The S-curve: Understanding the Dynamics of Worldwide Financial Liberalization

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Abstract

Using a new database of domestic financial reforms in 90 countries over 1973-2014, we document the globalization of financial liberalization that followed a S-curve path: the progress of financial liberalization was slow and gradual in early periods, accelerated during the 1990s, and slowed down again after 2000. Policymakers updated their beliefs about the effects of financial reforms on growth by learning from experiences of their own countries as well as other countries. While country-specific political and economic developments contributed to the evolution of financial reforms, informational diffusion through optimal Bayesian updating of policymakers' beliefs accounted for the timing and speed of financial liberalization in every country. The run-up of financial liberalization during the 1990s in emerging economies and low-income countries was driven largely by learning from successful financial reforms of advanced countries as early reformers.

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1 Introduction

One of the most important developments over the past four decades is the growing willingness of governments to open up the financial sector to market forces. Few policy choices are as fundamental as those that determine how a government should engage in—or resist—the forces of financial liberalization. To understand the worldwide advance of financial reforms, we provide a comprehensive database of domestic financial regulations, which covers 90 countries over a long period (1973-2014). We use this new dataset to document the most salient fact about global financial liberalization: the advancement of domestic financial liberalization in every country followed an S-curve path—it progressed slowly in the beginning, accelerated in the 1990s, and slowed down again after 2000.

To account for this fact, we follow Buera, Monge-Naranjo, and Primiceri (2011) and develop a dynamic structural model that incorporates policymaker's beliefs about the effects of domestic financial reforms on output growth and uncertainty about these effects. The existing literature shows that domestic financial reforms were strongly associated with economic growth (Jayaratne and Strahan, 1996; Bekaert et al., 2005; Levine, 2005; Prati et al., 2013). Our model highlights the feedback between financial reforms and Bayesian updating of policymakers' beliefs about the economic effects of policy decisions. With the new dataset for 90 countries over 1973-2014, we estimate the structural model and through the lens of the estimated model, we address three retrospective questions. Were there countries that played a leading role in the run-up of financial reforms during the 1990s in less developed countries such as Nigeria and Vietnam? How did the 2008 global financial crisis (GFC) affect the worldwide prospect for financial liberalization and its reversal? What factors drove the S-curve dynamics of financial liberalization in different income groups of countries?

Financial reforms are politically costly (Alesina et al., 2020) and their impacts on economic growth are uncertain. When making decisions about the speed of financial liberalization, policymakers in our model face a trade-off between growth benefits and political costs. They update their beliefs about growth impacts of financial reforms by learning from their own past experiences as well as other countries' experiences. We impose on the model a prior that beliefs are geographically correlated so that experiences of proximate countries provide more relevant information for learning than distant countries.[1] Based on their beliefs and the trade-off between growth benefits and political costs, policymakers choose optimal financial reform policy. Figure 1 illustrates the relationship between a change in the financial liberalization index and a growth differential between financially liberalized and repressed countries. As the figure shows, financial reforms accelerated when

[1]Spatial clustering of financial reforms is observed in the data (see Section 3). In the literature (Krugman, 1997; Head and Mayer, 2014), spatial closeness has been shown to matter for economic closeness.

financially liberalized countries had faster economic growth than financially repressed countries, and decelerated when financially liberalized countries grew slower than did financially repressed countries.

Our model interprets this close linkage between growth and reforms as a critical role of the belief formation in driving policy changes, especially during the early period of slow financial liberalization in emerging economies and low-income countries. Policymakers in each country observe growth performances in its own country and other countries, update their opinions about the effects of financial reforms, and make decisions of its domestic financial policy. Alternative models without belief formation, including a reduced-form model with time-fixed effects, have a worse fit to the data than our structural model both in sample and out of sample. Indeed, our model fits remarkably well to not only the average financial liberalization index, but also the financial liberalization index for each individual country—a challenging task both conceptually and computationally.

