}, and ρ_{rw}. We set these parameters so that they belong to our empirical confidence intervals. The endogenous component of the external interest rate spread, P^{ED}, requires us to calibrate three parameters (equation (4)). We choose $\overline{NEDY}$ so that the endogenous average level of the external debt-to-output ratio is consistent with our data. Starting from the regression in equation (17), we compute a confidence interval for $p_{ED,1}$ and set this parameter to 6.[6] We set $p_{ED,2}$ in order match the volatility of the estimated country spread in our data. The loading of the external credit conditions process on the long-run component, $\rho_{rw,x}$, is recovered from our VAR estimation.

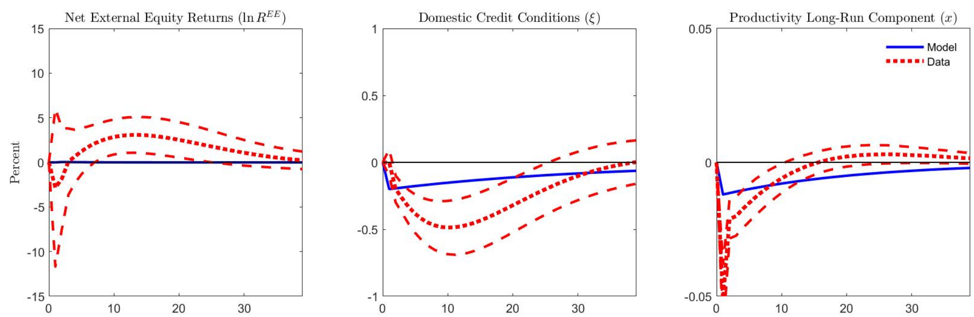
The discussion of the net external equity position is a novel feature of our study. We choose $\overline{NEEY}$ so that the endogenous average level of the net external equity-to-output ratio is consistent with our data. The elasticity in equation (7), p_{EE}, is consistent with the empirical estimates reported in equation (18).

We use our empirical results on NEE returns to calibrate the components reported in equations (6)–(8). Our VAR specified in equation (20) gives us confidence intervals for: (i) the persistence and the volatility parameters for the exogenous component in external expected returns (ρ_η and σ_η); (ii) the volatility of unexpected external equity shocks (σ_{ee}); (iii) the correlation between external interest rate and unexpected external equity shocks ($\rho_{rw,ee}$); and (iv) the correlation between the long-run component and the expected external equity shocks ($\rho_{\eta,x}$).

[6] In our empirical specification, the gross spread is defined as $\exp(\alpha + \beta z)$, where $z = NEDY - \overline{NEDY}$. In our model, the gross spread is $1 + p_{2,ED} \exp(p_{1,ED} z)$. When $z = 0$, the two functions have the same slope if $p_{1,ED} = \frac{\exp(\alpha)\beta}{\exp(\alpha)-1}$. St. Errors are derived by the delta method.



(a) External Credit Conditions Shock (r^w)



(b) NEE-ER Shock (η)

Fig. 3. **Model versus VAR: Fundamental Shocks.** This figure shows the responses of net external equity returns ($\ln R^{EE}$), domestic credit conditions (ξ), and the long-run component of productivity (x) to shocks from external credit conditions (r^w) and the NEE-ER (η). The model responses are based on the calibration in Table E1. The data responses are based on the VAR specified in equations (19)-(20) using data constructed from cross-country averages. Confidence intervals are HAC-adjusted. Our sources are detailed in Appendix C and our quarterly sample starts in 1995:Q1 and ends in 2018:Q4.

To better assess our calibration strategy, in Figure 3 we depict the implied dynamics of key exogenous processes in our model and compare them with their VAR counterparts. Specifically, we show the responses of net external equity returns ($\ln R^{EE}$), domestic credit conditions (ξ), and the long-run component of productivity (x) to external credit condition shocks (r^w) and NEE-ER shocks (η). Our parsimonious model specification captures the main features highlighted in the data: (i) an adverse shock to external credit conditions is associated with both lower expected productivity and negative external equity returns; (ii) an adverse NEE-ER shock is associated with adverse adjustments in both domestic credit conditions and expected productivity growth.

In principle, we could perfectly replicate our empirical responses by specifying a richer VAR structure for our exogenous processes in our model. We prefer our approach as it reproduces the main patters in the data with parsimony. In addition, our approach is sophisticated enough to highlight the transmission of internal and external financial conditions to long-term growth. This is a novel and relevant dimension of our study.[7]

4.2 Results

We simulate our SONOMA model and show that it captures several key dimensions of both macroeconomic and financial data across developed SOEs. Furthermore, we show that the model is successful in matching a notable number of moments that are not directly targeted in our calibration.

Simulated moments. In Table 2, we present several moments obtained from simulations and compare them to their empirical counterparts. Specifically, in the data we compute each moment at the country level and report its median as well as its cross-sectional dispersion, that is, the range implied by the second smallest and the second largest country-level estimates.

In the first panel of Table 2, we focus on standard macroeconomic moments. SONOMA inherits the ability of many standard SOE models in matching the behavior of macroeconomic aggregates in the data. In our model, investment growth (Δi) is more volatile than both output (Δy) and consumption (Δc), as in the data. In the model, consumption growth tends to be as volatile as output. This is due

[7] All of the other contemporaneous correlations among our shocks are set to zero as they are empirically small and irrelevant for our simulation results.

Table 2: **Performance of SONOMA**

Moments		Data Est.	Data Range	Model
Macro	$\sigma(\Delta i)/\sigma(\Delta y)$	2.18	[1.76 , 2.86]	1.95
	$\sigma(\Delta c)/\sigma(\Delta y)$	0.78	[0.65 , 1.02]	1.08
	$corr(\Delta i, \Delta c)$	0.27	[0.06 , 0.57]	0.64
	$corr(\Delta i, \Delta \log(D))$	0.11	[-0.05 , 0.27]	0.03
	$corr(\Delta y, \Delta h)$	0.27	[0.12 , 0.54]	0.53
Returns	$\mathbb{E}[r]$ (%)	0.87	[0.44 , 1.52]	1.54
	$corr(r, \Delta y)$	0.04	[-0.09 , 0.20]	0.10
	$\mathbb{E}[r_E - r]$ (%)	7.59	[5.73 , 11.28]	5.68
	$\sigma(r_E - r)$ (%)	21.43	[18.90 , 24.22]	7.27
	$\mathbb{E}[r_K - r]$ (%)	5.11	[2.85 , 7.02]	3.64
	$\sigma(r_K - r)$ (%)	14.82	[12.31 , 20.26]	4.94
	$\mathbb{E}[r - r^w]$ (%)	0.39	[0.17 , 1.39]	0.42
	$\sigma(r - r^w)$ (%)	0.25	[0.12 , 0.71]	0.62
Leverage	$\mathbb{E}[D/K]$ (%)	29.66	[16.94 , 41.30]	34.41
	$\sigma(D/K)$ (%)	5.06	[2.29 , 7.29]	6.67
	$corr(\Delta(D/K), \Delta y)$	0.34	[0.24 , 0.42]	0.05
	$\sigma(d/K)/\sigma(\Delta y)$ (%)	1.50	[1.05 , 1.94]	1.45
NFA	$\mathbb{E}[NED/Y]$ (%)	46.67	[-18.03 , 74.01]	53.53
	$\mathbb{E}[NEE/Y]$ (%)	17.65	[-21.80 , 34.56]	8.41
	$\sigma(\Delta(NED/Y))$ (%)	7.37	[4.05 , 10.04]	2.59
	$\sigma(\Delta(NEE/Y))$ (%)	9.15	[4.55 , 14.87]	8.04
	$corr(\Delta(NED/Y), \Delta y)$	-0.20	[-0.31 , -0.01]	-0.53
	$corr(\Delta(NEE/Y), \Delta y)$	-0.05	[-0.29 , 0.04]	-0.24
	$corr(\Delta(NED/Y), \Delta(NEE/Y))$	0.22	[0.16 , 0.38]	0.35
	$corr(NED/Y, D/K)$	0.17	[-0.16 , 0.87]	-0.36
	$corr(NEE/Y, D/K)$	0.51	[-0.68 , 0.85]	0.03
Current Acc.	$\sigma(\Delta NFA/Y)$ (%)	2.90	[1.98 , 5.10]	4.21
	$acf(\Delta NFA/Y)$	0.92	[0.65 , 0.98]	0.84
	$corr(\Delta NFA/Y, r)$	0.27	[-0.47 , 0.59]	0.56

Notes: Our data sources are detailed in Appendix C. Quarterly sample starts in 1995:Q1 and ends in 2018:Q4. Data moment estimates are the median of the moment values computed for each country in our sample. The data moment range shows the third smallest and third largest values. Both data and model moments are based on quarterly observations. Mean and volatility moments are annualized.

to the fact that the representative agents use the current account to hedge domestic shocks and keep investment and consumption slightly more correlated than in a closed economy.

Most importantly, the model is very successful in replicating the moderate correlation between output and labor growth (Δh) and it produces a slightly positive correlation between investment growth and corporate debt issuance ($\Delta \log D$). The latter dimension is very relevant given our interest for the role played by both financial frictions and shocks.

The second panel in Table 2 refers to our cross section of returns. SONOMA produces a low risk-free rate (r) while delivering a very sizable equity risk premium of 5.68% ($\mathbb{E}[r_E - r]$). To the best of our knowledge, this is the first model that produces such a high difference in the cost of debt and equity in an open economy setting. This risk premium is slightly lower than the median one estimated in the data, but it is both empirically plausible and close to the lower bound of our cross-sectional range. A similar result applies to the average unlevered excess returns ($\mathbb{E}[r_K - r]$). In addition, our calibration produces: (i) a mild positive correlation between output growth and the risk-free rate, and (ii) country-level spread between the cost of debt and the world risk-free rate ($r - r^w$) consistent with the data.[8]

Our success in explaining the behavior of equity returns is related to our ability to reproduce many empirical features of corporate leverage. In the third panel of Table 2, we show that our corporate debt-to-assets ratio (D/K) is as high and volatile as in the data. In addition, book-leverage variations ($\Delta(D/K)$) are slightly procyclical and the equity payout-to-asset ratio (d/K) is 1.5 times more volatile than output, consistent with the data.

More broadly, our equilibrium model tracks simultaneously many features of financial leverage both domestically and internationally. In the last two panels of Table 2, we focus on moments that are specific to our open economy setting. Given our calibration strategy, both the average level of the NEE-to-output (NEE/Y) and NED-to-output (NED/Y) ratios are consistent with our empirical range. Our model produces an excessively smooth NED-to-output ratio, but it replicates the volatility of

[8]The equity volatility puzzle is unresolved in our model. It is well-known that adding time-varying volatility could resolve the problem, but it would come at the cost of making the model less parsimonious. We leave this task to future research.

the NEE position. In addition, our model reproduces the counter-cyclicality of these components, i.e., their negative correlation with output growth. Both in the model and in the data, the variation of the NED-to-output ratio ($\Delta(NED/Y)$) and that of the NEE-to-output ratio ($\Delta(NEE/Y)$) feature a very moderate contemporaneous correlation with each other.

According to our data, the median contemporaneous correlation between book leverage and the subcomponents of the NFA is slightly positive. Our empirical range, however, is very wide and spans both negative and positive values for both NEE and NED. In general, we consider our model satisfactory as it features very small correlations. For example, our model produces a negative correlation between book leverage and NED in the order of -0.36 while our empirical lower bound is about -0.16. To better understand this result, we depict the responses of several variables of interest to our adverse financial shocks in Figure 4.

The representative firm responds to all of these shocks by reducing the equity payout in order to repurchase debt and reduce leverage. The response of NED, instead, changes across shocks. Specifically, when there is an external shock to the cost of debt, NED declines together with domestic corporate leverage, implying a positive comovement. In contrast, an adverse domestic credit shock produces a negative comovement, as the households finds it optimal to partially hedge the internal credit crunch by both borrowing more from abroad and reducing her NED position.

When external equities become more convenient, we observe a reallocation toward foreign equities financed by increasing foreign leverage, i.e., increasing NED. This reallocation increases the country spread (see equation (4)) and hence the cost of debt. As a result, domestic leverage declines and there is a negative comovement with NED. At the equilibrium, domestic corporate leverage has a mild negative correlation with external debt.

