Sovereign Default and the Disruption of Knowledge Diffusion

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Abstract

This paper shows that sovereign debt crises impose long-lasting growth costs by disrupting the diffusion of foreign technology. Using data on defaults and sudden stops, I document that emerging economies experience not only sharp contractions in output and trade but also persistent declines in patenting and total factor productivity. These losses are most severe in countries heavily reliant on imports from advanced economies, consistent with imports serving as a channel for learning from the global frontier. To account for these patterns, I develop a quantitative sovereign default model that embeds knowledge diffusion into the canonical Arellano (2008) framework. In the model, defaults restrict access to high-quality foreign intermediates, slowing the accumulation of domestic technology. Calibrated to Argentina's 2001–02 crisis, the model attributes roughly one-third of the long-run output cost of default to the learning channel. The results highlight that sovereign crises reduce not only contemporaneous output but also long-run productivity growth, underscoring hidden costs of default beyond temporary recessions.

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1 Introduction

Sovereign debt crises are among the most disruptive macroeconomic events for emerging economies. When governments default or face sudden stops in capital inflows, output collapses, trade contracts, and financial conditions deteriorate. Yet the costs of these crises extend well beyond the sharp short-run recessions that dominate policy debates. A striking but less appreciated fact is that innovation activity, proxied by patent applications, drops sharply in the aftermath of sovereign crises, and total factor productivity (TFP) remains depressed for years. These long-lasting losses raise a natural question: why do debt crises generate persistent productivity shortfalls, rather than the quick rebounds once market access is restored? Addressing this question is essential because it links sovereign crises not only to short-run fluctuations but also to the long-run growth trajectory of economies that rely on integration into world trade and finance.

This paper advances the view that the hidden growth cost of sovereign default arises from the disruption of international knowledge diffusion. Imports from advanced economies embed frontier technologies that serve as a key channel of learning for firms in emerging markets, where innovation relies heavily on imitation rather than original R&D. When defaults curtail access to high-quality foreign intermediates, domestic firms lose both the variety and the quality of inputs needed to learn and upgrade, slowing the accumulation of technology. I document this mechanism empirically by showing that sovereign defaults and sudden stops are systematically followed by persistent declines in both patenting and TFP, with the effects especially pronounced in countries that import heavily from advanced partners. To quantify these dynamics, I develop a quantitative sovereign default model that embeds trade mediated knowledge diffusion into the canonical framework of Arellano (2008). Following Buera and Oberfield (2020), the model allows domestic firms to learn from the pool of available inputs, so that defaults reduce future productivity growth by shrinking access to frontier varieties. Calibrated to Argentina's 2001–02 crisis, the model replicates the joint dynamics of output, trade, and innovation, and attributes roughly one-third of long-run output losses to the loss of learning. The analysis highlights that sovereign crises reduce not only contemporaneous output but also slow the process of catching up to the global technology frontier.

I begin by documenting that after a sovereign debt crisis, countries experience large and persistent macroeconomic downturn: output falls well below trend, imports contract sharply, and the net export-to-GDP ratio rises. Strikingly, alongside these aggregate patterns, domestic innovation, measured by patent applications, collapses. At first glance, this correlation could reflect both a decline in active innovation (new inventions) and in passive innovation (learning from abroad). I argue that the latter mechanism is central. When imports collapse, domestic producers lose access to high-quality foreign inputs that serve as vehicles for technology transfer. Consistent with recent evidence by LLind and Ramondo (2024), innovation in emerging markets is predominantly imitative rather than frontier-pushing. This distinction makes access to the global knowledge pool crucial. When trade with advanced partners is disrupted, opportunities for reverse engineering and knowledge diffusion shrink, leaving firms with fewer high-quality ideas to build upon.

To establish these patterns empirically, I combine the sovereign default events defined in Asonuma and Trebesch (2016) with patenting and trade data. Following defaults, patent applications decline by roughly 0.4 log points, and the effect persists for at least four years. This persistence suggests that the loss of learning opportunities through imports is both economically significant and long-lasting. Considering the broader role of innovation in driving productivity growth, these declines imply sizable cumulative costs. To check robustness, I also examine systematic sudden stop events, as in Bianchi and Mendoza (2020). The results show qualitatively similar, albeit somewhat smaller, declines in imports and patenting. This finding highlights that even without full financial exclusion, large shocks that depress imports, such as sudden exchange rate depreciation, can still generate meaningful disruptions to technology diffusion.

Finally, I explore heterogeneity across countries to shed light on the plausibility of the learning from imports channel. I construct a measure of average trading partner technology (ATT), defined as the import-share-weighted TFP of partner economies. The results reveal a striking asymmetry. Countries with above-median ATT who import heavily from advanced economies suffer much larger and more persistent declines in both patenting and TFP during crises. By contrast, countries that source primarily from lower-technology partners experience relatively modest losses. This cross-sectional evidence underscores that the

severity of crises depends critically on the quality of the learning pool. When access to frontier inputs is disrupted, emerging markets lose a disproportionately valuable channel of technology diffusion, magnifying the long-run costs of sovereign default.

To quantify the long-run costs of debt crises, I extend the canonical small open economy sovereign default model of Arellano (2008) by incorporating knowledge diffusion through trade. In this environment, the emerging economy borrows from international creditors and simultaneously learns from both domestic and foreign producers. Following Buera and Oberfield (2020), domestic firms draw ideas from the pool of varieties available in the domestic market. Innovation is modeled as passive imitation where firms can reverse-engineer existing inputs and occasionally improve upon them. The probability of upgrading is higher when the input pool contains more high-quality varieties, and lower when it is dominated by low-technology goods. Thus, the composition of imports directly shapes the speed of domestic productivity growth.

Sovereign default disrupts trade by reducing access to imported varieties. I follow Mendoza and Yue (2012) in assuming that when the government defaults, a fraction of foreign intermediates becomes unavailable. This loss can be interpreted as arising from working-capital constraints or sanctions imposed by advanced economies. Empirically, the assumption is supported by Gopinath and Neiman (2014), who document that during Argentina's 2001 crisis firms sharply reduced their imported intermediates, with the decline concentrated in capital and investment goods typically sourced from advanced countries.

This structure implies two reinforcing forces through which default disrupts learning. First, higher import prices during default induce substitution toward domestic varieties. Because domestic goods are typically lower quality than frontier imports, this shift reduces the opportunities for firms to learn from advanced technologies. Second, the outright loss of access to a fraction of foreign varieties directly shrinks the set of inputs available in the domestic idea pool. Together, these forces lower the probability that firms draw inspiration from high-quality technologies, thereby slowing the accumulation of productivity.

I calibrate the model to the experience of Argentina's 2001–02 default, which provides rich evidence on output, trade, and innovation dynamics during a severe crisis. Standard parameters such as the default penalty, sovereign spread, and debt-to-GDP ratio are disciplined

by the Argentine data. In addition, I target the dynamics of GDP and patent applications to identify the learning-related parameters. This calibration strategy goes beyond the unconditional moments and allows the model to capture the persistence of TFP and innovation losses observed in the data.

The calibrated model replicates the sharp contraction in GDP and imports at the onset of default, as well as the more protracted recovery of TFP. While GDP begins to rebound within a few years, the productivity frontier remains below its pre-crisis trend for much longer. The learning channel plays a key role in generating this persistence: shutting down the diffusion mechanism reduces long-run losses by about one-third. Quantitatively, the cumulative effect of foregone learning accounts for approximately 31 percent of the total GDP loss in the baseline model, highlighting the importance of technology diffusion in amplifying the cost of sovereign default.

Although the present analysis focuses on quantifying the costs of default, the framework naturally lends itself to evaluating policy interventions. In principle, governments could mitigate the persistent productivity losses by sustaining access to high-quality foreign inputs during crises. One way to capture this idea is to analyze the effects of temporary import subsidies or wage taxes that counteract the shift away from frontier varieties. Preliminary experiments suggest that targeted import subsidies could cushion the long-run decline in GDP and welfare. A systematic evaluation of such policies is left for future work, but the model highlights their potential relevance for managing the dynamic costs of default.

The first contribution of the paper is empirical. I provide new evidence that sovereign debt crises are followed not only by deep recessions and trade contractions, but also by long-lasting declines in innovation and productivity. Patenting activity falls sharply and remains depressed for years, and TFP fails to return to its pre-crisis trend. These patterns are strongest in countries that rely heavily on imports from advanced economies, consistent with the view that trade disruptions reduce opportunities for learning from the global frontier. This evidence highlights an overlooked margin of crisis costs. Sovereign defaults impair not just current output, but also the long-run process of technological catch-up.

The second contribution is theoretical. I embed a knowledge-diffusion mechanism à la Buera and Oberfield (2020) into the canonical sovereign default model of Arellano (2008).

In this framework, imports serve both as production inputs and as conduits for technology transfer. Default restricts access to high-quality intermediates, thereby reducing future productivity growth. Calibrated to Argentina's 2001–02 default, the model replicates the observed dynamics of output, trade, and innovation, and attributes roughly one-third of long-run output losses to the learning channel. This approach microfounds a persistent cost of default that has been treated as exogenous in previous models, and connects the composition of trade to sovereign borrowing capacity and welfare.

Before turning to the evidence, it is useful to situate this paper in relation to the existing literature.

Literature review

This paper builds on the modern sovereign default tradition that descends from Eaton and Gersovitz (1981), where default arises from the government's intertemporal choice under limited enforcement. Quantitative small open economy models such as Aguiar and Gopinath (2006) and Arellano (2008) explain debt levels, default frequencies, and spreads by combining income fluctuations with exclusion or output costs. Long-duration debt is central for matching spread dynamics and maturity choices (Chatterjee et al., 2007; Hatchondo and Martinez, 2009), and renegotiation interacts with default incentives (Yue, 2010). These frameworks discipline the mapping from fundamentals to sovereign borrowing costs and inform the calibration strategy used here.

A large empirical literature documents that defaults are associated with sizable and persistent output losses, higher borrowing costs, and disruptions to trade and finance. Surveys and evidence include Panizza et al. (2009); Panizza (2014). Spreads and haircuts comove with post-restructuring market access (Cruces and Trebesch, 2013). Trade falls during and after crises, consistent with financial frictions and reputational effects (Rose, 2005). In quantitative work, output costs enter either as financial exclusion or as endogenous wedges through production, labor, or trade linkages. Mendoza and Yue (2012) embed imported intermediates and working capital into an Arellano-type model, generating procyclical imports and spreads. Subsequent work explores default duration, maturity, and state-contingent instruments as additional margins shaping costs and recovery (e.g. Arellano and Ramanarayanan,

2012; Hatchondo et al., 2016). This paper contributes by shifting part of the default cost from reduced current efficiency to slower *technology* accumulation, which matches the persistence in TFP and patenting around crises documented in Section 2.