According to the estimated evolution of beliefs, in the beginning of the sample, policymakers in a majority of countries had a pessimistic view of the impact on growth of financial liberalization and underestimated the effectiveness of financial liberalization. By the end of the sample, a fraction of countries were still unconvinced that a high level of financial liberalization was conducive to high growth. Belief uncertainty was reduced through learning over time, but it was still high by the end of the sample. As countries accumulated more information about the efficacy of their own policy, however, the belief correlation across countries declined considerably over time. After the mid 2000s, the average gap between the believed and actual effects of financial liberalization on growth is close to zero.

Our estimation yields several key results. First, we find that informational diffusion from the experiences of advanced countries played a crucial role in the learning process. On average, advanced countries accounted for half of the belief evolution worldwide. Advanced countries promoted their financial reforms mainly from their own past experiences. Emerging economies and low-income countries, however, advanced their financial reforms mainly by learning from experiences of advanced countries, especially in the early period. High levels of financial liberalization in advanced countries served as a strong signal to the rest of the world for the positive effects of financial reforms on economic growth. If emerging economies and low-income countries had learned only from experiences among themselves but not from those of advanced countries, the level of GDP per capita in 2014 would have been, on average, 8.3% lower in emerging economies and 18.1% lower in low-income countries.

Second, we find that the GFC caused a reversal of belief about the effects of financial reforms on growth, especially in emerging economies. There was great uncertainty of belief in emerging

economies, which made policymakers' beliefs in these countries susceptible to large negative shocks to output growth during the financial crisis.

Third, learning about the effects of financial reforms on economic growth across countries and over time is a general policy-formation process that encompasses policy emulation and knowledge dissemination. Some studies take emulation as evidence of learning (Meseguer, 2005; Abiad and Mody, 2005); others argue that International Financial Institutions (IFIs) played an important role as informational facilitator to disseminate the knowledge learned from the success of financial reform leaders to the rest of the world (Quirk et al., 1994). Our model provides a concrete and structural interpretation of these (reduced-form) views within one single framework. Our estimation demonstrates that economic performances of countries with higher liberalization sent a strong signal to the rest of the world about the effectiveness of financial reforms. This informational diffusion gave rise to the temporal clustering of rapid financial reforms in the 1990s.

Fourth, the learning mechanism gives rise to the S-curve dynamics observed in the financial liberalization data. When the financial sector in most countries were repressed in the early period of the sample, information about the effects of financial reforms on growth did not have a strong signal; as a result, financial reforms were implemented slowly. After gradual increases in beliefs in the early period, financial liberalization around the world reached a level that sent a strong signal of reforms' positive effects on growth to policymakers, especially in emerging economies and low-income countries. Beliefs in these positive effects accelerated, leading to the run-up of worldwide financial reforms in the 1990s. As financial policy became maturer than in the early period, the process of learning was on average closer to completion. The slower process of belief updating resulted in a slower progress of financial liberalization worldwide in the 2000s. That is, the level of financial liberalization began to flatten out after 2000.

To be comparable with the existing literature, the model allows for other determinants of financial reforms documented in empirical studies: events such as economic and financial crises, the falling global interest rate (Abiad and Mody, 2005), and political factors (Giuliano et al., 2013; Elkins and Simmons, 2005). We find that the S-curve dynamics of financial liberalization were driven mainly by the evolution of beliefs, not by economic and political factors even though the effects of these factors are estimated to be statistically significant. More important is our finding that learning from the economic effects of financial reforms in advanced countries rather than from their own experiences accounted for the S-curve path of financial liberalization in emerging economies and low-income countries.

The rest of the paper is organized as follows. Section 2 places the contribution of our paper in the context of the existing literature. Section 3 discusses our financial liberalization data. Section 4

constructs the structural model and Section 5 presents estimation results. Policy implications and various counterfactual experiments are discussed in Section 6. Section 7 discusses the model's mechanism for understanding the S-curve dynamics. Section 8 offers concluding remarks.