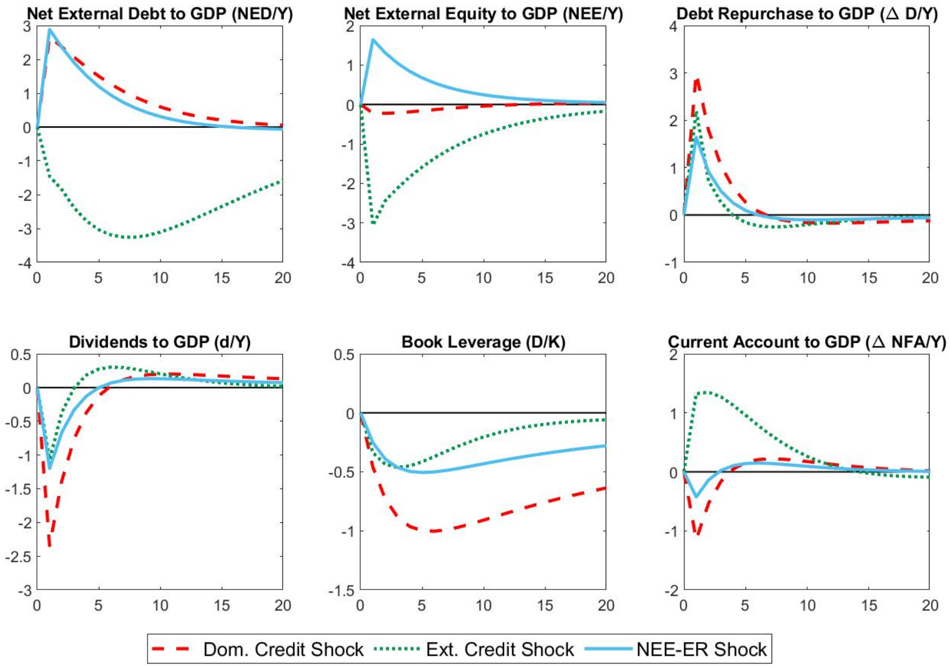
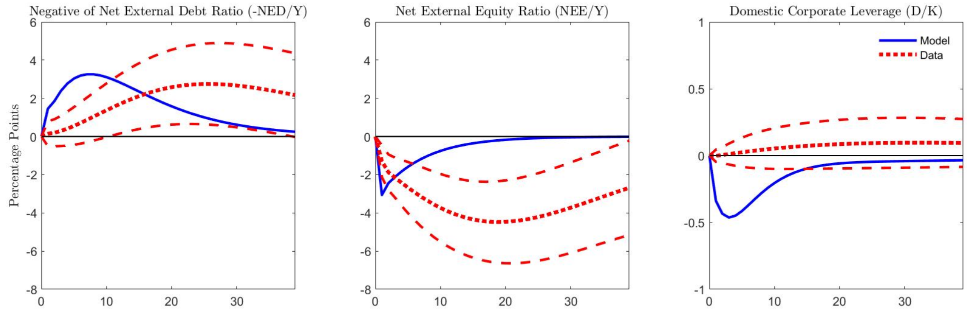


Fig. 4. **Impulse Responses in SONOMA.** This figure shows percentage deviations from steady state for variables expressed in logs (percentage point deviations from steady state for variables expressed in levels) in response to a one standard deviation adverse shock to domestic credit conditions (ξ), external credit conditions (r^w), or the NEE-ER (η). Our benchmark calibration is reported in Table E1 and the process to close the economy is described in Table 2.

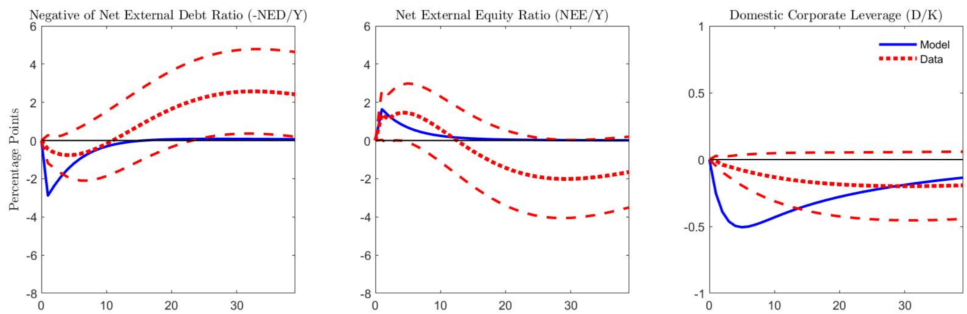
Finally, we note that the current account-to-output ratio ($\Delta NFA/Y$) in our model is as volatile and persistent as in the data. To the best of our knowledge, we are the first to match key properties of both the NFA and its subcomponents.

Impulse responses after external shocks. We produce a complete analysis of the impulse responses generated by our model in section 4.3. For the sake of focus, in Figure 5, we depict only the model-implied responses studied so far and compare them with their empirical counterparts. Overall, the model's predictions align well with our data-based responses, meaning that the model responses are similar to those in the data.

Specifically, in the aftermath of an adverse external credit shock, the composition of the NFA changes and we observe a reallocation of resources from external equities



(a) External Credit Conditions Shock

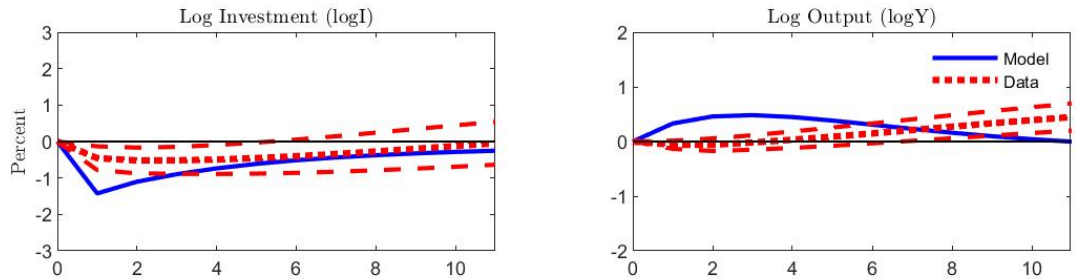


(b) NEE-ER Shock

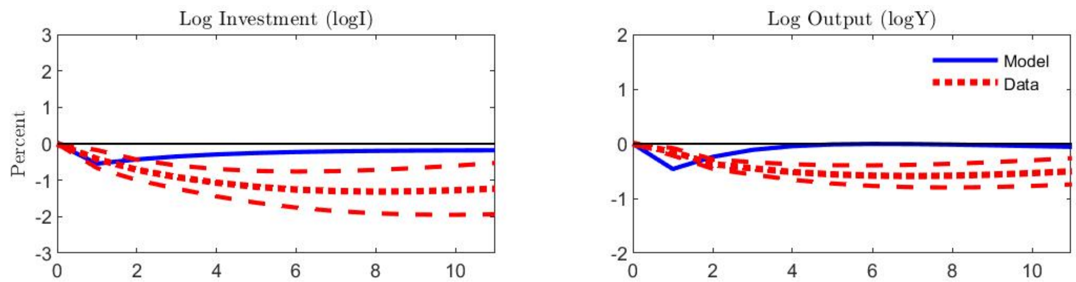
Fig. 5. **Model versus VAR: External Positions and Leverage.** This figure shows the responses of the negative of the net external debt ratio ($-NED/Y$), the net external equity ratio (NEE/Y), and domestic book leverage ratio (D/K) to shocks from external credit conditions (r^w) and the NEE-ER (η). The model responses are based on the calibration in Table E1. The data responses are based on the VAR specified in equations (19) and (21) using data constructed from cross-country averages. Confidence intervals are HAC-adjusted. Our sources are detailed in Appendix C and our quarterly sample starts in 1995:Q1 and ends in 2018:Q4.

to external credits. For a prolonged number of quarters, net external equities decline in order to free up resources for a decline in net external debt. In the data, this process builds up slowly and picks up after 20 quarters. In the model, this reallocation takes place mainly in the first 10 quarters. Domestic corporate leverage is nearly unchanged in the data at all horizons. In the model, there is a slight reduction of about 0.25% over the first ten quarters.

In the aftermath of an adverse NEE-ER shock, domestic corporate leverage declines in the data. This is a novel empirical fact that our model replicates very well. According to our model, the household should borrow more from abroad in order to



(a) External Credit Conditions Shock



(b) NEE-ER Shock

Fig. 6. **Model versus VAR: Economic Aggregates.** This figure shows the responses of log investment ($\log I$) and log output ($\log Y$) to shocks from external credit conditions (r^w) and the NEE-ER (η). The model responses are based on the calibration in Table E1. The data responses are based on the VAR specified in equations (19) and (21) using data constructed from cross-country averages. Confidence intervals are HAC-adjusted. Our sources are detailed in Appendix C and our quarterly sample starts in 1995:Q1 and ends in 2018:Q4.

invest in external equities. This reallocation increases the cost of debt and forces corporations to de-leverage. Our VAR suggests that this mechanism is empirical plausible and—in the case of the NEE position—statistically significant.

In Figure 6, we conduct a similar analysis turning our attention to macroeconomic aggregates such as investment and output.[9] Our empirical analysis suggests that external shocks have a strongly contractionary impact on investment. Our model captures these patterns. We are the first to show that shocks to external equities are as relevant as shocks to external credit conditions.

[9] In this case, our VAR is estimated using both productivity, investment, and output in log-levels, as opposed to innovations and growth rates.

In addition, our model suggests that output should decline after adverse external equity shocks whereas it should increase after external credit shocks. In the model, an improvement in the external Sharpe-ratio produces an incentive to reduce the holdings of domestic equities in favor of foreign equities. As a result, the domestic corporate sector shrinks and output declines as well. In contrast, when external credit conditions deteriorate, the agent must offset the increase in the cost of debt by increasing labor and output. By doing so, the country reduces its external debt-to-output ratio and hence its external debt spread (equation (4)). In the model this reaction unfolds immediately whereas in the data it picks up with a delay of about a year. This prediction of our model is both insightful and empirically plausible.

For the sake of completeness, in the appendix we depict the responses of these macroeconomic aggregates against productivity shocks (Figure G1). The magnitude of these responses are similar, implying that financial shocks can be as disruptive as productivity shocks.

SOE accounting: model vs data. Using model-simulated data, we run the same variance decomposition analysis that we perform in the data and that we presented in the Section 3.3. Figure 7 helps us in comparing the model results with the data. Since the model features only six exogenous shocks, in the data we exclude the contribution of the seventh empirical shock (white areas in Figure 2) and rescale the remaining shares to sum up to 100%, as in the model. In what follows we focus on the variance decomposition on horizons of at least 20 quarters, i.e., the beginning of the medium-cycle. Replicating the variance composition over shorter horizons is possible, but it would require us to adopt a much richer VAR structure on the exogenous shocks in our model. We prefer to study a more parsimonious model and judge its ability to explain medium- and long-horizon dynamics.

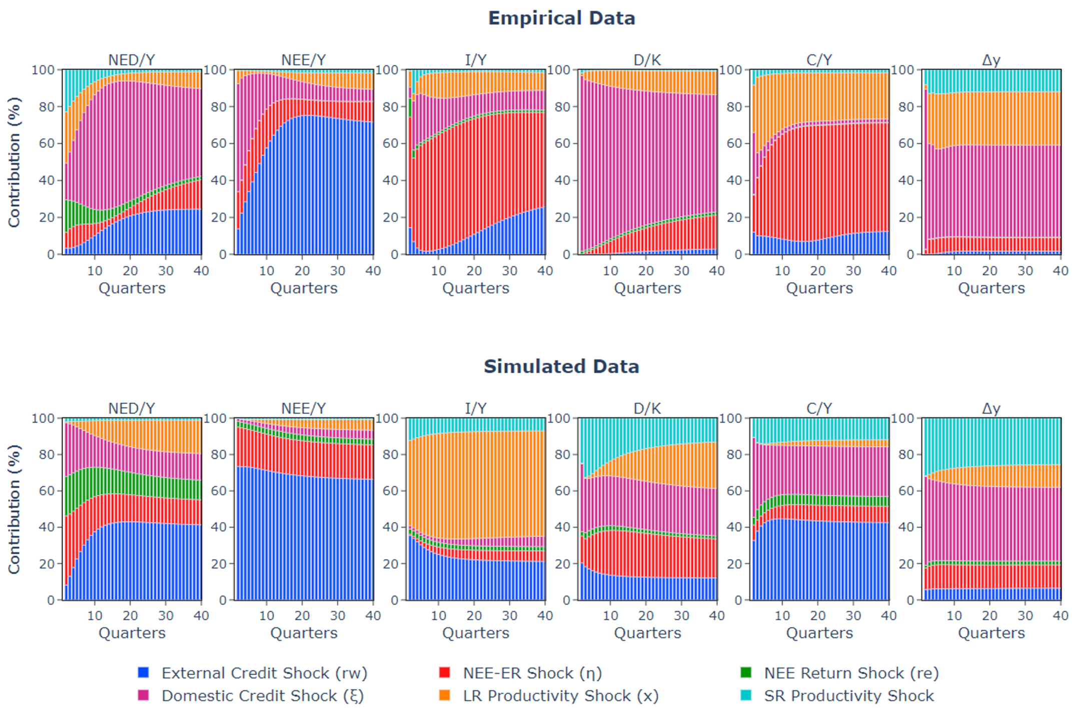


Fig. 7. Relevance of Exogenous Shocks: Model vs Data. This figure shows the variance decomposition over a 40-quarter horizon of the following variables of interest: net external debt-to-output ratio (NED/Y); net external equity-to-output ratio (NEE/Y); investment-to-output ratio (I/Y); corporate leverage, i.e., debt-to-assets ratio (D/K); consumption-to-output ratio (C/Y); and output growth (Δy). All results are based on the VAR specified in equations (19) and (21) using either data constructed from cross-country averages or simulated data from our SONOMA model. The empirical shares of variance are rescaled to sum up to 100%, as in the model. Our sources are detailed in Appendix C and our quarterly sample starts in 1995:Q1 and ends in 2018:Q4.

We highlight several dimensions in which the model successfully replicates the data and some discrepancies for which future work is required. Focusing on NED, for example, the model replicates the increasing role of shocks to both external credit conditions and Sharpe ratio. Both in the data and in the model, short-run productivity shocks are almost irrelevant for the dynamics of the NED-to-output ratio over a ten-year horizon, whereas productivity growth news shocks explain about 20% of its variance. The model gives a little bit more (less) weight to unexpected shocks to external equities (internal credit conditions) than in the data.

The variance decomposition of the NEE-to-output ratio in the model conforms very well with the data. External credit shocks and NEE-ER shocks dominate over the medium- and long-run, followed by internal credit shocks and growth news shocks. We find this result as very satisfactory, especially because this is a new dimension in the SOE literature. Over a ten-year horizon, about 45% of the variance of domestic corporate leverage (D/K) is explained by external shocks to credit conditions and expected returns as well as domestic long-run growth news. In our model, this share is slightly higher, about 60%. As a result, internal credit shocks are relatively less important than in the data.