The diffusion channel follows evidence that trade is a powerful conduit for foreign knowledge. Classic macro evidence links foreign R&D and openness to domestic TFP (Coe and Helpman, 1995; Coe et al., 1997; Keller, 2004). Structural trade-and-technology frameworks rationalize these facts through selection, variety, and idea flows (Eaton and Kortum, 2002). On the micro side, imported intermediates raise firm-level productivity by embodying superior techniques (Amiti and Konings, 2007; Halpern et al., 2015; Bas and Strauss-Kahn, 2015), and trade reforms shift technology adoption and product scope (Goldberg et al., 2010). Buera and Oberfield (2020) provide a tractable diffusion mechanism consistent with heavy-tailed productivity and learning from the pool of available ideas, which this paper adapts to endogenize the output costs of default. Evidence on imitation-led growth in emerging markets (Lind and Ramondo, 2024) motivates the focus on passive diffusion rather than domestic R&D.

When ideas arrive through imported varieties, private agents do not internalize the intertemporal learning externality, creating a role for policy that tilts the input mix toward high-knowledge goods. In Eaton–Kortum environments with diffusion, dynamic trade policy can correct these externalities and has explicit sufficient-statistic representations (Bai et al., 2025). Related optimal-policy traditions analyze industrial policy with learning-by-doing or knowledge spillovers (Grossman and Helpman, 1991; Young, 1991; Acemoglu et al., 2006), and more recent quantitative work studies targeted interventions when spillovers are heterogeneous across inputs and sectors. This paper's policy experiments fit into that logic by comparing untargeted import subsidies, export taxes, and variety-targeted subsidies that pay per "idea content" rather than per dollar of imports, showing larger diffusion and welfare gains for a given fiscal cost.

Relative to sovereign default models that impose exogenous output costs, this paper microfounds a persistent component of the cost through trade-mediated diffusion, which links the *composition* of imports to spreads and long-run growth. Relative to the diffusion literature, it embeds idea flows into an environment with default and long-term debt, allow-

ing the data-disciplined mapping from crisis duration and import disruptions to technology dynamics and welfare. The policy analysis bridges these literatures by evaluating simple, implementable instruments that target the diffusion margin during periods when private allocations underweight foreign varieties.

The rest of the paper proceeds as follows. Section 2 presents motivating evidence on the joint dynamics of GDP, trade, innovation, and TFP around sovereign debt crises. Section 3 develops the model. Section 4 calibrates the framework and presents the quantitative results. Section 5 decomposes the role of the learning channel, and Section 6 considers policy experiments. Section 7 concludes.

2 Motivating evidence

This sections describes the data sources and the empirical patterns observed around sovereign debt crisis periods. The patterns suggests a substantiate and persistent drop of GDP, import, patent application and TFP after sovereign debt crisis.

2.1 Data

The empirical analysis around sovereign debt crises involves both sovereign default and sudden stop events. For sovereign default events, I rely on the Asonuma and Trebesch (2016) database, which covers defaults from 1970 to 2020. I also include the European debt crises for Italy, Spain, Greece, Portugal, and Ireland. Even though these countries did not formally default, they experienced output and trade losses of comparable magnitude. For robustness, I use the sudden stop events listed in Bianchi and Mendoza (2020). The common feature across both types of events is a large drop in output, trade, international finance flows, and innovation activity.

To construct the event sample, I exclude overlapping crises within a short horizon to avoid double-counting outcomes. Each event window spans five years before and after the onset of the crisis, which balances capturing medium-run dynamics against maintaining sufficient sample size. Using both defaults and sudden stops ensures that the analysis is not driven by a single definition of crisis and allows me to compare episodes with full financial exclusion

to those involving sharp but temporary capital-flow reversals.

The combined dataset covers 45 sovereign default episodes across 28 emerging economies between 1970 and 2020, as well as 36 sudden stop events. The sample includes large Latin American economies (Argentina, Brazil, Mexico), several Asian economies (Indonesia, Philippines, Turkey), and selected European crises (Greece, Portugal, Spain). I exclude very small economies and countries with severe gaps in Comtrade or patent filings, such as some Sub-Saharan African economies. This restriction ensures comparability across datasets and prevents noisy measurement from driving results.

For macroeconomic outcomes, I use annual real GDP and TFP from the Penn World Table version 10.0, which provides consistent measures of output, capital stock, and employment. For innovation, I use the INPACT-S database (LaBelle et al., 2023), which compiles patent applications filed at national patent offices worldwide. I focus on applications filed in each country's home PTO and the USPTO. While patents are an imperfect proxy—patenting propensity varies across industries and countries—they remain the most consistent and internationally comparable indicator of inventive activity over long horizons (Abrams et al., 2013; Akcigit and Kerr, 2018). Moreover, by including filings at both home and U.S. offices, I capture both local inventive activity and attempts to access global markets, which can differ in sensitivity to financial shocks. Alternative measures such as R&D expenditures or publication counts are less feasible in this broad panel, as R&D data are sparse for emerging markets and publications capture primarily academic rather than commercial innovation.

Trade data come from UN Comtrade, which I aggregate at the 2-digit HS level. This level strikes a balance between detail and cross-country comparability: finer levels (e.g., 6-digit) suffer from missing observations and reclassification issues, while coarser levels (1-digit SITC) would obscure heterogeneity in input dependence. I then use the Muendler (2009) crosswalk to align industries in trade data with those in patent applications, enabling analysis of import dependence and innovation at the sector level. This disaggregated perspective provides more credible evidence on the learning-from-imports channel than aggregate correlations alone.

2.2 Output, trade, and innovation around debt crisis event

In this section, I first present the substantial drop in output, trade, and patent applications around sovereign debt crisis event. Next, I present the industry level patent application and import change after sovereign debt crisis as suggestive evidence on the learning by importing at more disaggregated level.

Throughout the following analysis, I consider the de-trended real variables using both linear trend and HP filter for annual data. I present the eventstudy around the sovereign debt crisis events including both sovereign default and European debt crisis in the main text. The sudden stop events result will be present in the appendix. Formally, I estimate the following event-study specification:

$$y_{i,t} = \alpha_i + \gamma_t + \sum_{\ell=-5}^{5} \beta_\ell \, \mathbf{1}\{\tau_{i,t} = \ell\} + \varepsilon_{i,t}$$

, where $y_{i,t}$ is the log-deviation of GDP (or imports, TFP, or patent applications) from trend, α_i are country fixed effects, and γ_t are year fixed effects. The variable $\tau_{i,t}$ counts years relative to the sovereign debt crisis date for country i. I normalize the year before the crisis ($\ell = -1$) as the reference period. The coefficients β_ℓ therefore trace out the dynamic response of each outcome around debt crisis events.

As documented in the previous literature, we do see a substantial deviation of real GDP and import from either the linear trend or HP filter trend component. The magnitude of drop in GDP using linear trend is around 10 percent at peak and is inline with previous estimation in the literature. The deviation from trend using HP filter suggests a much smaller loss around 2% at peak as the trend around sovereign debt crisis tend to be not linear and partially already capture in the trend component in HP filter. For example, among many sovereign default events, the countries tend to have relatively lower output level than in their historical average. This is inline with the prediction in sovereign default literature that several countries default in bad time.

[Insert Figure 1 about here]

[Insert Figure 2 about here]

At the same time, imports drop substantially in these countries. This decline reduces domestic producers' exposure to foreign varieties and, with it, to the technologies embedded in those goods. As shown by Amiti and Konings (2007) and Kasahara and Rodrigue (2008), lower imports of intermediate inputs can weaken both competition and learning, discouraging innovation and R&D. On the one hand, fewer imported inputs mean fewer choices for final-good producers, which raises the market power of domestic intermediate suppliers and reduces their incentive to improve quality. On the other hand, domestic firms also lose access to high-quality foreign intermediates as a source of learning. Together, these forces slow down TFP growth and generate the persistent deviation of TFP and output from trend following a debt crisis.

While patent applications are my primary measure of innovation, they are not the only possible proxy. In principle, one could also use R&D expenditures or scientific publication data. However, comparable R&D data are limited for emerging economies before 1990, and publication counts capture academic rather than commercial innovation. Patents remain the most consistent and internationally comparable indicator available at the annual frequency. To reduce noise, I focus on applications rather than grants, and I include filings both in the domestic PTO and at the USPTO, which captures attempts to commercialize inventions globally.

[Insert Figure 3 about here]

[Insert Figure 4 about here]

As shown in Figures 3 and 4, countries that experience debt crises suffer from a sharp decline in innovation activity, measured by patent applications, and an even more persistent drop in TFP. These observations are consistent with the prediction that domestic firms have weaker incentives to innovate when access to foreign inputs is limited. The results also suggest that the decline in innovation is a key driver of the slowdown in TFP growth, and that this effect is highly persistent. This amplification mechanism is important for quantifying the true cost of sovereign debt crises: focusing only on output losses understates the damage, since TFP remains depressed long after GDP begins to recover. In canonical sovereign default models with exogenous output costs, output falls due to financial exclusion and stochastic

productivity shocks, but both effects dissipate once market access is restored. Such models cannot explain why TFP stays below trend for extended periods. Taken together, the time-series evidence highlights a strong correlation between trade disruptions, particularly in imports, and declines in patenting activity.

The magnitudes implied by the event-study are economically large. A peak GDP loss of about 10 percent is comparable to findings in Mendoza and Yue (2012) and Arellano (2008), but what distinguishes my estimates is the persistence in TFP and patent applications. In the existing sovereign default literature, output recovers quickly once market access is restored. By contrast, the evidence here suggests that while GDP begins to revert toward trend within three years, TFP and innovation remain depressed even after five years, highlighting a qualitatively different propagation mechanism.

These results are robust to alternative detrending procedures and event definitions. Using an HP filter instead of a linear trend yields smaller contemporaneous losses but preserves the persistence of TFP and innovation shortfalls. Similarly, restricting the event sample to Asonuma and Trebesch (2016), or alternatively including sudden stops from Bianchi and Mendoza (2020), produces broadly consistent patterns. This robustness strengthens the interpretation that the persistent TFP losses are not mechanical artifacts of detrending or sample choice.

However, sovereign debt crises are not exogenous events, and the correlation between imports and innovation does not automatically imply causality. For example, as shown in Arellano et al. (2017), sovereign crises raise borrowing costs for the private sector, which directly discourages innovation by increasing its financing cost. To address this concern, I further examine imports and patent applications at the industry level. The intuition is that while firms may face tighter financial constraints during a crisis, heterogeneity in import dependence across industries can reveal differential effects on innovation. Industries that rely heavily on imported inputs and suffer large import drops are likely to experience stronger declines in innovation compared to those less dependent on imports. Consistent with this idea, Figure 5 shows a positive correlation between import changes and patent applications at the 4-digit HS industry level, suggesting that learning from imports plays an important role beyond financial frictions alone.

[Insert Figure 5 about here]

Given this suggestive evidence on the learning-from-imports channel, I next examine how the impact of debt crises differs across countries depending on the technology level of their trading partners.

2.3 Trade with high tech v.s. low tech trading partners

To better understand the role of learning from imports, it is important to examine how the impact of debt crises varies with the technology level of a country's trading partners. Intuitively, countries that import more from technologically advanced partners have greater opportunities to learn from frontier technologies and achieve higher-quality improvements. In contrast, when most imports come from lower-technology partners, the scope for knowledge diffusion is much more limited. To capture this idea, I construct a measure of average trading partner technology,

$$ATT = \sum_i \pi_{ij} T_j^{\rho}$$

where π_{ij} denotes the import share from partner j and T_j is the partner's TFP level. A higher ATT indicates that a country imports relatively more from advanced partners. I then conduct the same event-study analysis of GDP, imports, patent applications, and TFP, separately for countries with above- and below-median values of ATT.