2 Brief literature review

This paper contributes to a large strand of literature that studies economic and political forces that may have influenced financial reforms (e.g. Alesina and Roubini, 1992; Bartolini and Drazen, 1997; Rajan and Zingales, 2003; Giavazzi and Tabellini, 2005; Abiad and Mody, 2005; Mukand and Rodrik, 2005; Giuliano et al., 2013; Alesina et al., 2020). The work most related to ours is Abiad and Mody (2005), which use reduced-form panel regressions to study potentially important factors that contributed to domestic financial reforms around the world. Typical in the existing literature on financial reforms, such a reduced-form approach cannot fully account for the S-curve path of a country's financial liberalization; neither is it suitable for providing counterfactual policy analyses. Our structural model is designed to answer policy questions. It is fit to the data to take into account the observed relationship between growth and reforms; it allows one to distinguish an active learning process (i.e. Bayesian learning) from a passive imitation process (i.e. catching up with regional reform leaders) that the previous literature highlights. We show that country-specific events and characteristics, such as economic crises that might spur policy changes and democracy (Giuliano et al., 2013), did not play a dominant role in explaining the S-curve path of financial liberalization.

Models with learning have been widely applied to a variety of economic and financial issues.[2]. There is a strand of growing literature on the role of learning in policymaking (Primiceri, 2006; Sargent et al., 2006; Buera et al., 2011; García-Jimeno, 2016). Our structural model builds on Buera et al. (2011) who study how the worldwide evolution of beliefs explains market oriented policies measured by Sachs et al. (1995)'s binary indicator of trade openness. Our index of financial liberalization traces the magnitude of changes in financial policy at any given time. Since policy decisions in our model are not dichotomic, the S-curve path of policy changes poses a significant challenge, both analytically and computationally, for our model to account for the timing, pace, and magnitude of financial reforms in each country.

Our paper is related to the policy diffusion literature (Dobbin et al., 2007), which finds policy adoptions highly clustered temporally and spatially (e.g., Simmons and Elkins, 2004). The S-curve

[2]See, for example, the literature on culture change (Bikhchandani et al., 1992), technology adoption (Foster and Rosenzweig, 1995), female labor force participation (Fogli and Veldkamp, 2011; Fernández, 2013), the equity premium puzzle (Cogley and Sargent, 2008), financial crises (Boz and Mendoza, 2014), the business cycle (Van Nieuwerburgh and Veldkamp, 2006; Boz et al., 2011), and macroeconomic persistence (Milani, 2007)

path of global liberalization over time is observed in the political science literature, which argues that relevant information about the benefits of policy adoption is an important driving force behind policy diffusion—a mechanism that is consistent with the Bayesian updating theory. Empirical evidence on how, when, and why informational diffusion matters for policy adoption, however, is scant (Dobbin et al., 2007).[3] Our modeling strategy follows Buera et al. (2011)'s approach, which has recently been applied in the political science literature to understand countries' transition into and out of democracy (Abramson and Montero, 2020).

3 Financial liberalization in the past four decades

One of our main contributions is construction of a comprehensive database on financial liberalization for the past four decades. In this section, we describe how this database is constructed and document the key dynamic facts from the data that motivate our structural model in Section 4.

3.1 Data construction

Our database extends a unique database of domestic financial regulations described by Abiad et al. (2010) and covers 90 countries over a long period (1973-2014). This extended database provides the most comprehensive data of financial liberalizations to date. The construction of this database—the questions used to examine the degree of financial regulations and the coding rules—follows the approach of Abiad et al. (2010). An earlier version of the database, covering 36 countries for 1973-1996 and somewhat different reform categories, was used in Abiad and Mody (2005) to study what shapes and shakes financial reforms. Compared to Abiad and Mody (2005), our revised database adds two more aspects of financial policies—securities market policy and prudential regulations. At the same time, it removes a measure of operational restrictions such as government control over staff appointments, restrictions on bank's operating procedures, and resections on international financial transactions, because these restrictions differ qualitatively and substantially from country to country.