We now turn our attention to output and its main components, namely investment and consumption. In the data, output growth is mainly explained by internal credit shocks and growth news shocks. External shocks explain about 12% of variance over a ten-year horizon. The model replicates these facts quite well, except that it gives more (less) weight to short-run (long-run) shocks than in the data. This problem could be easily solved if we were to choose a more aggressive calibration of the long-run productivity component.

The data suggest that the consumption-to-output ratio dynamics are mainly explained by external financial shocks and long-run growth news shocks over the long-run. SONOMA attributes to these shocks about 50% of the total variance. This discrepancy is mainly driven by internal credit shocks as they are almost irrelevant in the data but account for 30% of the variance of the consumption-to-output ratio in the model. Both in the data and the model, however, all financial shocks combined explain about 75% of the fluctuations of the consumption share of output. This result confirms that financial shocks are prevalent in developed SOEs.

We conclude this analysis by focusing on the investment-to-output ratio. The data suggest that about 85% of the variance of this ratio is driven by financial shocks.

SONOMA features a share close to 40% and it attributes more weight on long-run news as opposed to external Sharpe-ratio shocks. Future research should consider different forms of capital accumulation frictions that make investment respond less (more) to growth news shocks (external equity shocks).

4.3 Inspecting the Mechanism

In this step, we inspect the mechanism, i.e., we analyze the various channels in our SONOMA model. We start by comparing our SONOMA setting with its closed economy counterpart. Next, we study the role of preferences and financial frictions. We conclude summarizing additional results reported in the appendix.

Closed SONOMA. In Table 3, we examine the performance of SONOMA when we remove one or more of its salient elements. For example, in the second column we show how our results change if we analyze the close economy version of our model.

In the closed SONOMA, the macroeconomic moments remain almost unchanged. In contrast, the asset pricing implications are very different, as the equity risk premium declines substantially. To better understand these results, in Figure 8 we depict key impulse responses with respect to adverse financial shocks for both our SONOMA model and its close-economy version. The responses to productivity shocks are similar across settings (see Figure G2, Appendix G).

We note three key results. First, domestic credit shocks are more relevant in the closed SONOMA than in SONOMA. Not surprisingly, if internal credit shocks cannot be hedged by adjusting the external positions, their contractionary impact is stronger. Since states with tight domestic conditions feature high marginal utility, the contribution of internal shocks to the equity premium is strong. Under our benchmark SONOMA setting, however, shocks to either the external cost of equity or the external

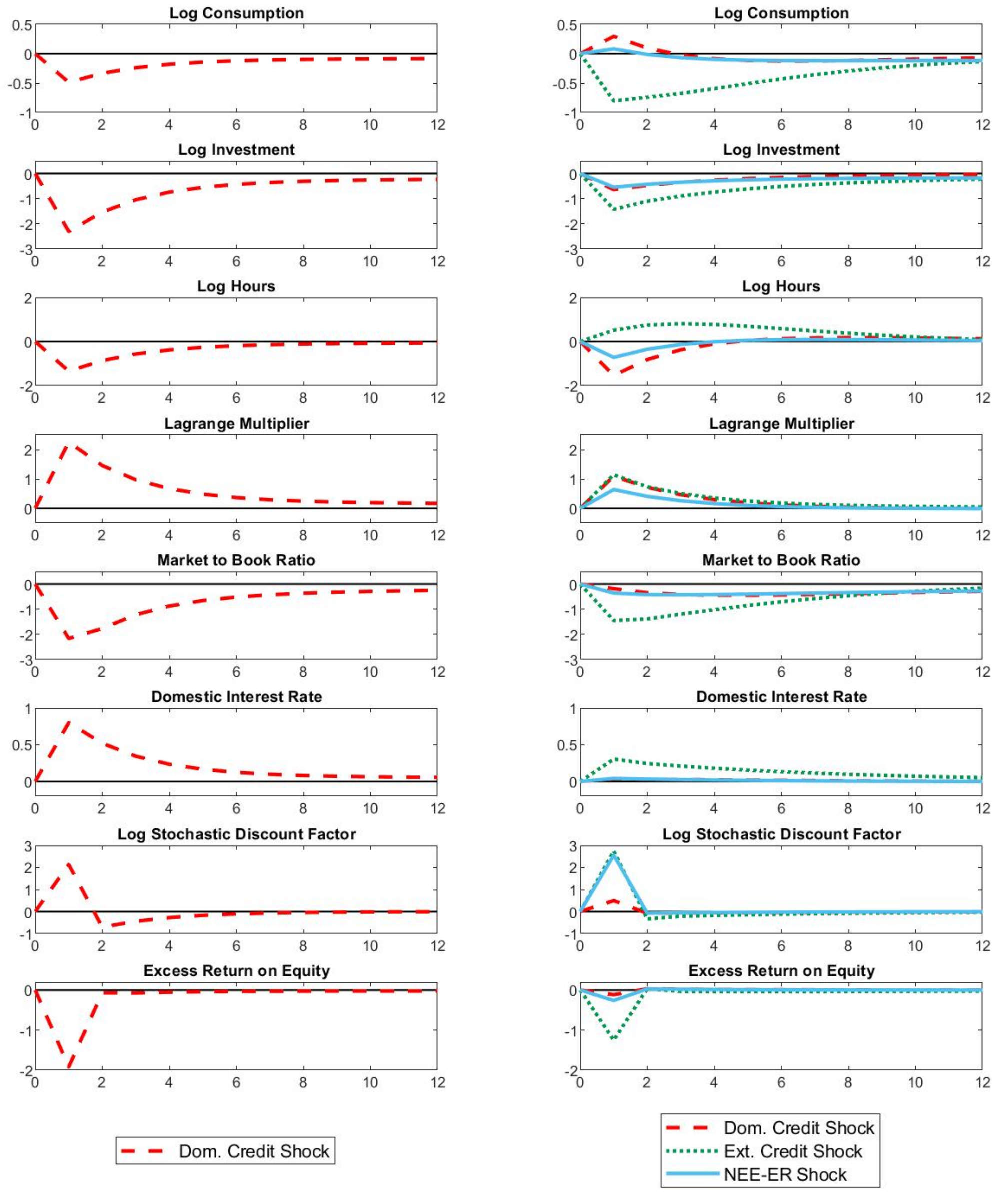
Table 3: **Inspecting the Mechanism**

Moments		SONOMA	Closed SONOMA	No EZ	No Dom. Financial Friction	No Financial Shocks
Macro	$\sigma(\Delta i)/\sigma(\Delta y)$	1.95	2.13	1.71	0.95	2.64
	$\sigma(\Delta c)/\sigma(\Delta y)$	1.08	0.89	1.18	0.56	1.52
	$corr(\Delta i, \Delta c)$	0.64	0.51	0.86	0.58	0.67
	$corr(\Delta i, \Delta \log(D))$	0.03	0.13	0.06	–	-0.52
	$corr(\Delta y, \Delta h)$	0.53	0.31	0.51	0.91	-0.46
Returns	$\mathbb{E}[r]$ (%)	1.54	5.04	4.18	1.06	1.42
	$corr(r, \Delta y)$	0.10	-0.03	0.21	0.02	0.32
	$\mathbb{E}[r_E - r]$ (%)	5.68	2.94	0.24	3.43	5.94
	$\mathbb{E}[r - r^w]$ (%)	0.42	0.00	3.06	-0.06	0.29
	$\sigma(r - r^w)$ (%)	0.62	0.00	1.12	0.71	0.31
Leverage	$\mathbb{E}[D/K]$ (%)	34.41	36.11	39.64	0.00	36.01
	$\sigma(D/K)$ (%)	6.67	5.88	7.27	0.00	5.32
	$corr(\Delta(D/K), \Delta y)$	0.05	0.14	0.07	–	-0.06
	$\sigma(d/K)/\sigma(\Delta y)$ (%)	1.45	1.47	1.49	0.25	1.63
NFA	$\mathbb{E}[NED/Y]$ (%)	53.53	–	58.47	53.02	55.10
	$\mathbb{E}[NEE/Y]$ (%)	8.41	–	6.84	8.84	6.73
	$\sigma(\Delta(NED/Y))$ (%)	2.59	–	2.12	4.06	0.44
	$\sigma(\Delta(NEE/Y))$ (%)	8.04	–	7.48	9.52	2.92
	$corr(\Delta(NED/Y), \Delta y)$	-0.53	–	-0.53	-0.84	-0.20
	$corr(\Delta(NEE/Y), \Delta y)$	-0.24	–	-0.10	-0.19	0.23
	$corr(\Delta(NED/Y), \Delta(NEE/Y))$	0.35	–	0.46	0.39	0.06
	$corr(NED/Y, D/K)$	-0.36	–	-0.38	–	-0.72
	$corr(NEE/Y, D/K)$	0.03	–	0.35	–	0.38
Current Acc.	$\sigma(\Delta NFA/Y)$ (%)	4.21	–	3.87	5.25	2.24
	$acf(\Delta NFA/Y)$	0.84	–	0.83	0.61	0.89
	$corr(\Delta NFA/Y, r)$	0.56	–	0.38	0.60	-0.40

Notes: "Closed SONOMA" denotes the closed economy version of our SONOMA setting. "No EZ" refers to the CRRA preferences case with $\gamma = 1/\psi = 1$, as in Jermann and Quadrini (2012). The "No Fin. Domestic friction" column refers to the case in which $\kappa = 0$ and debt is equal to zero in every period ($D = 0$). In the last column, we remove all financial shocks by setting their standard deviation to zero.

cost of debt are first-order and contribute to generate a very high risk premium despite the adjustments of the external positions.

Role of preferences. In the third column of Table 3, we show how our results change if we adopt time-additive log preferences as in Jermann and Quadrini (2012). On the macroeconomic side, we observe relevant changes: (i) investment becomes too smooth, whereas consumption becomes too volatile; and (ii) consumption and investment become highly correlated.



(a) Closed SONOMA (b) SONOMA

Fig. 8. **Impulse Responses in SONOMA vs Closed SONOMA.** This figure shows percentage deviations from steady state for variables expressed in logs (percentage point deviations from steady state for variables expressed in levels) in response to a one standard deviation adverse shock to domestic credit conditions (ξ), external credit conditions (r^w), or the NEE-ER (η). Our benchmark calibration is reported in Tables 1 and E1 (Appendix E).

On the asset pricing side, we have an even stronger deterioration of the results. This should not be surprising given that with CRRA preferences, news shocks are not priced. As a result, both long-run productivity growth changes and the long-run dynamics generated by financial shocks are no longer relevant for the determination of the risk premium.

Role of financial frictions and shocks. In the last two columns of Table 3, we assess the role of both financial shocks and frictions. Specifically, we first retain all shocks, but we remove the equity issuance costs ($\kappa = 0$) and we replace the collateral constraint (equation (12)) with one that sets corporate debt equal to zero in every period ($D = 0$). In turn, these changes make the domestic credit shock irrelevant because the firm is 100% equity-financed and equity issuance is free, as in a frictionless neoclassical model.

We observe a very pronounced decline in equity returns relative to the benchmark SONOMA setting. Importantly, the decline is not just mechanically due to financial leverage as unlevered returns ($r_K - r$) fall significantly as soon as financial frictions are removed. In Table 2, we report an unlevered risk premium of 3.64% for SONOMA, whereas in this case we have 3.43%. In addition, the external NFA position becomes even more volatile, in contrast to the data. These results confirm that the financial frictions studied in this manuscript are very important in all segments of the capital markets.

In the last column of Table 3, we retain all features of our SONOMA economy, but zero out financial shocks. In this case, consumption becomes much more volatile than output and the comovements of investment, domestic leverage, output and labor become counterfactual. The equity risk premium increases, but that is mainly driven by the fact that in the absence of these shocks, corporations choose a higher average level of leverage. In addition, the NEE position becomes too smooth and procyclical, in contrast to the data. The NED position becomes too smooth as well and its comovement with domestic leverage is excessively negative. The same consideration applies to the comovements between changes in the NFA position and the interest rate. These results confirm that financial shocks are relevant in explaining both equity dynamics and international positions.

4.4 Additional Results

In Appendix G, we document that in the data there exists a substantial amount of co-skewness among our external financing shocks and the domestic long-run growth conditions. Specifically, we find co-skewness between (i) the external credit shocks and long-run growth, and (ii) the NEE-ER shocks and long-run growth. After introducing a tail shock in SONOMA that mimics the extent of our empirical downside risk, we find large negative implications for capital accumulation and welfare.

5 Conclusions

We develop a new small open economy model (SONOMA) in which domestic corporate debt and equities are affected by shocks to both external credit and equity markets. In a novel empirical analysis of several small-but-developed economies, we show that both external debt and equity shocks are important determinants of domestic economic fluctuations, corporate leverage, and net foreign asset positions. SONOMA replicates our empirical facts about asset prices, financial flows, and economic activity over the medium- and long-run.

While emerging markets facing external financial shocks are extensively discussed in the literature, advanced small open economies are less studied. We believe that our model is an important first step in understanding the distinct dynamics of advanced small open economies that are exposed to both domestic and international financial shocks. Future research should consider other dimensions such as nominal frictions, monetary policy, fiscal risks. In addition, future work should address the concerns of de Groot et al. (2019).

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Appendix A: Model Solution Details

In what follows, we report our derivations step by step so that our computational methods can be easily replicated. Our set of equilibrium equations is solved by high-order pertubations computed in dynare++.