[Insert Figure 6 about here]

As shown in Figure 6, output losses are more severe in countries that import heavily from technologically advanced partners. For these high-ATT countries, TFP declines after debt crises follow a similar pattern but are even more persistent than GDP losses. These patterns are consistent with the learning channel: when imports from advanced partners collapse, countries lose access to high-quality technologies, leading to larger and longer-lasting productivity losses. By contrast, countries with low ATT experience only mild losses, since they rely less on high-technology imports and thus face smaller consequences when trade contracts. Moreover, because these countries were not strongly exposed to frontier

technologies to begin with, the learning channel was muted and did not generate persistent TFP losses.

The heterogeneity by ATT provides further support for the learning-from-imports channel. Countries that source heavily from advanced economies not only face larger immediate GDP contractions but also much more persistent TFP losses. This finding is consistent with Buera and Oberfield (2020), who emphasize the central role of frontier economies in global idea diffusion, and with Lind and Ramondo (2024), who document that emerging market innovation relies disproportionately on imitation of advanced-country technologies. In this sense, sovereign defaults disproportionately penalize economies that were previously best positioned to benefit from globalization.

An additional implication is that the composition of trade matters as much as the volume. Two countries may experience similar overall import declines, but if one relies more on high-technology partners, the long-run productivity consequences are significantly larger. This suggests that policies designed to stabilize access to advanced foreign inputs—such as preferential trade agreements or targeted import subsidies—may be particularly valuable during crises.

Finally, industry-level heterogeneity reinforces this interpretation. In high-ATT countries, sectors with greater import dependence experience sharper drops in patenting, consistent with the idea that access to frontier inputs facilitates sectoral upgrading. By contrast, in low-ATT countries, where imports are more concentrated in basic goods, the contraction in innovation is milder and largely mirrors the aggregate demand collapse.

Looking at the dynamics, the persistence of TFP losses stands out. In high-ATT countries, GDP gradually recovers to its pre-crisis trend within about three years, but TFP remains well below trend even five years after the crisis. This comparison highlights the importance of the learning channel and underscores that the source of imports—from whom a country learns—matters greatly for the long-run cost of sovereign debt crises.

To quantify the cost of sovereign debt crises associated with the loss of learning, I develop a small open economy sovereign default model that captures the effect of reduced imports on knowledge diffusion in the next section.

3 Model

This section introduces the model setup. The framework builds on the canonical sovereign default model of Arellano (2008) and incorporates technology diffusion as in Buera and Oberfield (2020). The innovation is to combine the sovereign borrowing problem with a dynamic technology diffusion mechanism, thereby endogenizing the output costs of default.

In the sovereign default literature, output losses have typically been introduced as an exogenous penalty that makes default unattractive, allowing the model to generate realistic default frequencies and debt levels (e.g. Aguiar and Gopinath, 2006; Arellano, 2008). Although this approach has been quantitatively successful, it leaves the nature of output costs under-specified. By contrast, a separate literature on international technology diffusion (Eaton and Kortum, 2002; Buera and Oberfield, 2020) has emphasized that trade is an important conduit through which less developed economies learn from the world frontier. These two literatures have largely developed in parallel. The aim of this paper is to bring them together, using a diffusion mechanism to provide microfoundations for the output costs of default.

I focus on passive diffusion of technology rather than active invention, consistent with the findings of Lind and Ramondo (2024), who show that innovation in emerging markets is primarily driven by imitation and spillovers from advanced economies. Accordingly, the model abstracts from active R&D and emphasizes technology diffusion through imports. In this setting, what matters for long-run productivity growth is not the scale of domestic research effort, but the extent to which domestic firms can access, imitate, and adapt ideas embodied in imported goods.

The starting point is the canonical small open economy sovereign default model of Arellano (2008), in which the government chooses whether to repay or default on its debt, and output losses in default are imposed exogenously. My contribution is to endogenize these output losses by embedding a knowledge-diffusion mechanism à la Buera and Oberfield (2020). In this environment, imports not only provide current production inputs but also determine the quality of the technology pool from which domestic firms can learn. Thus, sovereign default has dynamic costs beyond the immediate loss of credit access: by restricting imports,

it reduces learning opportunities and depresses future TFP growth.

This extension is motivated by the empirical patterns documented in Section 2: debt crises are followed by large and persistent declines in patenting and TFP, especially in economies that rely heavily on advanced trading partners. Standard models cannot generate such persistence because their output costs dissipate once market access is restored. By incorporating knowledge diffusion, the model provides a mechanism through which temporary trade disruptions translate into long-lasting productivity losses. Importantly, this mechanism also connects the composition of trade to sovereign borrowing costs: economies with greater exposure to frontier partners face larger long-run penalties from default, which helps explain why borrowing capacity differs systematically across countries.

The economy consists of a private sector and a government sector. The private sector includes households, which supply labor and consume final goods, and firms, which produce using both domestic and imported intermediates. The government makes dynamic international borrowing and default decisions. Technology evolves endogenously and is jointly determined by government borrowing choices and private sector outcomes. Time is discrete, one period corresponds to one quarter, and the horizon is infinite. The aggregate state is $(A_t, b_t, T_{H,t})$, where A_t is a transitory domestic productivity shock, b_t is outstanding long-term sovereign debt, and $T_{H,t}$ is the domestic technology frontier. The following subsections describe each sector in detail, beginning with the household, then the final-good producer and retailer, intermediate-good producers, and finally the international financier. The government's problem is presented after all market participants are introduced.

3.1 Household

The representative household in the home country supplies labor and consumes the final good. Households cannot borrow directly from international financial markets and thus rely on the government's borrowing decision to smooth consumption over time. Taking the government's choices as given, the household solves a static problem each period:

$$\max_{C,\ell} \frac{(C - \chi \frac{L^{1+\psi}}{1+\psi})^{1-\sigma}}{1-\sigma} \quad \text{s.t.} \quad C \leq wL + \Pi + \mathcal{T} \tag{1}$$

where C is final consumption, L denotes labor supply, w is the wage, Π are firm profits rebated to households, and $\mathcal{T}$ is the lump-sum transfer implied by the sovereign's borrowing decision. The first-order condition for labor supply is:

$$w = \chi L^{\psi}. \tag{2}$$

The utility function follows Greenwood–Hercowitz–Huffman (GHH) preferences, as in Mendoza and Yue (2012). Here, σ governs the curvature of consumption utility, ψ determines the Frisch elasticity of labor supply, and χ is a scaling parameter. The GHH specification eliminates the wealth effect on labor supply. In this way, households adjust labor effort only in response to changes in the real wage, not to changes in lifetime wealth. This choice is convenient because it ensures that fluctuations in labor supply respond more directly to shocks to wages and productivity, rather than being driven by intertemporal substitution depends on government's policy.

The absence of a wealth effect has important implications for the dynamics of default. When sovereign default raises the cost of imported inputs and reduces domestic productivity, the wage falls. Under GHH preferences, households reduce labor supply as a direct response to lower wages, amplifying the contraction in output. By contrast, with standard CRRA preferences, households would tend to increase labor supply in response to the decline in wealth, partially offsetting the fall in output. In the online appendix, I show that while both specifications produce qualitatively similar results, the GHH form generates sharper responses of output to default, consistent with the empirical evidence of large recessions during crises.

Households cannot directly access international financial markets and instead rely on the sovereign to intermediate external borrowing. This assumption reflects the limited role of household-level international credit in emerging economies and is standard in the sovereign default literature. It also implies that sovereign default directly constrains household con-

sumption smoothing. When the government loses access to credit markets, households experience sharper consumption volatility, which increases the welfare cost of default.

3.2 Final good producer and retailer

There is a representative final good producer that operates in a perfectly competitive environment. The producer combines labor ℓ and a composite material input M to produce the homogeneous final good Y. Taking factor prices as given, the producer solves:

$$\begin{aligned} &\max_{M,\ell} \; Y - P_M M - w\ell \\ &\text{s.t.} \quad Y = A\left(M^{1-\alpha_\ell}\ell^{\alpha_\ell}\right)^{\gamma}, \end{aligned} \tag{3}$$

where P_M is the price of the composite material bundle, w is the wage, α_ℓ denotes the share of labor in the production aggregator, and γ governs returns to scale. The term A is a transitory domestic productivity shock that is distinct from the endogenous technology frontier T_H.

The first-order conditions for profit maximization are:

$$A\gamma\alpha_\ell(M^{1-\alpha_\ell}\ell^{\alpha_\ell})^{\gamma-1}\ell^{\alpha_\ell-1}M^{1-\alpha_\ell} = w, \tag{4}$$

$$A\gamma(1-\alpha_\ell)(M^{1-\alpha_\ell}\ell^{\alpha_\ell})^{\gamma-1}\ell^{\alpha_\ell}M^{-\alpha_\ell} = P_M. \tag{5}$$

Equation (3) shows that the final good is produced with a Cobb-Douglas material-labor aggregator embedded in a decreasing-returns technology. The elasticity parameter α_ℓ controls the labor share in production, while γ captures scale effects. Fluctuations in A move current production efficiency, whereas the endogenous frontier T_H affects current allocations through the intermediate-good price index and evolves through knowledge diffusion in Section 3.3.1.

Composite-input sector

The composite material input M is assembled from differentiated varieties ω purchased from both domestic and foreign intermediate good producers. To allow for home bias in absorption, I introduce a parameter $\varphi \in (0,1)$ in the Armington aggregator. The material aggregator is described in reduced form to match the quantitative implementation. First, home and foreign bundles are defined by

$$Y_n = \left(\int_0^1 y_n(\omega)^{\frac{\nu-1}{\nu}} \, d\omega \right)^{\frac{\nu}{\nu-1}}, \qquad n \in \{H, F\}, \tag{6}$$

and the unit cost of assembling the composite material bundle is

$$\widetilde{P}_M = \left(\varphi^\eta P_H^{1-\eta} + (1-\varphi)^\eta P_F^{1-\eta} \right)^{\frac{1}{1-\eta}}. \tag{7}$$

Given $\widetilde{P}_M$, the demand system for home and foreign material inputs is

$$y_{HH} = \left(\frac{P_H}{\widetilde{P}_M} \right)^{-\eta} \varphi^\eta M, \qquad y_{HF} = \left(\frac{P_F}{\widetilde{P}_M} \right)^{-\eta} (1-\varphi)^\eta M. \tag{8}$$

Here P_H and P_F are the aggregate prices of domestic and foreign bundles, respectively. The parameter η is the Armington elasticity governing substitution between home and foreign goods, φ captures home bias in the composition of the material bundle, and ν determines substitution across varieties within each country.

Note that given the same variety ω, the foreign good $y_F(\omega)$ and the domestic good $y_H(\omega)$ are not perfect substitutes, since the composite-input sector aggregates them through an Armington CES aggregator with elasticity parameter η.