As compared with other measures, which place more weight on liberalizations of international capital flows (Edison and Warnock, 2003; Kaminsky and Schmukler, 2003), our database provides a broad indicator of liberalizations in the financial sector with a special emphasis on reforms in the *domestic* financial sector. The key advantage of our data over those used in previous works is a

[3]Sociologists describe policy diffusion with "tipping" or "threshold" paradigms (Schelling, 2006; Granovetter, 1978). The basic idea is that a country's authority is highly sensitive to the number of other countries that have adopted a particular policy. The idea of "thresholds" or critical mass points has been used for understanding the policy process in the sociology literature.

long time series (more than forty years) and a broad sample of countries at various development stages. Abiad et al. (2010) cover a shorter period (1973-2005). Our database extends through 2014 and covers the period following the GFC.[4] This major extension enables one to address the effects of the financial crisis on the financial liberalization process.

As state interventions in the financial sector take myriad forms, our database recognizes the multifaceted nature of changes in financial policy and records these changes in six distinct dimensions:[5] (i) credit controls, such as subsidized lending, directed credit or credit ceilings towards certain industries and excessively high reserve requirements; (ii) interest rate controls, such as floors, ceilings, and bands of interest rates; (iii) competition restrictions, such as entry barriers that may take the form of restrictions on participation, the scope of activities and geographic operational areas, and excessively restrictive licensing requirements; (iv) the degree of state ownership as measured by the share of banking assets controlled by state-owned banks; (v) the quality of banking supervision and regulation (e.g., whether the risk-based capital adequacy ratio in accordance with the Basel standards was adopted, and whether the banking supervisory agency was independent); and (vi) securities market policies, which include various policies that restricted or encouraged the securities market development.

The most important part of our database is its graded (rather than binary) score from zero to three for each dimension, with zero signaling the fully repressed reform, one partial repressed, two largely liberalized, and three fully liberalized. The aggregate index of domestic financial liberalization is the average of the six subcomponents and is then normalized between zero and one. The database thus provides a useful measure of both magnitude and timing of changes in financial policy changes that the typical binary measure of financial liberalization could not provide.

Identification of changes in the six subcomponents of financial liberalization is carried out by reading available financial reports and relevant research articles. This is a difficult task, which involved reading academic journal articles, central bank articles, relevant websites, and reports produced by the International Monetary Fund (IMF) such as Article IV Consultation, Financial System Stability Assessment, Global Financial Stability Report, IMF Selected Issues, and IMF Working Papers. IMF reports not only provide necessary country information about its financial reforms, but also help establish the unified scoring standard and consolidate evidence across countries and over time. The construction of our database maintains comparability across countries and time.[6]

[4] This is a major extension, which was a four-year process of collecting and processing the data.

[5] Unlike Abiad et al. (2010), our database separates domestic financial reforms from liberalizations in the external capital account, which measure a set of restrictions on financial transactions for residents and nonresidents with multiple exchange rates.

[6] For the primary sources for each sub-indicator, see the IMF working paper version of Abiad et al. (2010). The

To illustrates how each of the six subcomponents contributes to the financial liberalization index over time, we use Nigeria as a concrete example in Figure 2. The overall financial reform in Nigeria was advanced rapidly from the late 1980s to 2000. After the global financial crisis and to deal with a credit crunch after its domestic banking crisis, however, the Nigerian government pulled back some of the financial liberalization. In 2009, for instance, the government took steps to direct credit to certain sectors at a subsided interest rate. The Central Bank of Nigeria announced a guarantee of 300 billion Naira for new loans to small and mid-size enterprises (SMEs) from domestic banks and other financial institutions. The guarantee was made at banks prime lending rate, about 4-5 percent less than the regular rate (IMF, 2010, Box 2). The Development Finance Directorate at the Central Bank of Nigeria expanded its operations by directing loans to SMEs in sectors preferred by the government. These loans were guaranteed by the government at interest rates below the market rate. In July 2013, the Central Bank of Nigeria raised the banks' cash reserve requirement on public deposits from 12 percent to 50 percent (IMF, 2013). Consequently, the subcomponent "credit control" declined from three to one in 2009 and to zero in 2013. This decline is the main contribution to the overall decline in the index of domestic financial liberalization since 2009. In Section 6.2, we provide a detailed analysis of how the GFC led to a reversal of financial reforms in various countries.