Stochastic Discount Factor

The stochastic discount factor (SDF) of the household is given as

$$\widetilde{M}_{t+1} = \beta \left(\frac{\widetilde{C}_{t+1}}{\widetilde{C}_t} \right)^{-\frac{1}{\psi}} \left(\frac{U_{t+1}}{E_t \left[U_{t+1}^{1-\gamma} \right]^{\frac{1}{1-\gamma}}} \right)^{\frac{1}{\psi}-\gamma} \frac{\partial \widetilde{C}_{t+1} / \partial C_{t+1}^P}{\partial \widetilde{C}_t / \partial C_t^P}.$$

All of the variables in this expression are stationary and can be represented in Dynare++. In what follows, we use ' to denote time-$t+1$ variables.

Solving the Household (HH) Problem

The consolidated HH problem with Lagrange multipliers (LMs) is

$$\begin{aligned} U\left(B, S, D, NED, A\right) = \max_{\substack{C^P, H^{P,s}, \\ S', D', \\ NED', NEE'}} \; & W\left(\widetilde{C}\left(C^P, 1 - H^{P,s}\right), \left\{ U\left(S', D', NED', A'\right) \right\}_{A'} \right) \\ & + \Lambda_{BC} \left[w_P H^{P,s} - T_{LS} + S\left(V^{P,ex} + d\right) + \left(1 + r_{-1}\right) D \right] \\ & - \Lambda_{BC} \left[C^P + B' + S' V^{P,ex} + D' \right] \\ & + \Lambda_{BC} \left[NED' - \left(1 + r_{-1}^{ED}\right) NED \right] \\ & - \Lambda_{BC} \left[NEE' - \left(1 + r^{EE}\right) NEE \right], \end{aligned}$$

where we have substituted out leisure using the time constraint as $\ell = 1 - H^{P,s}$.

The FOCs are

$$
\begin{aligned}
0 &= W_1 \widetilde{C}_1 - \Lambda_{BC} \\
0 &= W_1 \widetilde{C}_2 + \Lambda_{BC} w_P \\
0 &= \sum_{z'} W_2' U_S' - \Lambda_{BC} V^{P,ex} \\
0 &= \sum_{z'} W_2' U_D' - \Lambda_{BC} \\
0 &= \sum_{z'} W_2' U_{NED}' + \Lambda_{BC} \\
0 &= \sum_{z'} W_2' U_{NEE}' - \Lambda_{BC}.
\end{aligned}
$$

The envelope conditions for S, D, and NED are

$$
\begin{aligned}
U_S &= \Lambda_{BC} \left(V^{P,ex} + d \right) \\
U_D &= \Lambda_{BC} \left(1 + r_{-1} \right) \\
U_{NED} &= -\Lambda_{BC} \left(1 + r_{-1}^{ED} \right) \\
U_{NEE} &= \Lambda_{BC} \left(1 + r^{EE} \right).
\end{aligned}
$$

Combine above together to get the following optimality conditions

$$
\begin{aligned}
w_P &= -\frac{\widetilde{C}_2}{\widetilde{C}_1} \\
V^{P,ex} &= \sum_{z'} \frac{W_2' W_1' \widetilde{C}_1'}{W_1 \widetilde{C}_1} \left(\left(V^{P,ex} \right)' + d' \right) \\
1 &= \sum_{z'} \frac{W_2' W_1' \widetilde{C}_1'}{W_1 \widetilde{C}_1} \left(1 + r'^{EE} \right) \\
\left(1 + r^{ED} \right)^{-1} &= \sum_{z'} \frac{W_2' W_1' \widetilde{C}_1'}{W_1 \widetilde{C}_1} \\
(1 + r)^{-1} &= \sum_{z'} \frac{W_2' W_1' \widetilde{C}_1'}{W_1 \widetilde{C}_1}.
\end{aligned}
$$

The interest rates on domestic firm debt (r) and external debt $\left(r^{ED} \right)$ must equal each other.

Solving the Firm Problem

The firm's consolidated problem with Lagrange multipliers is

$$\begin{aligned} V^P(K,D;A) = \max_{d,H^d,I,K',D'} & \, d + \mathbb{E}\left[M'V\left(K',D';A'\right)\right] \\ & + \Lambda_{BC}\left[(1-\tau_F)\left(F\left(K,H^{P,d},A\right) - wH^d\right) - I - d - \chi(d)\right] \\ & + \Lambda_{BC}\left[D' - D\left(1 + r^D_{-1}(1-\tau_F)\right)\right] \\ & + \Lambda_K\left[(1-\delta)K + I - \Phi\left(\frac{I}{K}\right)K - K'\right] \\ & + \Lambda_{CC}\left[\xi\left(K' - D'\right) - F\left(K,H^d,A\right)\right]. \end{aligned}$$

The FOCs are

$$\begin{aligned} 0 &= 1 - \Lambda_{BC}\left(1 + \chi'(d)\right) \\ 0 &= \Lambda_{BC}(1-\tau_F)(F_H - w) - \Lambda_{CC}F_H \\ 0 &= -\Lambda_{BC} + \Lambda_K\left(1 - \Phi'\left(\frac{I}{K}\right)\right) \\ 0 &= \mathbb{E}\left[M'V'_K\right] - \Lambda_K + \Lambda_{CC}\xi \\ 0 &= \mathbb{E}\left[M'V'_D\right] + \Lambda_{BC} - \Lambda_{CC}\xi. \end{aligned}$$

The envelope conditions are

$$\begin{aligned} V_K &= \Lambda_{BC}(1-\tau_F)F_K + \Lambda_K\left(1 - \delta - \frac{\partial}{\partial K}\left(\Phi\left(\frac{I}{K}\right)K\right)\right) - \Lambda_{CC}F_K \\ V_D &= -\Lambda_{BC}\left(1 + r^D_{-1}(1-\tau_F)\right). \end{aligned}$$

Combine together the FOCs and envelope conditions and then simplify to get the following optimality conditions:

$$\begin{aligned} w_P &= \left(1 - \frac{\left(1+\chi'(d)\right)\Lambda_{CC}}{1-\tau_F}\right)F_H \\ \left(1+\chi'(d)\right)\Lambda_{CC}\xi &= \frac{1}{\left(1-\Phi'\left(\frac{I}{K}\right)\right)} - \mathbb{E}\left[M'\left\{\frac{1+\chi'(d)}{1+\chi'(d')}\left[\left(1-\tau_F - \left(1+\chi'(d')\right)\Lambda'_{CC}\right)F'_K\right]\right\}\right]\dots \\ & - \mathbb{E}\left[M'\left\{\frac{1+\chi'(d)}{1+\chi'(d')}\left[\frac{\left(1-\delta-\frac{\partial}{\partial K'}\left(\Phi\left(\frac{I'}{K'}\right)K'\right)\right)}{\left(1-\Phi'\left(\frac{I'}{K'}\right)\right)}\right]\right\}\right] \\ \left(1+\chi'(d)\right)\Lambda_{CC}\xi &= 1 - \mathbb{E}\left[M'\left\{\frac{1+\chi'(d)}{1+\chi'(d')}\left(1 + r(1-\tau_F)\right)\right\}\right] \end{aligned}$$

These equations can be rewritten and expanded as

$$w_P = \left(1 - \frac{\tilde{\Lambda}_{CC}}{1-\tau_F}\right) F_H \tag{A1}$$

$$1 = \mathbb{E}\left[M' R_K^{'}\right] \tag{A2}$$

$$R_K^{'} = \frac{q_d'}{q_d}\left[\frac{\left((1-\tau_F) - \tilde{\Lambda}_{CC}'\right) F_K' + q_K^{'}\left(1 - \delta - \frac{\partial}{\partial K'}\left(\Phi\left(\frac{I'}{K'}\right) K'\right)\right)}{q_K - \tilde{\Lambda}_{CC}\xi}\right] \tag{A3}$$

$$\tilde{\Lambda}_{CC} = \frac{1 - \mathbb{E}\left[M'\left\{\frac{q_d'}{q_d}\left(1 + r\left(1-\tau_F\right)\right)\right\}\right]}{\xi} \tag{A4}$$

$$q_K = \frac{1}{1 - \Phi'\left(\frac{I}{K}\right)} \tag{A5}$$

$$q_d = \frac{1}{1 + \chi'\left(d\right)}, \tag{A6}$$

where we have defined

$$\begin{aligned} \tilde{\Lambda}_{CC} &\equiv \left(1 + \chi'\left(d\right)\right)\Lambda_{CC} \\ &\equiv \frac{\Lambda_{CC}}{q_d}. \end{aligned}$$

From this expression, the value of the exact LM is recovered as

$$\Lambda_{CC} = \frac{\tilde{\Lambda}_{CC}}{\left(1 + \chi'\left(d\right)\right)}$$

or

$$\Lambda_{CC} = q_d \tilde{\Lambda}_{CC},$$

where $\tilde{\Lambda}_{CC}$ is pinned down by the model equation above. If the collateral constraint binds in equilibrium then $\Lambda_{CC} > 0$ and

$$\xi\left(K' - D'\right) = F\left(K, H^{P,d}, A\right).$$

This constraint can be rearranged to define D' as

$$D' = K' - \frac{F\left(K, H^{P,d}, A\right)}{\xi}.$$

From this expression, we can see that $\xi > 0$ must be set sufficiently high in order for $D' > 0$ given a set of values for K' and $F\left(K, H^{P,d}, A\right)$.

If $\Lambda_{CC} \leq 0$, the collateral constraint may not be binding and D is determined by the following equation:

$$\begin{aligned} 1 &= \mathbb{E}\left[M'\left\{\frac{1+\chi'(d)}{1+\chi'(d')}(1+r(1-\tau_F))\right\}\right] \\ &= (1+r(1-\tau_F))\,\mathbb{E}\left[M'\left\{\frac{1+\chi'(d)}{1+\chi'(d')}\right\}\right]. \end{aligned}$$

If $\chi'(d) = \chi'(d') = 0$ (e.g., $\kappa = 0$), then the above optimality simplifies to

$$\Lambda_{CC}\xi = 1 - \mathbb{E}\left[M'\right](1+r(1-\tau_F)).$$

From the HH optimality conditions, we know that

$$\mathbb{E}\left[M'\right] = \frac{1}{1+r},$$

hence if $\tau_F > 0$ we obtain

$$\mathbb{E}\left[M'\right](1+r(1-\tau_F)) < 1,$$

meaning that $\Lambda_{CC} > 0$ with certainty and the collateral constraint binds in equilibrium. We solve the model assuming that the collateral constraint binds and check ex-post that Λ_{CC} is positive in our simulations.

Closed Economy Setting

Solving the closed-economy version of our model requires us to modify only a few equations. We replace the following equations

$$\begin{aligned} r_t^{ED} &= r_{t-1}^w + P_t^{ED} \\ r_t^{EE} &= \eta_{t-1} + P_t^{EE} + \sigma_{ee}\epsilon_{ee,t} \\ 1 &= E_t\left[M_{t+1}r_{t+1}^{EE}\right], \end{aligned}$$

with equations that impose

$$NED_t = NEE_t = r_t^{EE} = 0 \qquad \forall t.$$

Appendix B: Convex Distress Cost

This section shows the results from using a convexified cost instead of the collateral constraint in benchmark calibrations. As we can see in Table B1, our results are very similar regardless of whether we employ convex distress costs or assume a binding constraint.

In what follows, we describe in detail how the model equations are modified to include a convex distress cost instead of the binding constraint. We no longer include the equation for the collateral constraint, rather we convexify the penalty of violating the constraint. Specifically, the firm's condensed problem is

$$V^P(K, D; A) = \max_{d, H^{P,d}, I, K', D'} d + \mathbb{E}\left[M' V\left(K', D'; A'\right)\right]$$

subject to

$$\begin{aligned}(1-\tau_F)\left(F\left(K, H^d, A\right) - wH^d\right) - I &= d + \chi(d) + D\left(1 + r_{-1}^D(1-\tau_F)\right) - D' + CC \\ K' &= (1-\delta)K + I - \Phi\left(\frac{I}{K}\right)K\end{aligned}$$

where the constraint $\xi_t(K' - D') \geq F\left(K, H^d, A\right)$ is now captured by the convexified cost function CC. Following Croce et al. (2012), we use the following functional form

$$CC = A_{t-1} \times cc_1 \times e^{-cc_2\left[\xi_t(K'-D') - F\left(K, H^d, A\right)\right]}$$

and set the parameter cc_1 to be close to zero ($cc_1 = 0.001$), whereas the parameter cc_2 is chosen to be large ($cc_2 = 1000$).