In the quantitative implementation, the final-good producer pays the shadow price P_M for the composite material bundle, while the underlying resource cost of assembling that bundle is $\widetilde{P}_M$. The difference is rebated to households as profits of the composite-input sector:

$$d_M = (P_M - \widetilde{P}_M) M. \tag{9}$$

This is a reduced-form representation of the materials block rather than an explicit zero-

profit competitive retailer. In equilibrium, the implemented private block imposes

$$P_M = \widetilde{P}_M \frac{1 - \alpha_\ell \gamma}{(1 - \alpha_\ell)\gamma}. \tag{10}$$

This Armington structure implies that when foreign imports become more expensive or unavailable during default, the economy substitutes toward domestic goods. In the short run, this substitution cushions output losses by allowing production to continue with home inputs. However, in the longer run it reduces exposure to foreign varieties and thereby lowers the probability that domestic producers can learn from frontier technologies. In the default state I also allow for a direct variety-loss wedge: a fraction Ω of imported varieties becomes unavailable, which raises the effective cost of foreign inputs beyond the standard relative-price substitution channel.

This feature introduces a key externality: the composite-input sector internalizes only static price differences when assembling the bundle, but does not consider the effect of foreign variety exposure on future technology growth. As a result, private market allocations underweight foreign inputs from the perspective of long-run productivity growth. This difference between private and social incentives sets up the rationale for policy interventions (such as import subsidies) that I analyze later in Section 6.

Intuitively, the more substitutable domestic and foreign goods are (i.e., the higher the Armington elasticity η), the more easily the economy shifts away from foreign inputs during a crisis. While this reduces short-run output volatility, it exacerbates the long-run technology cost by cutting off learning from advanced partners. Conversely, if η is low, substitution away from imports is harder, meaning output falls more on impact but the knowledge pool is less disrupted. This tradeoff between static and dynamic costs is central to the quantitative results.

3.3 Intermediate good production

Intermediate firms produce differentiated varieties $\omega \in [0, 1]$ and are heterogeneous in their idiosyncratic technology level $z(\omega)$. For each country $n \in \{H, F\}$, productivities are drawn from a Fréchet distribution with scale parameter T_n and common shape parameter $\theta > 0$.

Denote the cumulative distribution function by $F_n(z)$; following the Eaton and Kortum (2002) convention,

Intermediate firms produce differentiated varieties $\omega \in [0,1]$ and are heterogeneous in their idiosyncratic technology level $z(\omega)$. Following the Eaton–Kortum (2002) framework, productivity draws are assumed to follow a Fréchet distribution. For each country $n \in \{H, F\}$, the distribution is characterized by a scale parameter T_n and a common shape parameter $\theta > 0$, with cumulative distribution function

$$F_n(z) \;=\; \exp\big\{ - T_n z^{-\theta} \big\}. \tag{11}$$

The shape parameter θ governs the dispersion of productivity draws. Higher θ implies less heterogeneity across firms, while a lower θ implies a fatter right tail and thus greater scope for exceptionally productive firms. The scale parameter T_n controls the level of the technology frontier. I interpret T_F as the exogenous world frontier, while T_H represents the domestic frontier, which evolves endogenously through knowledge diffusion in Section 3.3.1.[1]

In addition, there is an exogenous foreign demand for domestic varieties, which ensures that the home country can export. This demand influences equilibrium allocations and trade flows, but is not the central channel through which diffusion operates.

Each intermediate producer operates a simple linear technology and takes prices as given:

$$y(\omega) \;=\; z(\omega)\, \ell(\omega), \tag{12}$$

where $y(\omega)$ is output, $z(\omega)$ is the productivity draw, and $\ell(\omega)$ is labor input. Profit maximization is therefore

$$\pi(\omega) \;=\; \max_{\ell(\omega)} \; p(\omega)\, y(\omega) - w\, \ell(\omega) \quad \text{s.t.} \quad y(\omega) = z(\omega)\, \ell(\omega), \tag{13}$$

where w is the wage and $p(\omega)$ the variety-specific price. Under perfect competition, profits are zero and equilibrium prices are pinned down by marginal costs, $p(\omega) = w/z(\omega)$.

The intermediate-good sector is central to linking trade to technology diffusion. The

[1] This captures the idea that the home economy is catching up to, rather than shifting, the global frontier.

Fréchet distribution implies that there is always a thick right tail of high-z producers, so an increase in the domestic frontier T_H translates into a higher probability of drawing exceptionally productive firms and therefore technological upgrading. At the same time, because the retailer aggregates domestic and foreign varieties based on relative prices, the composition of the material input bundle depends on the cost and availability of foreign goods. A sovereign default that restricts or raises the price of imports reduces the presence of high-z foreign varieties in the domestic bundle. While the economy can substitute toward home inputs in the short run, this reduced exposure to frontier varieties diminishes learning opportunities, slowing the growth of T_H. Intermediate good production is therefore not only a source of current output but also the mechanism through which access to foreign ideas translates into long-run productivity growth.

3.3.1 Knowledge diffusion

After production, domestic firms can improve their technology by learning from the pool of varieties available in the domestic market. Following Buera and Oberfield (2020), the productivity of a new idea combines the firm's idiosyncratic research capability $q(\omega)$ with the quality of a source technology z_S:

$$z'(\omega) \;=\; q(\omega)\, z_S^{\rho}, \tag{14}$$

so that an improvement occurs whenever $q(\omega)\, z_S^{\rho} > z(\omega)$. The parameter $\rho \in (0,1)$ captures the elasticity of learning with respect to the source technology. Higher values imply that exposure to frontier ideas translates more effectively into productivity gains.

The random variable $q(\omega)$ represents the quality of the firm's research draw. Assume that it follows a Pareto distribution:

$$\Pr\big(q(\omega) > q\big) \;=\; \alpha\, q^{-\theta}, \tag{15}$$

where $\alpha > 0$ governs the arrival intensity of innovations and $\theta > 0$ determines the likelihood of extreme draws. A higher α increases the frequency of successful learning events, while a

lower θ implies a fatter tail, making radical improvements more likely.

Aggregating across firms, the distribution of domestic technologies remains Fréchet with scale parameter $T_{H,t}$. Intuitively, the Fréchet form is preserved because the probability of improvement is proportional to a power of the source technology z_S, which aligns with the power-law tail of the Fréchet distribution.[2] Let $G_t(z)$ denote the distribution of source technologies in the domestic idea pool. The continuous-time evolution of the domestic frontier satisfies

$$\frac{dT_{H,t}}{dt} \;=\; \alpha \int_0^{\infty} z^{\rho\theta}\, dG_t(z). \tag{16}$$

Since the pool consists of both domestic and imported varieties, I assume the probability of drawing from source $n \in \{H, F\}$ is proportional to its expenditure share in the material input bundle[3]:

$$\Pr\big(G_t = F_{n,t}\big) \;=\; \frac{p_{n,t}\, c_{n,t}}{p_{H,t}c_{H,t} + p_{F,t}c_{F,t}} \;\equiv\; \pi_{n,t}. \tag{17}$$

Using the Fréchet structure in (11) and standard integral results, the discrete-time law of motion for the domestic technology frontier is

$$T_{H,t+1} \;=\; (1-\delta)\, T_{H,t} \;+\; \alpha_s \sum_{n\in\{H,F\}} \pi_{n,t}\, T_{n,t}^{\rho}, \tag{18}$$

where $\delta \in (0,1)$ is the depreciation rate of knowledge and $\alpha_s \equiv \alpha\Gamma(1-\rho)$ is the effective diffusion-intensity parameter. In the quantitative implementation I work directly with α_s, so the Gamma constant is absorbed into the calibrated diffusion coefficient. The term $\pi_{n,t}$ captures the composition of the domestic idea pool, and $T_{n,t}^{\rho}$ scales the contribution of source n's frontier to future growth.

Equation (18) makes transparent how trade shapes technology growth. A larger expenditure share on frontier inputs, $\pi_{F,t}$, raises the expected quality of learning draws and accelerates the growth of $T_{H,t}$. During default episodes, two forces reduce the contribution of imports. First, *substitution* effect says that higher import prices shift expenditures toward

[2] See Appendix A.1 for a formal derivation.

[3] In Buera and Oberfield (2020), the assumption on learning uniformly across good or weight by trade share or expenditure share does not fundamentally change the results. Here I assume the learning probability is proportion to expenditure share as benchmark.

domestic inputs, lowering $\pi_{F,t}$. Second, *variety loss* implies that if certain frontier inputs become unavailable, they drop out of the pool G_t entirely. Both forces reduce the probability of drawing from high-quality sources, slowing the accumulation of ideas. This mechanism explains why TFP remains depressed long after output begins to recover. As a result, even a temporary disruption to imports has lasting consequences for the rate at which the domestic frontier converges toward the world frontier.

3.4 International financier

International creditors are modeled as competitive, risk–neutral investors with access to a risk–free asset yielding rate r_f. They are financed by households in the rest of the world and purchase sovereign discount bonds issued by the home country. Because investors are competitive and risk–neutral, equilibrium bond prices must satisfy a zero–profit condition, meaning that the expected return from lending to the sovereign equals the outside option r_f.

In contrast to models with purely one–period debt, I adopt the long–term debt structure of Chatterjee et al. (2007), in which a fraction δ_b of the debt matures each period while the remainder continues into the next period. This structure ensures that bond prices depend not only on current fundamentals but also on the expected continuation value of debt, which links today's spreads to the entire future path of default probabilities.

Formally, let $q(A, b', T'_H)$ denote the price of a long-term bond when the current productivity state is A, the sovereign chooses next-period debt b', and the implied next-period domestic technology frontier is T'_H. A fraction δ_b of outstanding debt matures each quarter, and the remaining fraction trades next period at the continuation price. In addition, the bond pays a coupon c each period it remains in good standing. The baseline calibration sets $c = r_f$. In the implemented code, the price schedule is independent of the current debt level b once the sovereign has chosen to repay in the current period, so current debt affects the sovereign's decision problem through the resource constraint but not directly through the price at which new debt is issued.[4] The zero–profit condition is given by

[4]This simplification is specific to the baseline GHH specification. In an earlier CRRA version of the model, current debt affected the current transfer through the government's budget constraint, which in turn

$$q(A, b', T'_H) = \frac{1}{1+r_f}\,\mathbb{E}_{A'}\Big[\big(1 - D(A', b', T'_H)\big)\Big(\delta_b + c + (1-\delta_b)\,q(A', b'', T''_H)\Big)\Big], \tag{19}$$

where $D(\cdot)$ is an indicator equal to one if the government defaults in the next period. The first term inside the parentheses, $\delta_b + c$, represents the payoff from the fraction of bonds that mature plus the coupon payment, which the sovereign delivers only if it repays. The second term, $(1-\delta_b)\,q(\cdot)$, represents the continuation value of the fraction of bonds that remain outstanding and can be resold in the secondary market.

Equation (19) is standard in the quantitative sovereign default literature (e.g. Aguiar and Gopinath, 2006; Arellano, 2008; Yue, 2010). It embeds the key feature that sovereign debt is priced under the threat of default: as default risk rises, the expected payoff falls, lowering the bond price q. In equilibrium, this drives up sovereign spreads, linking domestic fundamentals to international borrowing costs.