3.2 S-curve dynamics of global financial liberalization

Figure 3–4 present the evolution of the average of composite financial indicators and of sub-indicators over the period 1973-2014. For countries in all income groups, there was a strong upward trend, in fits and starts, toward the fully liberalized financial system over the past forty years. Before the 1980s, state interventions and government controls were pervasive in both advanced and developing countries. Credit allocation was largely controlled by the government, interest rates were subject to ceilings or other forms of regulation, and barriers to entry into the financial system were high. Since then, many countries have adopted more liberal practices in the financial sector, although far from completely. After the mid-2000s and especially the GFC, the liberalization process began to slow down and was even reversed in some countries, mostly because of tighter credit controls in several countries.

The most salient fact is a rapid transition to a more liberalized financial system that was concentrated in certain periods along the upward trend. This fact is a "S-curve" path by both the composite index and sub-indicators. That is, changes were relatively rare in the early and late

narrative approach used in our data construction maps questions into text and then into indicators. Current economic activities do not affect the constructed indicators of financial liberalization in the concurrent year.

periods of the sample, while the bulk of reforms was concentrated in the first half of the 1990s. The "S-curve" pattern holds for different income groups and across different regions. It represents significant policy changes not only in transition economies (e.g., Eastern Europe and the former Soviet Union) but also in Western Europe, Latin America, and Sub-Saharan Africa. Statistically, there was a temporal clustering of policy changes: reform counts fit a negative binomial distribution (assuming the data is clustered) better than the distribution from a random, nonclustered process such as the Poisson.

In addition to this temporal clustering, there is evidence of spatial clustering of policy changes—countries within certain regions tended to adopt more liberal financial policies (or reverse them) together around a similar time and in a similar fashion (Figure 5). For example, most of the reforms in Latin America (except for Argentina and Chile, which introduced reforms earlier) took place in the late 1980s and early 1990s, while financial liberalization in Sub-Saharan Africa began later with the most acceleration occurring between 1993 to 1997. Countries in South and East Asia (e.g., China, Korea, India, Philippines, and Vietnam) opted for a more gradual approach—opening up their financial sectors in small steps—and many of these countries reversed financial liberalization following the GFC.

At the level of individual countries, the status quo—no change in policy—was the norm, representing over 75 percent of country-year observations in the whole sample. Financial reforms—a positive change in the indicator—constituted 21.2 percent of observations, among which large reforms accounted for about 7 percent.[7] Reversals—negative changes in the indicator—were less frequent and most of them occurred toward the end of the sample (after 2005). These reversals accounted for less than 4 percent of country-year observations.

Consistent with these observations, our model specified in Section 4 assumes that growth shocks and policymakers' beliefs are both spatially correlated so that experiences of proximate countries provide more relevant information for one another than those of distant countries. While neighboring countries chose similar policies, however, we show in Section 5 that policymakers' beliefs in these countries were heavily influenced by successful financial reforms in advanced countries via informational flows across countries.[8]

[7] A change in the indicator larger than or equal to the ninety-five percentile for the distribution of indicator changes is classified as a large reform.

[8] In Appendix A, we provide reduced-form evidence for a country's learning from its own past and neighbors' experiences.

4 The model

In this section, we propose a structural model for policymakers' choices of financial policies and the evolution of policymakers' beliefs across countries.

4.1 Policymakers' problem

Following Prati et al. (2013), we assume that growth of GDP per capita in the current period is determined by the level of GDP per capita in the last period and the liberalization level in the financial sector as in the following model:

$$g_{i,t} = c_i + \alpha_i y_{i,t-1} + \beta_i r_{i,t} + \xi_{i,t},\ t = 1, \ldots, T, \tag{1}$$

where $g_{i,t}$ is GDP growth per capita in country i at time t (annually in our data), $y_{i,t-1}$ is the log of a one-year lag of GDP per capita and $r_{i,t}$ is the level of financial liberalization.[9] Each country's growth depends on its own country-specific factor (c_i) and the country-specific effects of lagged GDP level (α_i) and financial liberalization level (β_i). In this hierarchical linear model, we assume that the growth shock vector $\xi_t \equiv [\xi_{1,t}, \ldots, \xi_{n,t}]' \overset{\text{i.i.d.}}{\sim} \mathcal{N}(0, \Omega)$, where n is the number of countries. The shock $\xi_{i,t}$ ($i \in \{1, \ldots, n\}$) is exogenous to $g_{i,t}$ but correlated to shocks in other countries.[10]