The firm's problem is

$$\begin{aligned}V^P(K, D; A) = \max_{d, H^{P,d}, I, K', D'} & \; d + \mathbb{E}\left[M' V\left(K', D'; A'\right)\right] \\ & + \Lambda_{BC}\left[(1-\tau_F)\left(F\left(K, H^d, A\right) - wH^d\right)\right] \\ & + \Lambda_{BC}\left[-I - d - \chi(d) + D' - D\left(1 + r_{-1}^D(1-\tau_F)\right) - CC\right] \\ & + \Lambda_K\left[(1-\delta)K + I - \Phi\left(\frac{I}{K}\right)K - K'\right],\end{aligned}$$

where Λ denotes lagrangian multipliers. The associated first order conditions are:

$$
\begin{aligned}
0 &= 1 - \Lambda_{BC}\left(1 + \chi'(d)\right) \\
0 &= \Lambda_{BC}\left[(1-\tau_F)(F_H - w) - \frac{\partial CC}{\partial H^d}\right] \\
0 &= -\Lambda_{BC} + \Lambda_K\left(1 - \Phi'\left(\frac{I}{K}\right)\right) \\
0 &= \mathbb{E}\left[M' V_K'\right] - \Lambda_K - \Lambda_{BC}\frac{\partial CC}{\partial K'} \\
0 &= \mathbb{E}\left[M' V_D'\right] + \Lambda_{BC}\left(1 - \frac{\partial CC}{\partial D'}\right).
\end{aligned}
$$

The envelope conditions are

$$
\begin{aligned}
V_K &= \Lambda_{BC}\left[(1-\tau_F)F_K - \frac{\partial CC}{\partial K}\right] + \Lambda_K\left(1 - \delta - \frac{\partial}{\partial K}\left(\Phi\left(\frac{I}{K}\right)K\right)\right) \\
V_D &= -\Lambda_{BC}\left(1 + r_{-1}^{D}(1-\tau_F)\right).
\end{aligned}
$$

Combine together the FOCs and envelope conditions to get the following optimality conditions

$$
\begin{aligned}
\Lambda_{BC} &= \frac{1}{1 + \chi'(d)} \\
(1-\tau_F)(F_H - w_P) &= \frac{\partial CC}{\partial H^{P,d}} \\
\Lambda_{BC} &= \Lambda_K\left(1 - \Phi'\left(\frac{I}{K}\right)\right) \\
\Lambda_K + \Lambda_{BC}\frac{\partial CC}{\partial K'} &= \mathbb{E}\left[M'\left\{\Lambda_{BC}'\left[(1-\tau_F)F_K' - \left(\frac{\partial CC}{\partial K}\right)'\right]\right\}\right] \\
&= +\mathbb{E}\left[M'\left\{\Lambda_K'\left(1 - \delta - \frac{\partial}{\partial K'}\left(\Phi\left(\frac{I'}{K'}\right)K'\right)\right)\right\}\right] \\
\Lambda_{BC}\left(1 - \frac{\partial CC}{\partial D'}\right) &= \mathbb{E}\left[M'\left(\Lambda_{BC}'\left(1 + r(1-\tau_F)\right)\right)\right].
\end{aligned}
$$

After some simplifications:

$$
\begin{aligned}
(1-\tau_F)(F_H - w_P) &= \frac{\partial CC}{\partial H^{P,d}} \\
\left(\frac{1}{1+\chi'(d)}\right)\left(\frac{1}{\left(1-\Phi'\left(\frac{I}{K}\right)\right)} + \frac{\partial CC}{\partial K'}\right) &= \mathbb{E}\left[M'\left\{\frac{1}{1+\chi'(d')}\left[(1-\tau_F)F_K' - \left(\frac{\partial CC}{\partial K}\right)'\right]\right\}\right] \\
&= +\mathbb{E}\left[M'\left\{\frac{\left(1-\delta-\frac{\partial}{\partial K'}\left(\Phi\left(\frac{I'}{K'}\right)K'\right)\right)}{\left(1+\chi'(d')\right)\left(1-\Phi'\left(\frac{I'}{K'}\right)\right)}\right\}\right] \\
1-\frac{\partial CC}{\partial D'} &= (1+r(1-\tau_F))\,\mathbb{E}\left[M'\left(\frac{1+\chi'(d)}{1+\chi'(d')}\right)\right].
\end{aligned}
$$

These equations can be rewritten and expanded as

$$
\begin{aligned}
\frac{\partial CC}{\partial H^d} &= (1-\tau_F)(F_H - w) \\
1 &= \mathbb{E}\left[M' R_K'\right] \\
R_K' &= \left(\frac{q_d'}{q_d}\right)\left(\frac{\left[(1-\tau_F)F_K' - \left(\frac{\partial CC}{\partial K}\right)'\right] + q_K'\left(1-\delta-\frac{\partial}{\partial K'}\left(\Phi\left(\frac{I'}{K'}\right)K'\right)\right)}{\left(q_K + \frac{\partial CC}{\partial K'}\right)}\right) \\
\frac{\partial CC}{\partial D'} &= 1-\mathbb{E}\left[M'\left(\frac{q_d'}{q_d}\right)(1+r(1-\tau_F))\right] \\
q_K &= \frac{1}{1-\Phi'\left(\frac{I}{K}\right)} \\
q_d &= \frac{1}{1+\chi'(d)}.
\end{aligned}
$$

Using the functional form

$$
CC = A_{t-1} \times cc_1 \times e^{-cc_2\left[\xi_t(K'-D') - F\left(K, H^d, A\right)\right]}
$$

we have the following expressions for the derivatives

$$
\begin{aligned}
\frac{\partial CC}{\partial H^{P,d}} &= CC \times cc_2 \times F_H \\
\left(\frac{\partial CC}{\partial K}\right)' &= CC' \times cc_2 \times F_K' \\
\frac{\partial CC}{\partial K'} &= CC \times (-cc_2) \times \xi \\
\frac{\partial CC}{\partial D'} &= CC \times cc_2 \times \xi
\end{aligned}
$$

Table B1: Model with Convex Distress Costs

Moments		Binding Constraint	Convexified Constraint
Macro	$\sigma(\Delta i)/\sigma(\Delta y)$	1.95	1.94
	$\sigma(\Delta c)/\sigma(\Delta y)$	1.08	1.08
	$corr(\Delta i, \Delta c)$	0.64	0.65
	$corr(\Delta i, \Delta \log(D))$	0.03	0.01
	$corr(\Delta y, \Delta h)$	0.53	0.54
Returns	$\mathbb{E}[r]$ (%)	1.54	1.45
	$corr(r, \Delta y)$	0.10	0.08
	$\mathbb{E}[r_E - r]$ (%)	5.68	5.91
	$\sigma(r_E - r)$ (%)	7.27	7.05
	$\mathbb{E}[r_K - r]$ (%)	3.64	3.77
	$\sigma(r_K - r)$ (%)	4.94	4.93
	$\mathbb{E}[r - r^w]$ (%)	0.42	0.33
	$\sigma(r - r^w)$ (%)	0.62	0.55
Leverage	$\mathbb{E}[D/K]$ (%)	34.41	35.99
	$\sigma(D/K)$ (%)	6.67	6.18
	$corr(\Delta(D/K), \Delta y)$	0.05	0.05
	$\sigma(d/K)/\sigma(\Delta y)$ (%)	1.45	1.38
NFA	$\mathbb{E}[NED/Y]$ (%)	53.53	52.67
	$\mathbb{E}[NEE/Y]$ (%)	8.41	8.54
	$\sigma(\Delta(NED/Y))$ (%)	2.59	2.72
	$\sigma(\Delta(NEE/Y))$ (%)	8.04	8.69
	$corr(\Delta(NED/Y), \Delta y)$	-0.53	-0.53
	$corr(\Delta(NEE/Y), \Delta y)$	-0.24	-0.28
	$corr(\Delta(NED/Y), \Delta(NEE/Y))$	0.35	0.34
	$corr(NED/Y, D/K)$	-0.36	-0.33
	$corr(NEE/Y, D/K)$	0.03	0.02
Current Acc.	$\sigma(\Delta NFA/Y)$ (%)	4.21	4.33
	$acf(\Delta NFA/Y)$	0.84	0.84
	$corr(\Delta NFA/Y, r)$	0.56	0.63

Notes: The calibration for our benchmark open economy setting SONOMA is reported in Table 1.

Hence $CC \times cc_2$ replaces the multiplier ($\tilde{\Lambda}_{CC}$) in front of the borrowing constraint in our benchmark model.

Appendix C: Data Sources

In the table below, we summarize our main sources by data type. The sample for each data source and country is detailed in a companion document (Croce et al. (2019), available here: `https://sites.google.com/view/sonoma-macrofin/home`) that we update regularly together with the exhibits in this manuscript.

Table C1: Summary of Data Sources

Panel A: List of Sources	
Name	**Acronym**
Bank of International Settlements	BIS
International Monetary Fund	IMF
Organisation for Economic Co-Operation and Development	OECD
Penn World Table	PWT
Ken French Data Library	KF
Bloomberg	BLOOM
Panel B: Data Sources	
Variable	**Source**
National aggregates (GDP, C, I)	OECD
Depreciation	PWT
Labor hours	OECD, PWT
Private sector debt	BIS
Net external debt	IMF
Domestic interest rates	OECD
Public equity data	KF, BLOOM
Inflation	IMF
Exchange rates	IMF

Notes: This table summarizes our main data sources.

National Aggregates. Quarterly gross domestic product, investment, and consumption data are from the OECD. The data series are pulled from the statistics tool (`https://stats.oecd.org/`) as the full time series are considered estimates and therefore not posted on the main OECD website. Other comprehensive databases such as the IMF's *International Financial Statistics* database only include the recent period (e.g., from the mid 1990s for most European countries).

Depreciation. Annual average depreciation rates are from the PWT.

Labor Income Share. Annual labor income share values are from the PWT.

Labor. Quarterly and annual hours worked are computed from OECD labor data. for most of our countries from Haver Analytics. We compute quarterly (annual) hours worked as the product of quarterly (annual) number of persons employed by the average annual number of hours worked.

Private Sector Debt. Quarterly credit to non-financial corporations from all lenders is available from the BIS.

Net External Debt. Quarterly and annual asset and liability positions in U.S. dollars are available from the IMF's *Balance of Payments and International Investment Position Statistics* database. We follow the same method as Lane and Milesi-Ferretti (2007) to compute net external debt from the reported asset and liability positions. While Lane and Milesi-Ferretti (2007) do make available their *External Wealth of Nations* dataset, they only provide annual data.

Domestic Interest Rates. Quarterly long-term interest rates are available from the OECD. We construct domestic interest rates as the sum of a benchmark large economy (e.g., Germany) plus the spread between the benchmark large economy and the small open economy.

Public Equity Data. Monthly equity returns with dividends (r^{cum}) and without dividends (r^{ex}) are available from the Ken French Data Library. We compute quarterly price-dividend ratios in three steps. First, we compute monthly price (p) and dividend (d) series using the recursion $p_t = (1 + r_t^{ex})p_{t-1}$ and $d_t = (1 + r_t^{cum})p_{t-1} - p_t$ after initializing $p_0 = 1$. Second, we compute monthly price-dividend ratios as $PD_t = p_t / \sum_{\tau=t-11}^{t} d_\tau$. Third and finally, we compute quarterly price-divided ratios as the average of the monthly values in a given quarter. For Portugal, the quarterly price-dividend series is from Bloomberg for the MSCI Portugal Index ($MXPT\ Index$).

Inflation. Quarterly consumer price indices for all items are available from the IMF's *International Financial Statistics* database. We use these series in two ways. First, we construct measures of quarterly inflation in order to convert nominal returns into real returns. Second, we deflate nominal quantities using the price index in order to compute real growth rates.

Exchange Rates. Quarterly exchange rates are available from the IMF's *International Financial Statistics* database. We use these data to compute gross domestic product figures in U.S. dollars in order to compute net external debt ratios. The external debt data are only provided in U.S. dollars.

World Price-Dividend Ratio. We use the "Major Markets" international index provided by the Ken French Data Library to construct the P/D ratio. This index is composed from all the country-level indexes in the library. We follow the same method to construct quarterly price-dividend ratios as described in Public Equity Data for individual countries. The Major Markets index is also used to represent world equity returns in our country-level volatility-adjusted spread (VAS) measures.

Appendix D: Additional Empirical Results

In Table D1, we report the results obtained when extracting the long-run component.

Table D1: Extracting Long-Run Productivity Growth (x)

Log Price-Dividend Ratio	0.014***
	(5.52)
Inflation	0.158***
	(4.94)
Risk-free Rate	0.027
	(0.36)
R^2	0.074
N	898

This table shows the coefficient estimates from the following panel regression:

$$\Delta a_t^{j,dm} = \beta' X_{t-1}^{j,dm} + \epsilon_{a,t}^j$$

where the dependent variable is the productivity growth rate. All variables are demeaned at the country level and therefore we omit the constant term. Standard errors are heteroskedasticity-consistent. t-statistics are in parentheses. $^*p < 0.10$; $^{**}p < 0.05$; $^{***}p < 0.01$.

In Table D2, we report our country-level results for the estimation of the external interest rate spread (P^{ED}) coefficients.

Table D2: Extracting External Credit Conditions (r^w)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Panel	Finland	Italy	Portugal	Spain	Sweden	Switzerland
Lag Demeaned NED/Y	0.0025***	0.0015*	0.0037***	0.0051***	0.0025***	0.0030*	0.0017***
	(5.24)	(1.69)	(3.99)	(4.37)	(3.41)	(1.95)	(3.71)
Constant	0.0008***	0.0009	0.0020***	0.0031**	0.0008	0.0018***	-0.0008
	(2.98)	(1.57)	(3.26)	(2.57)	(0.90)	(2.83)	(-1.54)
R^2	0.249	0.120	0.481	0.584	0.456	0.065	0.317
N	877	96	96	88	96	96	96

This table shows the coefficient estimates from the following panel regression:

$$\ln\left(1 + P_t^{ED,j}\right) = \ln(p_{ED,2}^j) + p_{ED,1}^j \left(NED_t^j/Y_t^j - \overline{NEDY}^j\right) + \varepsilon_t^j$$

where the dependent variable is the log of one plus the difference between the real interest rate of country j and the real German rate. The independent variable is the the demeaned net external debt ratio for country j. See section 3.1 for additional details. Standard errors are HAC-adjusted. t-statistics are in parentheses. $^*p < 0.10$; $^{**}p < 0.05$; $^{***}p < 0.01$.