In the present model, an additional state variable, the domestic technology frontier T_H, enters the bond price schedule. Because technology evolves endogenously through the knowledge diffusion channel, international financiers internalize the fact that today's import composition influences tomorrow's productivity growth and therefore repayment capacity. This makes sovereign spreads a function not only of current debt and output shocks but also of the long-run growth outlook. In the quantitative solution I allow for small taste or political shocks to the sovereign's repayment and borrowing decisions, which smooth the implied price schedule and help stabilize convergence under long-term debt.

Intuitively, the financier sector closes the model's international market by tying the sovereign's borrowing cost to both short–run fundamentals and long–run growth prospects. This channel is essential for connecting the learning mechanism to debt dynamics. Defaults that restrict imports not only reduce technology growth directly but also worsen borrowing conditions by lowering expectations of future repayment capacity.

affected household labor supply through the wealth effect. Because labor supply changes the wage and therefore relative intermediate-good prices, the current debt position could then affect the expenditure share π_H and the implied law of motion for T'_H. In that case it is natural to let the bond price schedule depend on both current debt and new issuance. Under GHH preferences, the wealth effect on labor supply disappears, so this additional dependence collapses in the implemented baseline.

3.5 Government

The home government is benevolent and chooses borrowing and default decisions to maximize domestic household lifetime utility. In making these choices, the government internalizes the private sector's equilibrium responses, recognizing that borrowing today alters relative prices, import composition, and therefore future technology growth. This distinguishes the setup from sovereign default models that have output costs imposed exogenously. In addition to the endogenous diffusion cost, I allow default to trigger an immediate exogenous productivity penalty. Let

$$A^D(A) = A - \max\{0, \lambda_0 A + \lambda_1 A^2\}, \tag{20}$$

so that default lowers current production efficiency even before the slower-moving technology channel operates.

Definition 1 (Private allocation)**.** *Given a bond price schedule $q(\cdot)$ charged by international financiers, the current state of the economy (A, b, T_H), and a government borrowing decision over next-period debt b', a private allocation with the final good as numéraire is a collection*

$$\{y_{HH}, y_{HF}, y_{FH}, M, C, \ell, L, P_H, P_F, P_M, w, d_M, d_f, d_x, \pi_H, T'_H\}$$

such that:

1. *The household budget constraint holds:*

$$C = wL + d_M + d_f + d_x + \mathcal{T}.$$

2. *Household labor supply satisfies the GHH first-order condition, Eq. (2).*

3. *The domestic and foreign bundle prices satisfy the Eaton–Kortum price-index formulas, with the foreign bundle price additionally reflecting the default-induced variety-loss wedge when the sovereign is in default.*

4. *The composite-input sector satisfies*

$$\widetilde{P}_M = \left(\varphi^\eta P_H^{1-\eta} + (1-\varphi)^\eta P_F^{1-\eta}\right)^{\frac{1}{1-\eta}},$$

together with the demand system in Eq. (8), the pricing relation in Eq. (10), and the profit definition in Eq. (9).

5. *Final-good profits and export profits satisfy*

$$d_f = A(\ell^{\alpha_\ell} M^{1-\alpha_\ell})^\gamma - w\ell - P_M M, \qquad d_x = (P_{HF} - P_H) y_{FH},$$

where P_{HF} is the export price charged abroad.

6. *Foreign demand for home exports is exogenous and given by $y_{FH} = I_F P_{HF}^{-\nu}$.*

7. *Labor market clearing holds:*

$$wL = w\ell + P_H(y_{HH} + y_{FH}).$$

8. *The final-good producer's first-order conditions with respect to labor and materials hold.*

9. *The domestic expenditure share satisfies*

$$\pi_H = \frac{P_H y_{HH}}{P_H y_{HH} + P_F y_{HF}},$$

and the domestic frontier evolves according to Eq. (18).

The government takes into account that these equilibrium allocations depend on its borrowing choice. At the start of each period, after observing the state (A, b, T_H), the government draws small political or taste shocks that perturb the default and borrowing decisions. These shocks are introduced to capture reduced-form political disturbances and, quantitatively, to smooth the fixed point under long-term debt. Let $V^R(A, b, T_H; b')$ denote the value associated with repayment and choice of next-period debt b', and let $V^D(A, T_H)$ denote the value of default. The repayment branch is

$$
\begin{aligned}
V^R(A, b, T_H; b') &= u(C, L) + \beta \mathbb{E} V(A', b', T'_H) \\
\text{s.t.} \quad \mathcal{T} &= q(A, b', T'_H)\big[b' - (1-\delta_b)b\big] - (\delta_b + c)b, \\
T'_H &= (1-\delta)T_H + \alpha_s \sum_{m \in \{H,F\}} \pi_m \, T^{\rho}_m.
\end{aligned}
\tag{21}
$$

Conditional on repayment, the government chooses over the debt grid with logit probabilities

$$
\omega(b' \mid A, b, T_H) = \frac{\exp\big(V^R(A, b, T_H; b')/\rho_b\big)}{\sum_{\tilde{b} \in \mathcal{B}} \exp\Big(V^R(A, b, T_H; \tilde{b})/\rho_b\Big)},
\tag{22}
$$

and the continuation value under repayment is the probability-weighted average

$$
V^R(A, b, T_H) = \sum_{b' \in \mathcal{B}} \omega(b' \mid A, b, T_H)\, V^R(A, b, T_H; b').
\tag{23}
$$

If the government defaults, it enters financial autarky. In this state, it cannot issue new debt, transfers satisfy $\mathcal{T} = 0$, production uses the penalized productivity level $A^D(A)$ from Eq. (20), and imported varieties are partially shut down by the wedge Ω. Each period there is an exogenous probability $1 - \lambda$ of regaining access to international markets. The default value is therefore

$$
\begin{aligned}
V^D(A, T_H) &= u(C, L) + \beta\Big[\lambda\, \mathbb{E} V^D(A', T'_H) + (1-\lambda)\, \mathbb{E} V(A', 0, T'_H)\Big] \\
\text{s.t.} \quad \mathcal{T} &= 0, \\
T'_H &= (1-\delta)T_H + \alpha_s \sum_{m \in \{H,F\}} \pi_m \, T^{\rho}_m.
\end{aligned}
\tag{24}
$$

The repayment and default branches are then aggregated through a second logit smoothing device:

$$
p_D(A, b, T_H) = \frac{\exp\big(V^D(A, T_H)/\rho_D\big)}{\exp(V^R(A, b, T_H)/\rho_D) + \exp(V^D(A, T_H)/\rho_D)},
\tag{25}
$$

$$
V(A, b, T_H) = \big(1 - p_D(A, b, T_H)\big)\, V^R(A, b, T_H) + p_D(A, b, T_H)\, V^D(A, T_H),
\tag{26}
$$

where ρ_b and ρ_D govern the dispersion of borrowing and default shocks, respectively. As these parameters approach zero, the model converges to the standard deterministic sovereign default problem with sharp policy rules.

Equations (23) and (24) highlight the trade-offs faced by the sovereign. Repayment preserves access to international credit markets and supports technology growth through continued imports, but comes at the cost of honoring debt obligations. Default provides short-run relief from debt repayment but eliminates market access and, by disrupting imports, slows the pace of knowledge diffusion. The parameter λ governs the persistence of exclusion, while λ_0 and λ_1 determine the size of the additional contemporaneous default penalty. Together, these parameters shape the severity of default costs in the quarterly model.

4 Quantitative results

This section presents the quantitative analysis of the model. I begin by describing the calibration strategy, distinguishing between targeted parameters that are chosen to match key empirical moments and untargeted outcomes that serve as validation checks. I then examine the mechanism through which the model translates sovereign default into persistent productivity losses, focusing on the interaction between import composition and knowledge diffusion. Finally, I present the main quantitative results, quantifying the loss of output and welfare associated with learning disruptions and the consecutive decline in TFP.

The quantitative exercise has three objectives. First, it ensures that the model can replicate standard sovereign default moments such as default frequencies, average spreads, and debt-to-GDP ratios. Second, it tests whether the diffusion mechanism can match the empirical evidence on technology dynamics around crises, including the persistence of TFP declines. Third, it uses the calibrated framework to conduct counterfactual experiments that isolate the role of diffusion in amplifying the costs of default.

4.1 Calibration

The model contains a total of 14 parameters that govern the behavior of the economy. Six of these are assigned externally based on estimates from the existing literature, while the remaining eight are calibrated internally using a simulated method of moments (SMM). The internal calibration minimizes the weighted distance between model-implied and empirical moments:

$$Err = \sum_j \frac{(M_j - M_j')^2}{\frac{1}{2}M_j + \frac{1}{2}M_j'}, \tag{27}$$

where M_j denotes the empirical moment and M_j' its model counterpart.

Assigned parameters

Table 1 reports the six externally assigned parameters and their sources. The model is solved at a quarterly frequency. The risk-free rate r^f is set at 1%, which corresponds to an annualized rate of approximately 4%, consistent with international borrowing costs in emerging markets. The labor share parameter α_L is assigned a value of 0.58, in line with the average labor share in total value added.

The risk aversion coefficient σ is set equal to 2, a standard value in the quantitative sovereign default literature. The Frisch elasticity of labor supply is set to 0.45, following Mendoza and Yue (2012). This parameter shapes the response of labor supply to changes in wages and thus plays an important role in amplifying output losses during default episodes. Because estimates of the Frisch elasticity vary considerably across studies, I report a sensitivity analysis in the appendix to verify the robustness of the quantitative results.

The Armington elasticity of substitution across home and foreign varieties and the elasticity across intermediate varieties within each country are also drawn from Mendoza and Yue (2012). These parameters govern the extent to which the economy can substitute toward domestic inputs during episodes of restricted imports. In particular, higher elasticities allow the economy to substitute more easily, cushioning short-run output losses but reducing exposure to frontier varieties and thereby amplifying long-run technology costs. Appendix B reports robustness checks with alternative values of the Armington elasticity.

Finally, the shape parameter θ of the Fréchet distribution governing productivity draws is

set following Buera and Oberfield (2020). This ensures consistency with the diffusion literature and allows direct comparison with their estimates of international technology spillovers.

[Insert Table 1 about here]

Calibrated parameters

The remaining eight parameters are calibrated jointly using a simulated method of moments, targeting both business cycle statistics and the behavior of output and imports around sovereign default events. The calibration focuses on the Argentine default of 2001, which provides rich empirical evidence on the dynamic response of GDP and trade flows. Although parameters are jointly determined, several are particularly tied to specific moments.

The persistence of the efficiency shock in final-good production, ρ_A, is set to 0.9 to match the autoregressive coefficient of GDP. Since default events are rare, the persistence of A shocks primarily shapes the autocorrelation structure of GDP over time. The standard deviation of the A shock, σ_A, is set to 0.012 (about 5% annually), chosen to match the observed volatility of GDP in the data.

The technology depreciation rate, δ, governs the erosion of knowledge during default. It is calibrated to reproduce the observed dynamics of TFP and patent applications shown in Figure 4. The estimated value implies a relatively high depreciation rate, around 20% annually in the absence of learning. This parameter should be interpreted as a detrended measure that captures not only the obsolescence of existing technologies but also the effects of population growth, consistent with the semi-endogenous growth literature.