Policymakers have perfect knowledge of the model parameters c_i, α_i, and the covariance matrix of growth shocks Ω. But they do not know the effect of financial policies on growth (β_i) and believe that the effects are potentially correlated across countries. Their perceived growth process is

$$g_{i,t} = c_i + \alpha_i y_{i,t-1} + \beta_{i,t|t-1} r_{i,t} + u_{i,t},$$

where $u_t \equiv [u_{1,t}, \ldots, u_{n,t}]' \overset{\text{i.i.d.}}{\sim} \mathcal{N}(0, \Omega)$ and $\beta_{i,t|t-1} \equiv \hat{E}_{t-1}\beta_i$ is their belief of the effect of financial reforms. Define $z_{i,t} \equiv g_{i,t} - c_i - \alpha_i y_{i,t-1}$. The perceived process can be rewritten as

$$z_{i,t} = \beta_{i,t|t-1} r_{i,t} + u_{i,t}, \tag{2}$$

$$r_{i,t} = r^*_{i,t} + \eta_{i,t}, \quad \eta_{i,t} \overset{\text{i.i.d.}}{\sim} \mathcal{N}(0, \lambda_i), \tag{3}$$

where $r^*_{i,t}$ is financial policy or reform chosen by policymakers and $\eta_{i,t}$ is a shock that is independent across countries and time and uncorrelated with the growth shock $\xi_{i,t}$. The shock $\eta_{i,t}$ represents an error for implementing financial reforms and also reflects a statistical discrepancy of constructing the index of financial forms.

[9] As discussed in Section 3.1, $g_{i,t}$ does not affect $r_{i,t}$ contemporaneously.

[10] See Appendix B for detailed estimation results for equation (1).

Following the learning literature (Sargent, 1999; Primiceri, 2006; Sargent et al., 2006; Buera et al., 2011), we posit that policymakers' objective is to maximize economic growth and at the same time minimize political costs by choosing $r^*_{i,t}$ that solves

$$\max_{r^*_{i,t}} \hat{E}_{t-1}\left[z_{i,t} - \frac{\psi}{2}(r^*_{i,t} - \bar{r}_{i,t})^2\right]$$

subject to (2) and (3), where $\hat{E}_{t-1}$ denotes policymakers' subjective expectations and both $r^*_{i,t}$ and $\bar{r}_{i,t}$ are predetermined at time $t-1$. Coefficient ψ represents the magnitude of the political cost, which is a quadratic function of the distance between optimal policy choice $r^*_{i,t}$ and the socially acceptable "norm" of financial liberalization $\bar{r}_{i,t}$. This norm is a function of various variables, including a country-specific factor (δ_i) and a vector of time-varying political and economic variables ($\nu_{i,t}$) such as indicators for political development, GDP per capita relative to that in U.S., indicators for various crises, and the global interest rate. The norm of financial liberalization takes the following functional form

$$\bar{r}_{i,t} = \frac{\exp\left(\delta_i + \nu'_{i,t}\phi\right)}{1 + \exp\left(\delta_i + \nu'_{i,t}\phi\right)}, \tag{4}$$

where the parameters δ_i and ϕ are to be estimated and $\bar{r}_{i,t}$ is bounded between 0 and 1.

Solving the policymaker problem leads to optimal financial reform for country i at time t as

$$r^*_{i,t} = \max\{0, \bar{r}_{i,t} + \psi^{-1}\beta_{i,t|t-1}\}. \tag{5}$$

The optimal reform decision depends on the country's liberalization norm and policymakers' belief about the effect of financial reforms. When the norm increases or belief becomes stronger, policymakers will choose more liberalized policy.