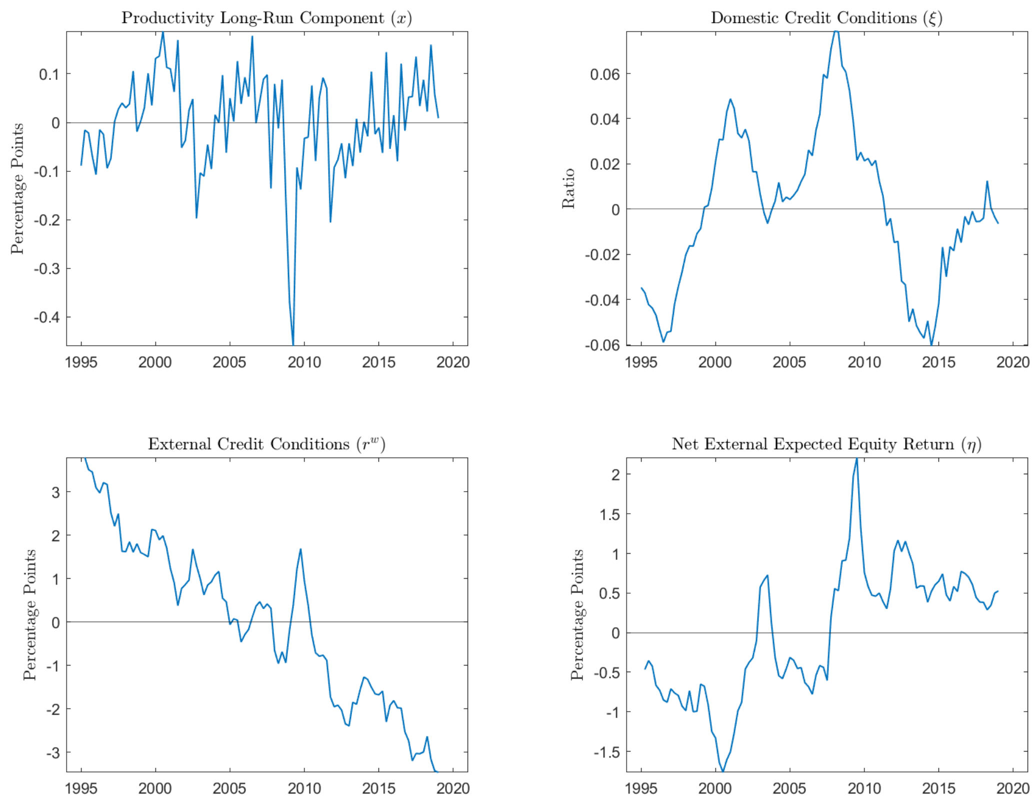


Fig. D1. **Common Estimated Processes.** This figure shows our estimated long-run component (x), domestic credit conditions (ξ), external cost of debt (r^w) and external expected return on net equity (η). All results are based on a cross sectional average across the countries in our sample. All series are demeaned.

In Figure D1, we depict the fundamental exogenous processes used in our empirical analysis. In each panel, we depict a cross-country average of the process of interest.

In Figure D2 and D3, we depict impulse responses computed using country-level data, as opposed to cross country averages.

Figure D4 show the joint distribution of country-level shocks recovered from our country-level VARs.

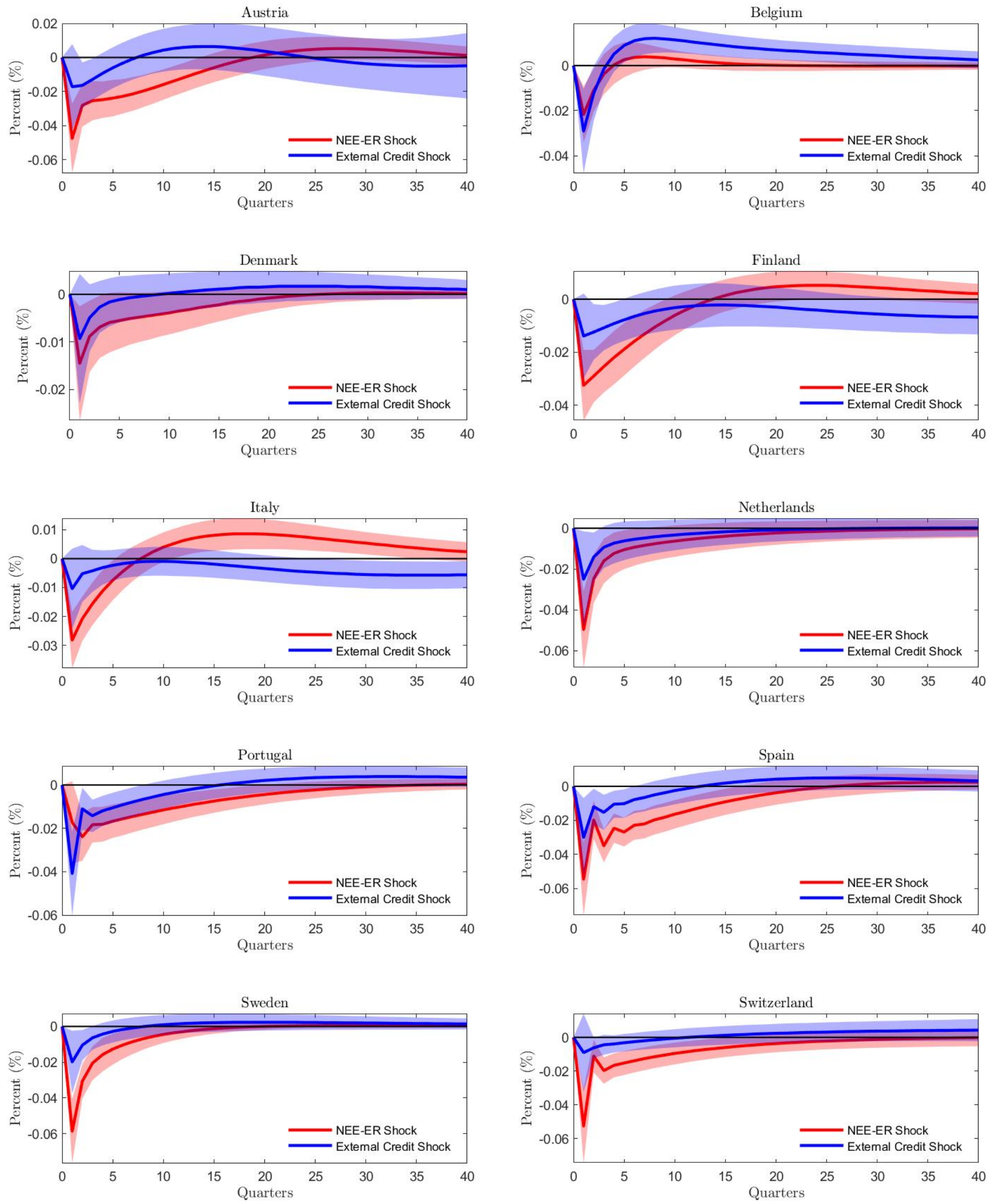


Fig. D2. **Impulse Responses in Data VAR by Country: Productivity Long-Run Component (x).** This figure shows the responses of the long-run component of productivity (x) to adverse shocks from external credit (r^w) and equity (NEE-ER, η) markets. All results are based on the VAR specified in equations (19)-(20) using individual country-level data. Confidence intervals are HAC-adjusted. Our sources are detailed in Appendix C and our quarterly sample starts in 1995:Q1 and ends in 2018:Q4.

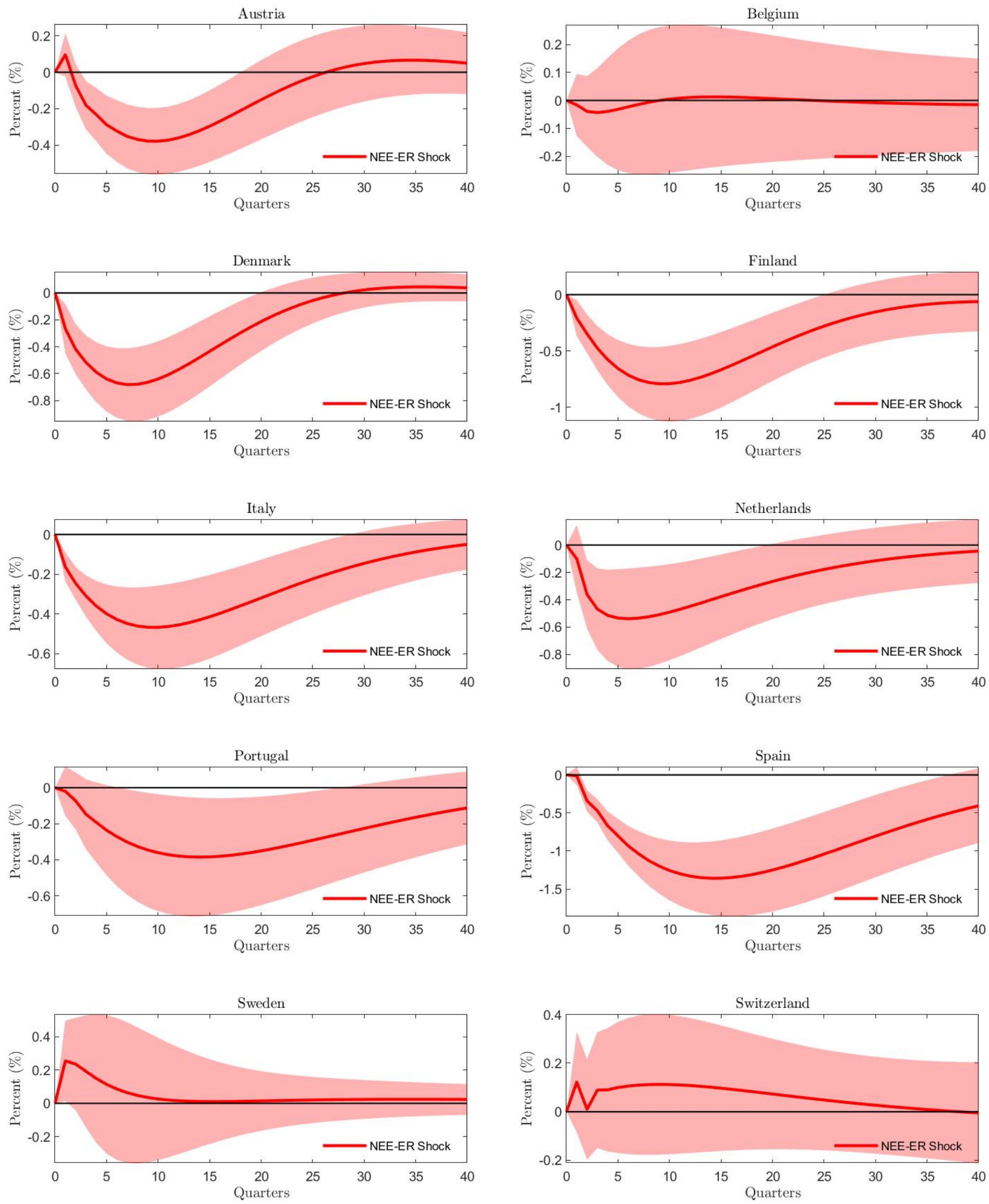


Fig. D3. **Impulse Responses in Data VAR by Country: Domestic Credit Conditions (ξ).** This figure shows the responses of domestic credit conditions (ξ) to adverse shocks from external equity (NEE-ER, η) markets. All results are based on the VAR specified in equations (19)-(20) using individual country-level data. Confidence intervals are HAC-adjusted. Our sources are detailed in Appendix C and our quarterly sample starts in 1995:Q1 and ends in 2018:Q4.

Fig. D4. **VAR Residual Scatter Plots.** This figure shows the VAR residuals (i.e., innovations) from the external credit conditions (r^w) and NEE-ER (η) equations against the long-run productivity news (ϵ_x). All results are based on the VAR specified in equations (19)-(20) using country-level data. Our sources are detailed in Appendix C and our quarterly sample starts in 1995:Q1 and ends in 2018:Q4.

Table E1: SONOMA Benchmark Calibration

Preferences			Estimate/Moment
Relative Risk Aversion	(γ)	10	$\mathbb{E}[r^{ex}]$
Intertemporal Elasticity of Substitution	(ψ)	2	$\sigma(\Delta c)/\sigma(\Delta y)$
Subjective Discount Rate	(β)	0.99	$\mathbb{E}[r^{ED}]$
Consumption-Leisure Aggregator			
Consumption Coefficient	(φ)	0.35	$\mathbb{E}[C/Y]$
Elasticity of Substitution	(f)	0.3	$corr(\Delta y, \Delta h)$
Production			
Capital Share	(α)	0.36	JQ(2012)
Capital Depreciation Rate	(δ)	0.10/4	JQ(2012)
Capital Adjustment Cost Elasticity	(ϕ_2)	1.5	$\sigma(\Delta i)/\sigma(\Delta y)$
Corporate Tax Rate	(τ_F)	0.35	JQ(2012)
Productivity Growth Rate			
Average	(μ_a)	0.020/4	$\mathbb{E}[\Delta y]$
Volatility of Short-Run Shock	(σ_a)	0.046/2	0.041/2 (0.003/2)
Persistence of Long-Run Component	(ρ_x)	0.95	0.93 (0.02)
Volatility of Long-Run Shock	(σ_x)	$0.10\sigma_a$	0.08 (0.01)

Notes: This table reports our benchmark quarterly calibration for a subset of canonical parameters. The last column reports either a direct empirical estimate of the calibrated parameter or a specific moment that we target in our calibration procedure. JQ(2012) refers to parameter values that we get directly from Jermann and Quadrini (2012). Our smoothing parameter θ for the process determining the standards of living process, SL, is equal to 0.50.

Appendix E: Calibration (II)

In this section, we discuss the calibration of canonical parameters that are common to many production-based asset pricing models. Focusing on preferences, we choose the coefficient of relative risk aversion γ, the subjective discount factor β, and the intertemporal elasticity of substitution ψ in the spirit of the long-run risk literature (see, among others, Bansal et al. 2012 and Croce 2014). Specifically, the subjective discount factor β, is set to match the average country-specific interest rate, r_t. The IES is calibrated to be greater than one and enables us to match the volatility of consumption to that of output. The relative risk aversion is set to 10 and enables us to produce a high average equity excess return, $E[r^{ex}]$.