The foreign technology frontier, T_F, is calibrated to match the relative real wage between the home economy and the rest of the world. The arrival rate of ideas, α, determines the steady-state domestic technology level and is chosen to replicate the average terms of trade. The fraction of imports banned during default, Ω, is calibrated to reproduce the import collapse observed in Figure 2.

Finally, the default-cost parameters λ_0 and λ_1, together with the discount factor β, are disciplined by sovereign debt statistics. These jointly determine the sovereign's willingness to borrow and default, and are therefore chosen to match an average default probability of

0.69% quarterly (about 3% annually), the mean bond-to-GDP ratio, and the average spread observed in the data.

[Insert Table 2 about here]

Model fit

Table 3 reports the targeted and untargeted moments, and Figure 7 illustrates the dynamic responses of output and imports around default events. The model successfully matches the majority of the targeted moments, including default frequency, average spreads, debt-to-GDP ratio, and the volatility and persistence of GDP. The main discrepancy arises in the correlations between trade flows and GDP. In the model, GDP fluctuations are driven solely by A shocks. A positive productivity shock raises output but also increases labor demand and wages, which makes domestic goods more expensive and reduces exports. As a result, the correlation between exports and GDP is negative, while the correlation between imports and GDP is close to one. This limitation reflects the fact that the model does not incorporate additional sources of business cycle fluctuations beyond productivity.

Turning to the dynamics, the model replicates both the level and persistence of output losses during crises. GDP declines by about 10% at the trough, and the half-life of recovery is approximately 2.5 years, consistent with the data. Full recovery is slower than observed, reflecting two reinforcing forces. First, the persistence of productivity shocks, captured by ρ_A, generates slow mean reversion in output. Second, the gradual rebuilding of the technology frontier following a default prolongs the recovery. Because the loss of imports reduces learning opportunities, technology converges back to trend only slowly.

The import dynamics are also well captured. Imports fall sharply after default, consistent with the Argentine experience. The drop reflects two forces: (i) the import ban parameter Ω, which directly removes a fraction of goods from the bundle, and (ii) lower demand for intermediates when A is low. Both forces reduce the probability of drawing from high-quality foreign varieties, thereby depressing technology growth. These dynamics highlight the central mechanism of the model: sovereign default has persistent costs not only because of financial exclusion but also because it disrupts the process of learning from imports.

Overall, the model matches the main sovereign default moments while providing a novel explanation for the long-lasting productivity losses observed in the data. The next section formally decomposes the contribution of the diffusion channel to output and welfare costs.

[Insert Table 3 about here]

[Insert Figure 7 about here]

5 Decomposition of the learning channel

This section quantifies the contribution of the learning channel to the output and welfare costs of sovereign default. The strategy is to take the calibrated model and compare the benchmark dynamics to counterfactual scenarios in which technology diffusion is shut down. Each counterfactual is simulated for 150,000 periods, and default events are collected to construct average impulse responses around default.

I consider two counterfactual scenarios.

First, I shut down the diffusion mechanism entirely by fixing the technology frontier at its pre-default level. In this case, the only consequences of default are *financial exclusion*—the sovereign loses access to international markets—and the *static costs* of default, namely the import ban Ω and the penalty on production efficiency A in the final-good sector. This scenario corresponds to the standard environment in the sovereign default literature, where output costs are exogenous and transitory.

Second, I retain the import ban and the production efficiency penalty, but again fix the technology frontier at the pre-default level. This counterfactual isolates the role of diffusion by holding technology constant, so that dynamics are driven solely by financial exclusion, lower efficiency A, and the import ban. The difference between this scenario and the benchmark model measures the fraction of output losses attributable to the learning channel.

Figure 8 plots the decomposition. The learning channel is not quantitatively important in the initial quarters after default, because knowledge accumulation and destruction are inherently slow-moving processes. Instead, output declines at impact are primarily driven by

the fall in A and the import ban Ω. However, as time passes, the persistent effect of reduced learning opportunities becomes increasingly important. The A shock gradually mean reverts, allowing GDP to recover partially, but the technology frontier remains depressed relative to its pre-default level. As a result, the learning channel explains a growing share of the output gap at medium horizons, and is ultimately responsible for the long-run persistence of default costs.

[Insert Figure 8 about here]

5.1 Duration of default and the learning channel

The quantitative importance of the learning channel depends crucially on the duration of default. Short episodes generate limited technology losses, while longer episodes compound the effects of reduced learning opportunities. To evaluate this mechanism, I simulate the model over a long horizon and collect default events of different lengths. I then compare the dynamics of output and technology for defaults that last exactly four quarters versus twelve quarters.

Figure 9 illustrates the results. In short defaults (left panel), the gap between the benchmark model and the counterfactual without diffusion is small and begins to close quickly, before the stock of knowledge has time to decline substantially. By contrast, in longer defaults (right panel), the area between the benchmark path and the no-diffusion path widens significantly. The extended disruption of imports reduces the probability of drawing from high-quality foreign varieties for a sustained period, leaving the technology frontier persistently below its pre-default trend.

This prediction is consistent with the empirical findings of Farah-Yacoub et al. (2024), who show that prolonged defaults are associated with larger and more persistent welfare losses, sometimes approaching permanence. Because technology accumulation is a slow-moving process, it can take up to three additional years for T_H to converge back to its pre-default path after a long default. Relative to a counterfactual without default, where technology continues to grow smoothly, the cumulative gap is even larger.

Quantitatively, the model implies that learning accounts for roughly one-seventh of the

total output cost during the default period itself, and an additional one-seventh of the losses that materialize after the country exits default. This persistence arises because knowledge diffusion compounds gradually, so even after GDP begins to recover, the technology frontier remains depressed. As a result, the model generates slower TFP recovery relative to GDP recovery, in line with the empirical evidence documented in Section 2.

[Insert Figure 9 about here]

6 Policy experiments

As discussed in Section 3, the private economy does not internalize the effect of input composition on technology evolution. During default episodes, the country suffers a sharp decline in imports, which slows technology growth because retailers substitute heavily toward domestic varieties. Retailers choose the input bundle to minimize current costs based on relative prices, without considering the dynamic impact of foreign variety exposure on future knowledge accumulation. This externality implies that laissez-faire allocations result in a technology frontier that is inefficiently low during default.

Motivated by this inefficiency, I examine the role of government policies in mitigating the loss of learning. Specifically, I study whether tax and tariff instruments can improve social welfare by altering input choices during default. The guiding principle is that the government may wish to subsidize imports to internalize the dynamic externality, while distortionary taxes on exports or labor income may deliver less effective outcomes.

6.1 Export taxes and import subsidies

I now focus on two policy instruments that directly affect the composition of inputs during default: an export tax and an import subsidy. Both policies alter relative prices in the retailer's problem and therefore shift the expenditure shares $\pi_{H,t}$ and $\pi_{F,t}$ that govern technology diffusion through Eq. (18).

An *export tax* τ_X reduces the relative return to selling goods abroad. If domestic producers face a net export price of $(1 - \tau_X)P_H$, then the effective demand for home varieties

from foreign markets falls:

$$Y_{H,t}^{X,\,\text{after tax}} = (1-\tau_X)\, Y_{H,t}^{X}.$$

The immediate effect is to shift more domestic varieties back into the home input bundle, raising $\pi_{H,t}$. While this increases the supply of inputs available domestically, it distorts production incentives and reduces overall trade volumes. As a result, the export tax does not directly increase exposure to frontier foreign technologies, and its effect on long-run growth is limited.

By contrast, an *import subsidy* s lowers the effective cost of foreign inputs for the retailer. With the subsidy, the retailer's problem becomes

$$\max_{Y_H, Y_F, M} \; P_M M - P_H Y_H - (1-s) P_F Y_F,$$

subject to the CES aggregator

$$M = \left(Y_H^{\frac{\eta-1}{\eta}} + Y_F^{\frac{\eta-1}{\eta}} \right)^{\frac{\eta}{\eta-1}}.$$

The subsidy directly increases the expenditure share on foreign varieties,

$$\pi_{F,t}(s) = \frac{(1-s) P_{F,t} Y_{F,t}}{P_{H,t} Y_{H,t} + (1-s) P_{F,t} Y_{F,t}},$$

which in turn raises the expected quality of learning draws and accelerates the growth of the domestic frontier $T_{H,t+1}$.

Intuitively, the export tax works indirectly by reshuffling domestic output between foreign and home markets, while the import subsidy directly tackles the externality at its source by making frontier goods cheaper. Because technology accumulation depends on exposure to foreign varieties, the import subsidy is better targeted: it equates the marginal benefit of a higher frontier tomorrow with the marginal cost of lower real consumption today. The quantitative analysis in the next subsection compares these two instruments and evaluates their welfare implications.

6.2 Variety-targeted import subsidies

As an extension, I consider a policy that differentiates among imported inputs by their potential to contribute to learning. In practice, not all imported goods embody the same degree of frontier knowledge: imports of capital goods and high-technology intermediates are more strongly linked to productivity spillovers than imports of basic commodities. To capture this heterogeneity in reduced form, I split the foreign input bundle into high-knowledge varieties (F_H) and low-knowledge varieties (F_L).

The retailer's problem becomes

$$\max_{Y_H, Y_{F_H}, Y_{F_L}, M} P_M M - P_H Y_H - (1 - s_H) P_{F_H} Y_{F_H} - (1 - s_L) P_{F_L} Y_{F_L},$$

subject to

$$M = \left(Y_H^{\frac{\eta-1}{\eta}} + Y_{F_H}^{\frac{\eta-1}{\eta}} + Y_{F_L}^{\frac{\eta-1}{\eta}} \right)^{\frac{\eta}{\eta-1}}.$$

The corresponding import expenditure shares are

$$\pi_{F_H,t} = \frac{(1 - s_H) P_{F_H,t} Y_{F_H,t}}{P_{H,t} Y_{H,t} + (1 - s_H) P_{F_H,t} Y_{F_H,t} + (1 - s_L) P_{F_L,t} Y_{F_L,t}},$$

$$\pi_{F_L,t} = \frac{(1 - s_L) P_{F_L,t} Y_{F_L,t}}{P_{H,t} Y_{H,t} + (1 - s_H) P_{F_H,t} Y_{F_H,t} + (1 - s_L) P_{F_L,t} Y_{F_L,t}}.$$

Knowledge diffusion then depends more heavily on the high-knowledge share:

$$T_{H,t+1} = (1 - \delta) T_{H,t} + \alpha \, \Gamma (1 - \rho) \Big[\pi_{H,t} \, T_{H,t}^{\rho} + \pi_{F_H,t} \, T_F^{\rho} + \zeta \, \pi_{F_L,t} \, T_F^{\rho} \Big],$$

where $\zeta \in (0, 1)$ scales down the contribution of low-knowledge imports.

The policy experiment sets $s_H > s_L$, with the average fiscal cost held fixed at the same level as an untargeted import subsidy. In effect, the government concentrates its subsidy resources on varieties with higher spillover content. This targeted approach raises $\pi_{F_H,t}$ relative to $\pi_{F_L,t}$, delivering stronger technology growth for the same budgetary outlay.

Intuitively, a uniform subsidy encourages all imports equally, regardless of their knowledge content. By contrast, a variety-targeted subsidy pays "per idea" rather than "per dollar

of imports."

7 Conclusion

This paper has documented a novel and persistent cost of sovereign default. Beyond the well-known collapse in GDP and trade, I show that defaults are followed by sharp and long-lasting declines in total factor productivity and patenting activity. These patterns suggest that the costs of default extend beyond temporary output contractions: even when GDP eventually rebounds, the welfare of the economy remains depressed because the technology frontier recovers only slowly.

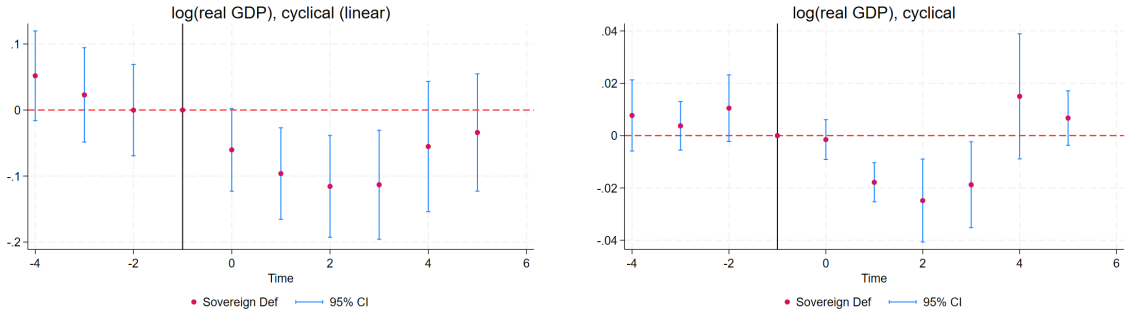
To account for these facts, I develop a quantitative model that augments the canonical sovereign default framework of Arellano (2008) with the knowledge-diffusion mechanism of Buera and Oberfield (2020). Imports play a dual role: they serve as inputs into current production and, more importantly, as a source of learning from the global frontier. A sovereign default reduces access to frontier varieties, thereby slowing technology growth and prolonging the recovery. This channel provides a natural explanation for the persistence in productivity losses observed in the data, which standard default models with purely exogenous output costs cannot generate.

Quantitatively, the calibrated model matches both business cycle moments and the dynamic responses of output and trade around default episodes. The decomposition exercise shows that the learning channel accounts for roughly one third of the long-run output losses from default. Moreover, its importance grows with the duration of financial exclusion, consistent with recent empirical evidence that prolonged defaults are especially costly.

The broader implication is that the cost of default cannot be fully understood by looking only at contemporaneous output losses or borrowing spreads. Sovereign default disrupts the process of technology accumulation, generating persistent welfare costs even after output recovers. Incorporating this channel helps reconcile the observed persistence of default crises with theory, and underscores the importance of trade policy and international cooperation in mitigating the long-term consequences of financial crises.

Figures

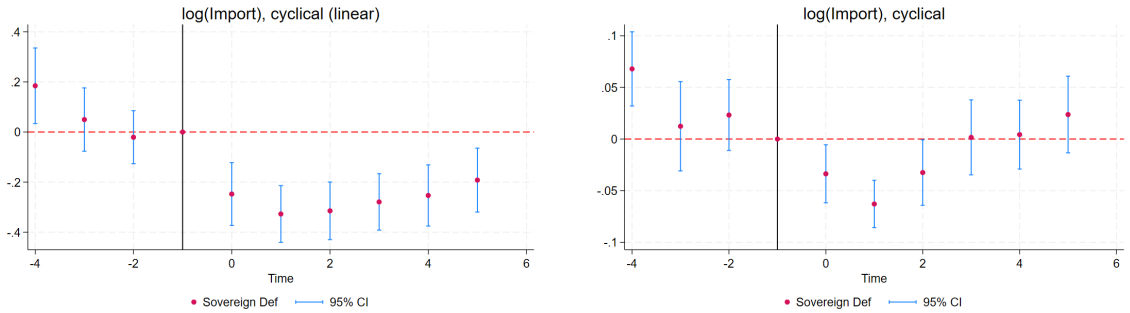
Figure 1: Detrended real GDP around debt crisis



(a) Linear detrended (b) HP detrended

Note: Figure presents the impact of sovereign default crisis on GDP. I consider both HP filter with annual frequency and linear trend to de-trend the data.

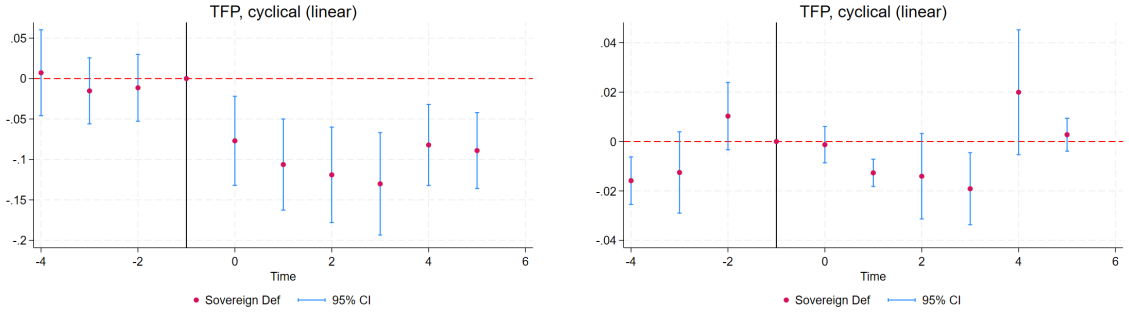
Figure 2: Detrended import around debt crisis



(a) Linear detrended (b) HP detrended

Note: Figure presents the impact of sovereign default crisis on import. I consider both HP filter with annual frequency and linear trend to de-trend the data.

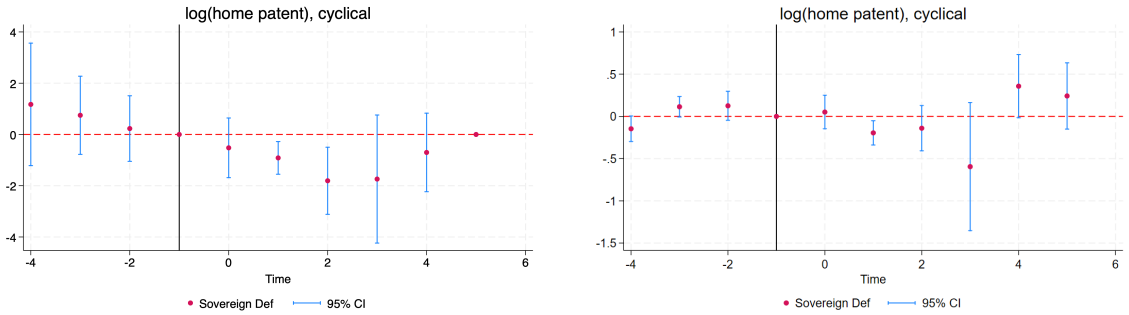
Figure 3: Detrended TFP around debt crisis



(a) Linear detrended (b) HP detrended

Note: Figure shows the impact of sovereign debt crises on total factor productivity (TFP). Both an HP filter (annual frequency) and a linear trend are used to de-trend the data. TFP is taken from the Penn World Table and measured at constant national prices.

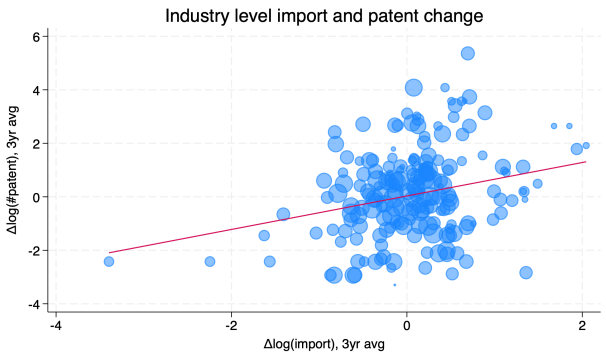
Figure 4: Detrended # of patent applications around debt crisis



(a) Linear detrended (b) HP detrended

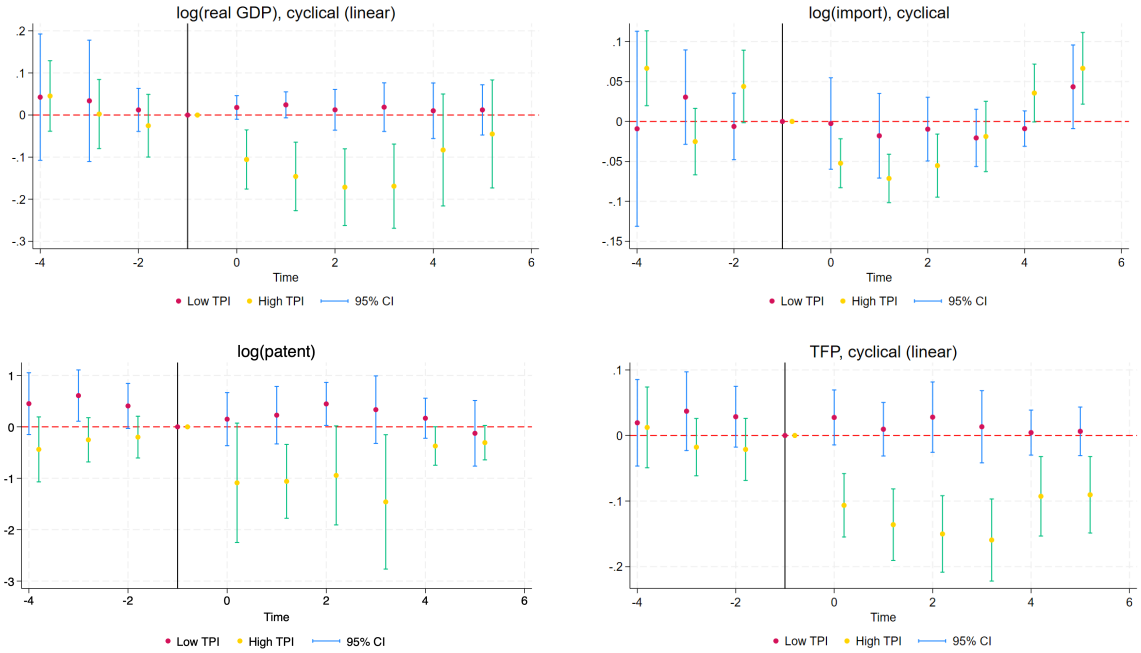
Note: Figure shows the impact of sovereign debt crises on patent applications filed at domestic patent offices. Both an HP filter (annual frequency) and a linear trend are used to de-trend the data. Source: INPACT-S.