Since we use a CES aggregator to construct the consumption bundle $\widetilde{C}_t$ in equation (2.1), we need to calibrate two parameters: the consumption weight φ, and the elasticity of substitution coefficient f. Our choices of parameter are comparable to other studies in the international macroeconomics literature such as, for example, Zetlin-Jones and Shourideh (2017). In addition, we need to calibrate the smoothing parameter for the standards of living process. We choose a moderate value, $\theta = 0.50$.

The countries in our cross section are all developed and share production characteristics that are similar to those in other advanced economies, such as the United States. As a result, we choose values for capital share of output α and capital depreciation rate δ that are close to values used in previous studies by Kaltenbrunner and Lochstoer (2010), Jermann and Quadrini (2012), and Croce (2014). We set the coefficient of the elasticity of adjustment cost ϕ_2 to 1.5 in order to match the volatility of investment growth relative to that of output growth. Our value is smaller than $\phi_2 = 7$ used by Croce (2014), but it is larger than 0.7 used by Kaltenbrunner and Lochstoer (2010). The corporate tax rate changes across countries, but $\tau_F = 0.35$ is a good representative value, given our sample. In Jermann and Quadrini (2012) economy, the value of τ_F determines whether the enforcement constraint is binding. In our model, the enforcement constraint is not always binding in simulations. However, this does not affect the results. As a robustness check, we carry out an exercise where instead of a collateral constraint, the economy faces a convex distress cost (which imposes a steep convex penalty). As shown in Appendix B, the output of this exercise are very close to the benchmark model that features collateral constraints.

We next turn to the productivity growth process. Its average growth, μ_a, is set to match the average growth rate in the sample. We jointly estimate the volatility of short-run shocks (σ_a), the persistence of the productivity long-run component (ρ_x); and the relative volatility of the long-run shocks (σ_x/σ_a) from an unbalanced panel of countries in our sample.[10] The two correlations between the long-run component and external financial condition shocks, $\rho_{rw,x}$ and $\rho_{\eta,x}$, are based on our VAR estimation.

[10]We use an unbalanced panel since the balanced panel starts in 1995, and is thus too short for estimating this parameter satisfactory. In addition, in order to minimize short-sample noise, the persistence parameter is estimated using a 4-quarter moving average of the long-run component.

Appendix F: Replication of Jermann and Quadrini

In this section, we first show that we are able to replicate the results in Jermann and Quadrini (2012). Next, we show how these results change when modifying the parameter values to those in SONOMA.

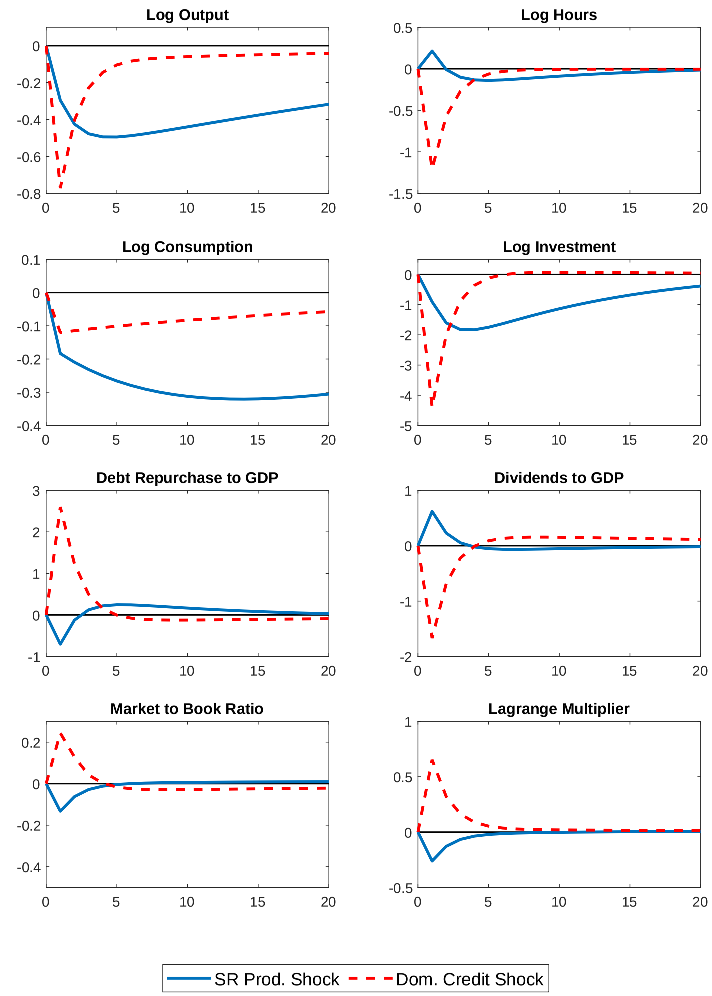
Table F1 shows the calibration that we use to replicate the benchmark model in Jermann and Quadrini (2012). These parameter values are the same as those in their paper with the following exceptions: we set $(\sigma_a, \mu_\xi, \sigma_\xi) = (0.0045 \times 3/2, 0.35, 0.005)$ instead of $(\sigma_a, \mu_\xi, \sigma_\xi) = (0.0045, 0.1634, 0.0098)$. We choose these values in order to match (i) their steady-state quarterly debt-to-output ratio of 3.36; and (ii) the impulse response functions seen in Figure 6 of Jermann and Quadrini (2012).

The main reason of this change is that their production function, $F(A_t, K_t, H_t) = A_t K_t^\theta H_t^{1-\theta}$, is not consistent with balanced growth when A is non-stationary. By using $F(A_{t-1}, K_t, H_t) = K_t^\theta (A_{t-1} H_t^{1-\theta})$ as production function, balanced growth is preserved and we simply need to modify slightly the shock sizes and average level of ξ to quantitatively match their output.

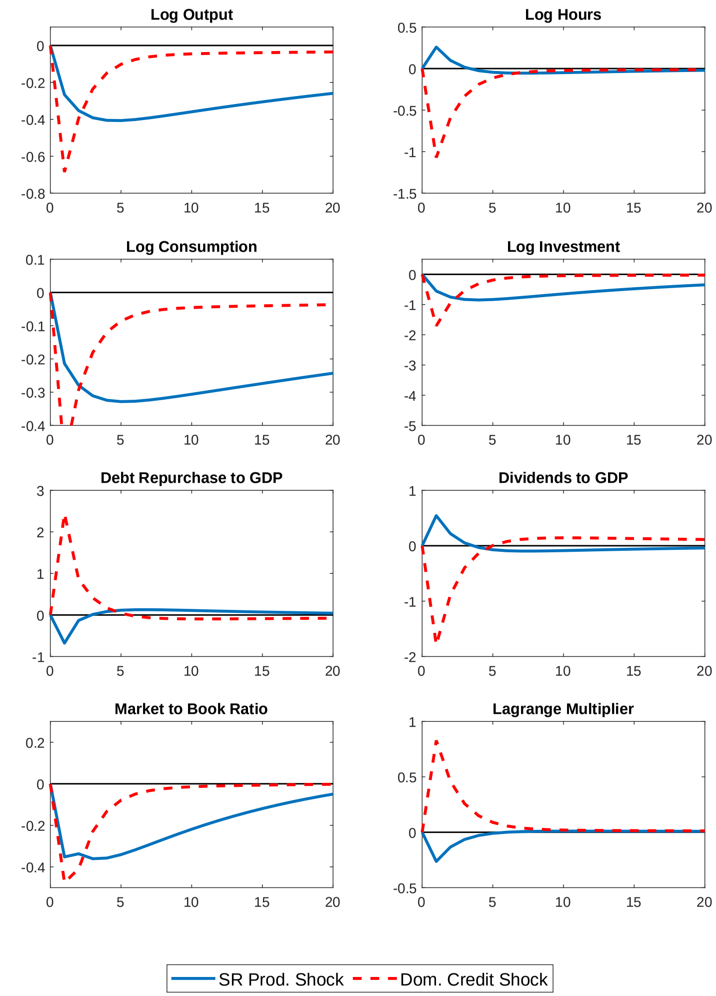
Table F1: Calibration to Replicate Jermann and Quadrini (2012)

Preferences		Replication	JQ (w. CAC)	Stronger CAC, Prod. LRR
Relative Risk Aversion	(γ)	1.1	1.1	1.1
Intertemporal Elasticity of Substitution	(ψ)	0.91	0.91	0.91
Subjective Discount Rate	(β)	0.98	0.98	0.99
Consumption-Leisure Aggregator				
Consumption Coefficient	($\tilde{w}_1$)	1.00	1.00	0.35
Leisure Coefficient	($\tilde{w}_2$)	1.88	1.88	0.65
Elasticity of Substitution	(f)	1.0	1.0	1.0
Production				
Capital Share	(α)	0.36	0.36	0.36
Capital Depreciation Rate	(δ)	0.10/4	0.10/4	0.10/4
Capital Adjustment Cost Elasticity	(ϕ_2)	1000	5	2
Corporate Tax Rate	(τ_F)	0.35	0.35	0.35
Productivity Growth Rate				
Average	(μ_a)	0.000/4	0.000/4	0.020/4
Volatility of Short-Run Shock	(σ_a)	0.014/2	0.014/2	0.046/2
Persistence of Long-Run Component	(ρ_x)	0.95	0.95	0.95
Volatility of Long-Run Shock	(σ_x)	$0.00\sigma_a$	$0.00\sigma_a$	$0.10\sigma_a$
Domestic Financial Markets				
Average Domestic Credit Conditions	(μ_ξ)	0.35	0.35	0.35
Persistence of Domestic Credit Conditions	(ρ_ξ)	0.97	0.97	0.97
Volatility of Domestic Credit Conditions Shock	(σ_ξ)	0.010/2	0.010/2	0.010/2
Equity Adj. Cost Coefficient	(κ)	0.146	0.146	0.146

Notes: Parameter values to replicate the benchmark model in Jermann and Quadrini (2012).



(a) Benchmark



(b) Benchmark with Capital Adjustment Costs

Fig. F1. **Replication of Impulse Responses.** This figure shows percentage deviations from steady state for variables expressed in logs and percentage point deviations from steady state for variables expressed in levels. "Benchmark" refers to the benchmark calibration in Jermann and Quadrini (2012) (see Table F1). To add capital adjustment costs, we set the capital adjustment costs parameter as $\phi_2 = 5$. All responses refer to the realization of adverse shocks to productivity and credit conditions.

Table F2: From Closed Replication to Closed SONOMA

Moments		JQ (w. CAC)	Stronger CAC, Prod. LRR	Closed SONOMA
Macro	$\sigma(\Delta i)/\sigma(\Delta y)$	2.46	2.48	2.13
	$\sigma(\Delta c)/\sigma(\Delta y)$	0.73	0.62	0.89
	$corr(\Delta i, \Delta c)$	1.00	0.92	0.51
	$corr(\Delta i, \Delta \log(D))$	0.51	0.67	0.13
	$corr(\Delta y, \Delta h)$	0.85	0.92	0.31
Returns	$\mathbb{E}[r]$ (%)	7.14	3.96	5.04
	$corr(r, \Delta y)$	-0.34	-0.42	-0.03
	$\mathbb{E}[r_E - r]$ (%)	0.07	0.51	2.94
	$\sigma(r_E - r)$ (%)	1.13	4.35	7.63
	$\mathbb{E}[r_K - r]$ (%)	0.02	0.28	2.10
	$\sigma(r_K - r)$ (%)	0.45	1.98	4.65
	$\mathbb{E}[r - r^w]$ (%)	0.00	0.00	0.00
	$\sigma(r - r^w)$ (%)	0.00	0.00	0.00
Leverage	$\mathbb{E}[D/K]$ (%)	53.85	41.54	36.11
	$\sigma(D/K)$ (%)	2.27	4.30	5.88
	$corr(\Delta(D/K), \Delta y)$	0.49	0.66	0.14
	$\sigma(d/K)/\sigma(\Delta y)$ (%)	1.30	1.61	1.47

Notes: "JQ (w. CAC)" is our Jermann and Quadrini (2012) replication calibration (Table F1) with capital adjustment costs set to $\phi_2 = 5$. "Stronger CAC, Prod. LRR" means that we (i) further tighten capital adjustment costs to the level in SONOMA; (ii) increase the short-run shock volatility to level in SONOMA; and (iii) add long-run risk. The Closed SONOMA calibration is the same as the benchmark open economy calibration except that the open economy parameters are superfluous.

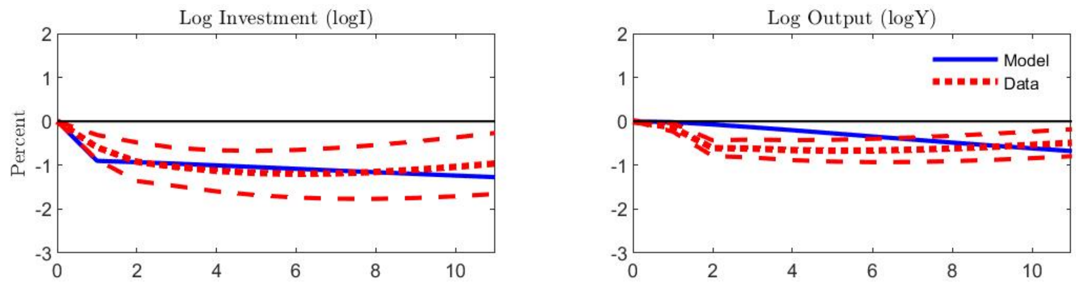
In Figure F1, we depict impulse responses that confirm our replication effort. Panel (a) (left) can be compared against Figure 6 of Jermann and Quadrini (2012), and panel (b) (right) can be compared against their Figure 7. In Table F2, we show how key simulated moments change as we move towards the Closed SONOMA calibration. By comparing the moments across columns, we see three key outcomes that differ in Closed SONOMA.