Figure 5: Change in import and patent applications, 3yr difference



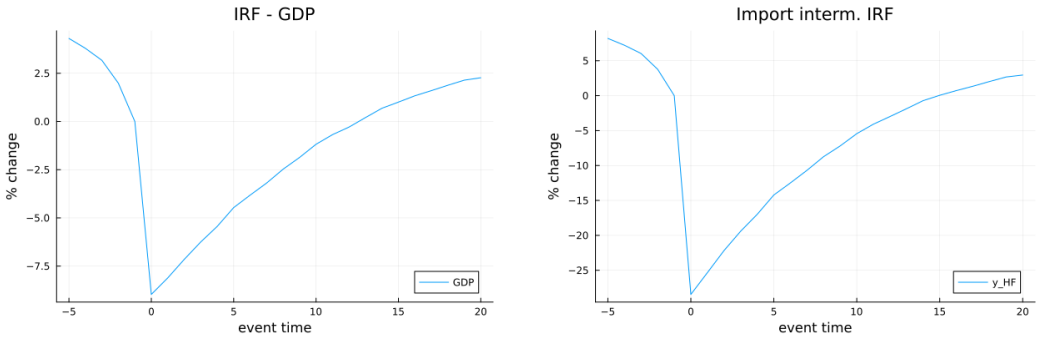
Note: Figure shows three-year changes in imports and patent applications. The figure suggests a strong positive correlation between import growth and local patenting activity. Industries are defined at the HS-4 digit level and cross-walked to the NAICS classification in the INPACT-S patent database.

Figure 6: detrended GDP and import based on ATT



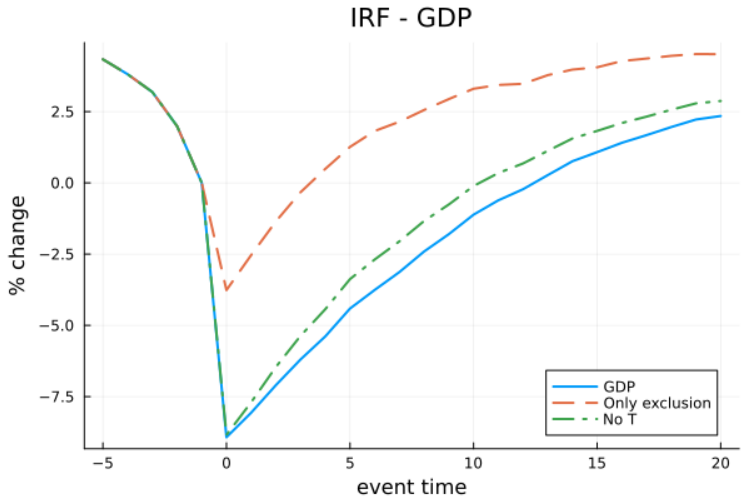
Note: Figure plots the impact of sovereign debt crises on TFP and patent applications at domestic patent offices, distinguishing countries by the technological level of their trading partners. Yellow dots show event-study estimates for countries that trade heavily with high-technology partners, while red dots correspond to countries more reliant on lower-technology partners. The blue and green bands represent 95% confidence intervals.

Figure 7: Dynamic of GDP and import, model



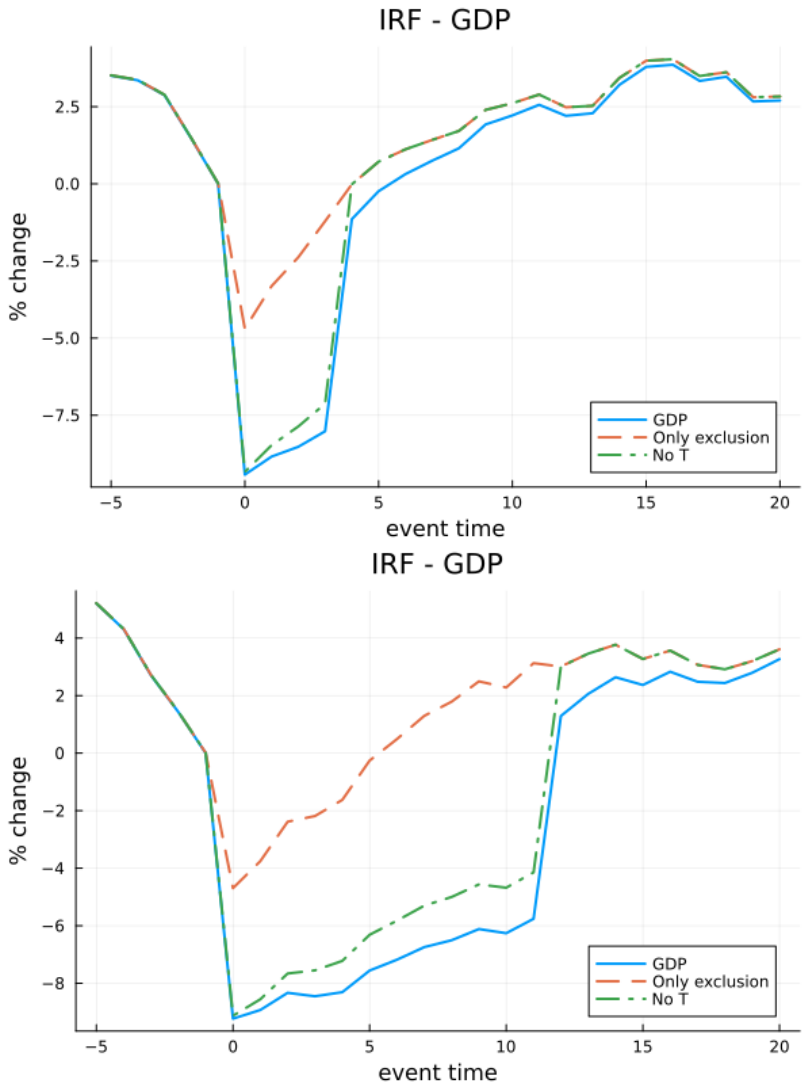
Note: Figure shows the impact of sovereign debt crises on GDP and imports from the model's impulse response functions. The model is simulated over a long panel, and event windows are collected to compute the average responses.

Figure 8: Decomposition of mechanism



Note: Figure shows the decomposition of default costs in the model. In the baseline, the sovereign faces both an import ban and financial exclusion. Two counterfactuals are considered: the green line plots outcomes without the learning channel (while retaining the import ban and financial exclusion), and the orange line isolates the case of financial exclusion only, without any import ban.

Figure 9: Differential impact with different duration



Note: Figure shows the differential impact of sovereign defaults of varying duration, highlighting the contribution of the learning channel. The figure suggests that the learning channel plays a relatively minor role in short defaults but becomes increasingly prominent when defaults are prolonged.

Tables

Table 1: Assigned parameters

Parameter	Meaning	Value	Source/Moments
	Assigned parameters		
r^f	Risk free rate	1%	International borrowing rate
α_L	Span parameter	0.6 †	Avg. labor share
σ	Risk aversion	2.0	Standard in literature
ϕ	Probability of re-entry	0.082	Average recovery duration (3 yr)
ψ	Inverse Frisch elasticity	0.45	Mendoza and Yue (2012)
η	Armington elasticity	2.86	Mendoza and Yue (2012)
ν	Dixit-Stiglitz elasticity	2.54	Mendoza and Yue (2012)
θ	Shape parameter of T	4.0	Buera and Oberfield (2020)
δ_b	Matured bond fraction	0.04	Average maturity

Coupon payment implies an average maturity of approximately 6.25 years. † Sensitivity analysis with alternative values of the span parameter yields no quantitatively significant changes in the results.

Table 2: Calibrated parameters

Parameter	Meaning	Value	Source/Moments
	Calibrated parameters		
ρ_A	AR(1) of productivity	0.9	AR(1) of GDP
σ_A	Std. of productivity shock	0.012	Std. of GDP
δ	Technology depreciation	0.2	TFP dynamics (Fig. 4)
T_F	Foreign technology frontier	38	Relative real wage
I_F	Foreign demand parameter	6e-4	Relative size of labor force
α	Idea arrival rate	0.15	Average terms of trade
Ω	Fraction of import ban	0.13	Import dynamics (Fig. 2)
λ_0	Default cost parameter	-0.18	Average spread
λ_1	Default cost parameter	0.21	Std. of spread
β	Discount factor	0.905	Default probability

Note: The AR(1) parameter for GDP is estimated directly from the data, outside the model. The innovation diffusion parameter is disciplined by the dynamic response of TFP, capturing both its magnitude and persistence. The default cost parameters are identified from the observed spread and the empirical probability (frequency) of default.

Table 3: Moment match between data and baseline model

Moments	Data	Baseline
Targeted Moments		
AR(1) GDP	0.82	0.89
Std. GDP	4.7%	6.02%
Rel. wage	2.5	3.0
Avg. terms of trade	1.2	1.49
Avg. trade share	31%	31.4%
Avg. spread	1.86%	1.28%
Std. spread	0.78%	0.48%
Default prob	0.69%	0.94%
Un-targeted Moments		
Debt to GDP ratio	35%	25.4%
Cor(Spread,GDP)	-0.62	-0.34
Cor(Imp,GDP)	0.66	0.91
Cor(Exp,GDP)	0.27	-0.98

Note: The model is simulated for 200,000 periods, discarding the first and last 10,000 observations to remove initialization and end-point effects. Moments are then computed from the remaining long panel and compared to the corresponding data statistics.

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Appendix A: Proofs and Derivations

A.1 Evolution of the technology distribution

This appendix derives the law of motion for the domestic technology frontier in Section 3.3.1.

Let $F_t(z)$ denote the cumulative distribution of productivity draws at time t, and $G_t(z)$ the distribution of source ideas available in the domestic market. Following Buera and Oberfield (2020), the probability that a new idea improves upon the current technology z is

$$z'(\omega) = q(\omega)\, z_S^{\rho}, \qquad \text{with } q(\omega) \sim \text{Pareto}(\alpha, \theta). \tag{28}$$

The arrival rate of useful innovations implies the following differential equation for the evolution of $F_t(z)$:

$$\frac{d \ln F_t(z)}{dt} = -\alpha z^{-\theta} \int_0^{\infty} x^{\rho\theta}\, dG_t(x). \tag{29}$$

Solving (29) yields

$$F_t(z) = \exp\Big\{ - z^{-\theta} \int_0^t \alpha \int_0^{\infty} x^{\rho\theta}\, dG_\tau(x)\, d\tau \Big\}. \tag{30}$$

Hence, if the initial distribution $F_0(z)$ is Fréchet with scale T_0, the distribution remains Fréchet for all t:

$$F_t(z) = \exp\big(- T_t z^{-\theta} \big), \tag{31}$$

with scale parameter

$$T_t \equiv T_0 + \int_0^t \alpha \int_0^{\infty} x^{\rho\theta}\, dG_\tau(x)\, d\tau. \tag{32}$$

A.2 Discrete-time law of motion

Let $\pi_{n,t}$ denote the expenditure share on inputs from source $n \in \{H, F\}$. Then the distribution of source ideas can be written as a convex combination,

$$G_t(z) = \sum_{n \in \{H,F\}} \pi_{n,t} F_{n,t}(z). \tag{33}$$

Substituting into the integral above and using the moment generating property of the Fréchet distribution,

$$\int_0^\infty x^{\rho\theta}\, dF_{n,t}(x) = \Gamma(1-\rho)\, T_{n,t}^{\rho}. \tag{34}$$

The evolution of the frontier is therefore

$$T_{H,t+1} = (1-\delta)T_{H,t} + \alpha\Gamma(1-\rho) \sum_{n\in\{H,F\}} \pi_{n,t}\, T_{n,t}^{\rho}, \tag{35}$$

which corresponds to equation (18) in the main text. □