First, the correlation between investment growth and consumption growth becomes smaller than one. Second, average excess returns (i.e., the equity premium) increase significantly as well as the volatility of excess returns. This result was to be expected given that Closed SONOMA features EZ preferences, higher risk aversion, and an intertemporal elasticity of substitution greater than one. Third, we see the volatility of the firm debt to capital ratio increases, meaning that the firm is more actively changing its debt position.

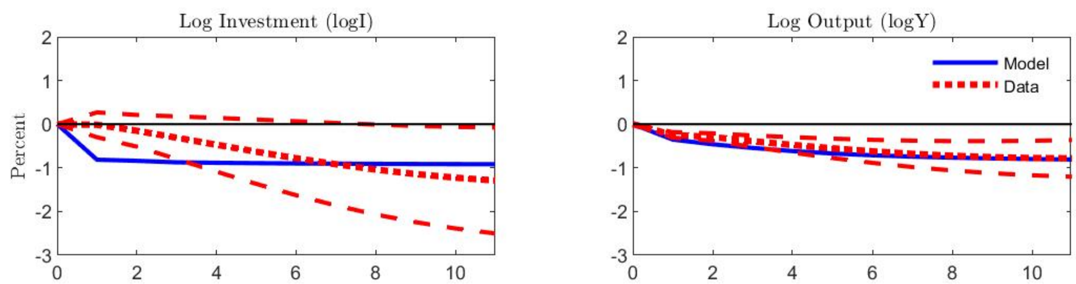
Appendix G: Additional Results

Appendix G.1. Impulse Response Functions

In this section, we show impulse response functions of potential interest to the reader. Figure G1 depicts the responses of key macroeconomic variables after adverse productivity shocks both in our SONOMA setting and in the data.



(a) Long-Run Productivity Shock



(b) Short-Run Productivity Shock

Fig. G1. **Model versus VAR: Economic Aggregates and Productivity.** This figure shows the responses of log investment ($\log I$) and log output ($\log Y$) to shocks to long-run productivity growth (x) and short-run productivity growth (Δa). The model responses are based on the calibration in Table E1. The data responses are based on the VAR specified in equations (19) and (21) using data constructed from cross-country averages. For both model and data, the shock sizes for long-run and short-run productivity growth are 1.0% and 0.1%, respectively. Confidence intervals are HAC-adjusted. Our sources are detailed in Appendix C and our quarterly sample starts in 1995:Q1 and ends in 2018:Q4.

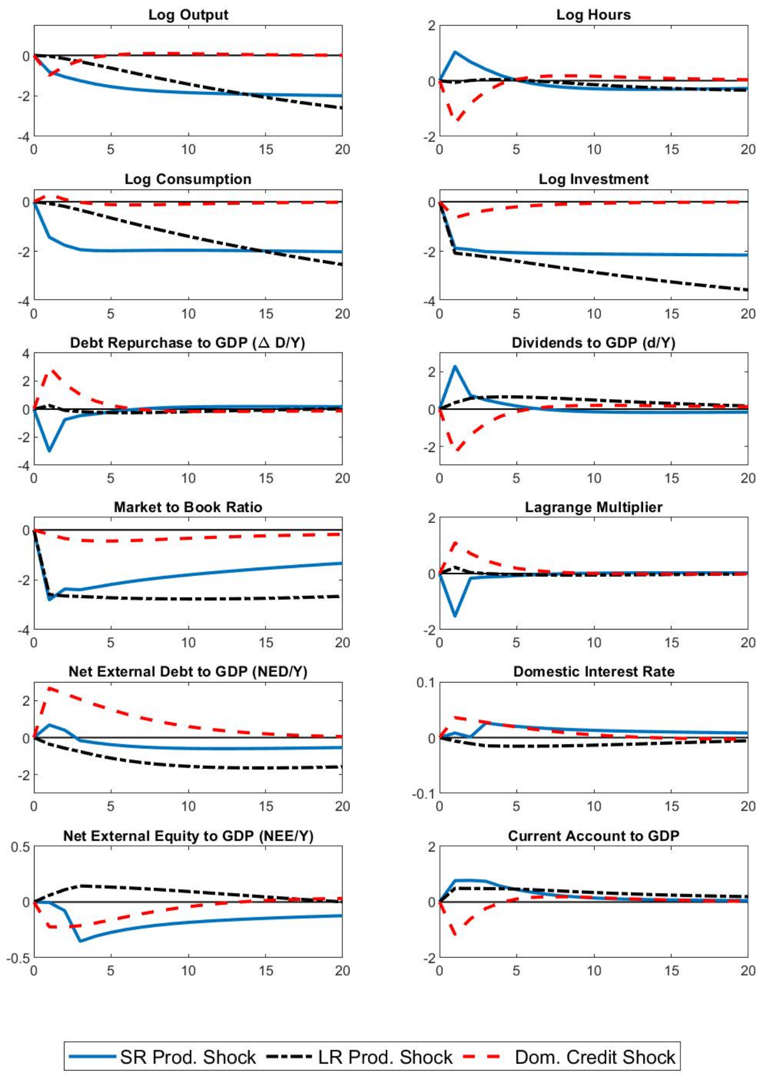


Fig. G2. **Impulse Responses to Productivity Shocks in SONOMA.** This figure shows percentage deviations from steady state for variables expressed in logs (percentage point deviations from steady state for variables expressed in levels) in response to a one standard deviation adverse shock to domestic credit conditions (ξ), long-run productivity growth (x), or short-run productivity growth (Δa). Our benchmark calibration is reported in Table E1.

Figure G2 is based on our SONOMA benchmark setting and compares the responses after an adverse domestic credit shock to those after adverse productivity shocks.

Appendix G.2. Co-skewness

A visual inspection of the residuals estimated using country-level VARs reveals a notable clustering of extreme adverse external financial shocks and downside long-run growth (see Figure D4, Appendix D). Equivalently, the data suggest that there may be an adverse co-skewness between these variables.

In what follows, we formally assess whether downside long-run growth shocks are realized simultaneously with either extreme positive (i.e., adverse) NEE-ER or external credit condition shocks. To test this hypothesis, we compute Harvey and Siddique co-skewness measures,

$$CoSk(\epsilon_z, \epsilon_y) = \frac{\mathbb{E}[\epsilon_{z,t+1} \cdot \epsilon_{y,t+1}^2]}{\sqrt{\mathbb{E}[\epsilon_{z,t+1}^2]} \cdot \mathbb{E}[\epsilon_{y,t+1}^2]}.$$

Specifically, we first recover the residuals from estimating the VAR in equations (19)–(20) with country-level data. Next, we estimate both $CoSk(\epsilon_{r^w}, \epsilon_x)$ and $CoSk(\epsilon_\eta, \epsilon_x)$ using a generalized method of moments (GMM) estimator.[11] Since adverse external shocks take positive values, a positive co-skewness refers to bad states of the world.

Our estimated co-skewness values for $CoSk(\epsilon_{r^w}, \epsilon_x)$ and $CoSk(\epsilon_\eta, \epsilon_x)$ are positive and statistically significant (Table G1). Hence we cannot reject the existence of a common adverse tail shock in both external credit conditions and long-run productivity growth, and between NEE-ER and long-run productivity growth. To the best of our knowledge, our study is the first one documenting this empirical fact.

Since we find no significant skewness in domestic credit shocks and no other statistically relevant results on co-skewness across other shocks, in our model we treat all other processes as subject to symmetric innovations.

Tail shocks in SONOMA. Given our empirical evidence, we augment SONOMA with tail shocks by including a common jump shock, J_t, in the NEE-ER, the external credit conditions process, and the long-run component:

$$r_t^w = (1-\rho_{rw})(\mu_{rw} - j_0) + \rho_{rw} r_{t-1}^w + \sigma_{rw}\epsilon_{rw,t} + (1-\rho_{rw}) J_t \tag{G7}$$

$$\eta_t = (1-\rho_\eta)(\mu_{rw} + s_{rw} - j_0) + \rho_\eta \eta_{t-1} + \sigma_\eta \epsilon_{\eta,t} + (1-\rho_\eta) J_t \tag{G8}$$

$$x_t = (1-\rho_x) j_0 \rho_x x_{t-1} + \sigma_x \epsilon_{x,t+1} + \rho_{rw,x}\sigma_{rw}\epsilon_{rw,t+1} + \rho_{\eta,x}\sigma_\eta\epsilon_{\eta,t+1} - (1-\rho_x) J_t, \tag{G9}$$

[11] For each co-skweness coefficient, $CoSk$, we use the following set of over-identifying moment conditions:

$$\mathbb{E}[\epsilon_{z,t}^j \cdot (\epsilon_{y,t}^j)^2 - CoSk] = 0 \quad j = 1, \cdots, 10,$$

where all residuals have been standardized first. For robustness, we also perform this estimation using an unbalanced panel regression. The resulting estimates are both quantitatively and qualitatively similar to those obtained from our two-step GMM procedure (Table G1).

Table G1: Co-Skewness with Long-Run Growth Shocks

External Variable	Moment	Estimate	Confidence Interval
External Credit Conditions	$CoSk(\epsilon_{r^w}, \epsilon_x)$	0.166	[0.070 , 0.261]
NEE-ER	$CoSk(\epsilon_\eta, \epsilon_x)$	0.231	[0.060 , 0.402]

Notes: This table reports estimates of the co-skewness ('$CoSk$') between country-level innovations to the long-run component of productivity (ϵ_x^j) and either shocks to the external credit conditions (ϵ_{r^w}) or the NEE-ER, i.e., the external expected equity returns (ϵ_η). Numbers in square brackets represent the 10th and 90th percentile values based on Newey and West (1987) HAC-adjusted standard errors. All results are based on the VAR specified in equation (19)-(20) using country-level data. Our sources are detailed in Appendix C and our quarterly sample starts in 1995:Q1 and ends in 2018:Q4.

where, $J_t = j_0 e^{j_1 \cdot \epsilon_{j,t}} > 0$, $\epsilon_{j,t} \sim N(0,1)$, and $j_1 = 1.9$ and $j_0 = 2.e^{-5}$ so that this process is on average close to zero but it also feature infrequent large realizations.

We report simulation results from this model in Table G2. With the inclusion of an adverse tail shock, SONOMA generates positive co-skewness values that are within the empirical confidence intervals presented in Table G1.

Compared to our benchmark SONOMA, this model setting produces a higher equity premium (by 24 basis points) and a 1% decline in the average level of capital. Given this lower level of capital accumulation, the representative agent suffers a welfare loss of about 12% of life-time consumption. These results suggest that adverse tail shocks may have strong detrimental effects on both the real economy and welfare.

Table G2: SONOMA with Adverse Jump Shocks

Moments		Without Jump Shock	With Jump Shock
Macro	$\sigma(\Delta i)/\sigma(\Delta y)$	1.95	1.94
	$\sigma(\Delta c)/\sigma(\Delta y)$	1.08	1.08
	$corr(\Delta i, \Delta c)$	0.64	0.65
	$corr(\Delta i, \Delta \log(D))$	0.03	0.01
	$corr(\Delta y, \Delta h)$	0.53	0.54
Returns	$\mathbb{E}[r]$ (%)	1.54	1.45
	$corr(r, \Delta y)$	0.10	0.08
	$\mathbb{E}[r_E - r]$ (%)	5.68	5.91
	$\sigma(r_E - r)$ (%)	7.27	7.05
	$\mathbb{E}[r_K - r]$ (%)	3.64	3.77
	$\sigma(r_K - r)$ (%)	4.94	4.93
	$\mathbb{E}[r - r^w]$ (%)	0.42	0.33
	$\sigma(r - r^w)$ (%)	0.62	0.55
Leverage	$\mathbb{E}[D/K]$ (%)	34.41	35.99
	$\sigma(D/K)$ (%)	6.67	6.18
	$corr(\Delta(D/K), \Delta y)$	0.05	0.05
	$\sigma(d/K)/\sigma(\Delta y)$ (%)	1.45	1.38
NFA	$\mathbb{E}[NED/Y]$ (%)	53.53	52.67
	$\mathbb{E}[NEE/Y]$ (%)	8.41	8.54
	$\sigma(\Delta(NED/Y))$ (%)	2.59	2.72
	$\sigma(\Delta(NEE/Y))$ (%)	8.04	8.69
	$corr(\Delta(NED/Y), \Delta y)$	-0.53	-0.53
	$corr(\Delta(NEE/Y), \Delta y)$	-0.24	-0.28
	$corr(\Delta(NED/Y), \Delta(NEE/Y))$	0.35	0.34
	$corr(NED/Y, D/K)$	-0.36	-0.33
	$corr(NEE/Y, D/K)$	0.03	0.02
Current Acc.	$\sigma(\Delta NFA/Y)$ (%)	4.21	4.33
	$acf(\Delta NFA/Y)$	0.84	0.84
	$corr(\Delta NFA/Y, r)$	0.56	0.63
Co-skewness	$CoSk(\epsilon_{rw}, \epsilon_x)$	-0.01	0.26
	$CoSk(\epsilon_\eta, \epsilon_x)$	0.00	0.29
Welfare	$E[log(U/A)]$	-1.54	-1.66
	$E[log(K/A)]$	1.72	1.71

Notes: The calibration for SONOMA (i.e., "Without Jump Shock") is reported in Table E1. The common adverse jump shock is modeled as in equations (G7)–(G9) and the corresponding parameter values ($j_0 = 2.e^{-5}$ and $j_1 = 1.9$) are chosen to match the observed co-skewness values in the data (Table G1).