4.2 Evolution of policymakers' beliefs

We now specify how policymakers' beliefs evolve over time in the Bayesian framework. Denote $z_t \equiv [z_{1,t}, \ldots, z_{n,t}]'$, $\beta \equiv [\beta_1, \ldots, \beta_n]'$, and $R_t \equiv diag([r_{1,t}, \ldots, r_{n,t}])$. We rewrite equation (2) in compact form

$$z_t = R_t\beta + u_t, \quad u_t \sim \mathcal{N}(0, \Omega), \tag{6}$$

where $\mathcal{N}$ represents a Gaussian distribution. The prior on β at the beginning of the sample ($t = 1$) is

$$\beta \sim \mathcal{N}\left(\beta_{1|0}, \Sigma^{-1}_{1|0}\right),$$

where $\beta_{1|0}$ is the prior mean and $\Sigma_{1|0}$ is the precision matrix, which takes the form of

$$\Sigma_{1|0}^{-1} = V \cdot L \cdot V,$$

where the diagonal elmenets of $V = diag([\sigma_{1,1|0}, \ldots, \sigma_{n,1|0}])$ are a priori standard deviations and L is a priori correlation matrix. Policymakers have a prior belief that the effect of financial liberalization on growth of a country is more correlated with that of nearby countries and less correlated with distant countries. To implement this idea in a tractable way, we follow Buera et al. (2011) and assume that the prior correlation between the effects of financial reforms on growth of countries i and j is a parametric function of geographic distance between those two countries:

$$L_{ij} = \exp[-d_{ij}\gamma],$$

where we restrict γ to be nonnegative and d_{ij} is the geographic distance between countries i and j.

Given initial belief $\beta_{1|0}$ and precision matrix $\Sigma_{1|0}$, policymakers adopt Bayesian learning to optimally update the mean and precision matrix of the distribution of β as

$$\Sigma_{t+1|t} = \Sigma_{t|t-1} + R_t' \Omega^{-1} R_t, \tag{7}$$

$$\beta_{t+1|t} = \beta_{t|t-1} + \Sigma_{t+1|t}^{-1} R_t' \Omega^{-1} \left(z_t - R_t \beta_{t|t-1} \right), \tag{8}$$

where $\beta_{t+1|t} \equiv \hat{E}_t \beta = [\beta_{1,t+1|t}, \ldots, \beta_{n,t+1|t}]'$. Since beliefs are potentially correlated, country i's economic performance is a signal for all countries and thus it affects not only $\beta_{i,t+1|t}$ but also $\beta_{j,t+1|t}$. We will discuss, in Section 7, the key factors that shape the S-curve dynamics of global financial liberalization.

5 Empirical results

In this section, we estimate our learning model, assess the model's fit, present the empirical results based on our posterior mode estimation, and analyze the evolution of beliefs implied by the model. The estimation method follows Buera, Monge-Naranjo, and Primiceri (2011) by using the Bayesian procedure to reduce a heavy computational burden. Computational issues and technical details of estimation are provided in Appendix C.

5.1 Estimated parameter values

Table 1 reports posterior estimates of the correlation (γ), the political cost (ψ), and parameters in the liberalization norm (ϕ). The column under the heading "M1" reports the estimates for the baseline model, most of which are statistically significant. The estimate of γ implies that the cross-country correlation in prior beliefs decreases with geographic distance between countries' capitals (in thousands of kilometers) and that the average belief correlation among all countries in 1980 is about 73%. The estimate of ψ implies that if optimal financial reform policy deviates from its norm by 0.1, the political cost is equivalent to a 0.036% loss in GDP growth.

We control for country fixed effects. Follow the existing literature, we select political and economical variables as determinants of the norm for financial reforms in equation (4). We find that the norm for financial liberalization is negatively correlated with the log value of relative GDP (per capita). This finding is consistent with the results in cases without learning (column labeled by "M2") and with the reduced-form regression result presented in Appendix A. If a country has already achieved a high GDP level (relative to U.S.), its economic development is mature enough that the society would not find it necessary to demand further financial liberalization. As the country's income rises, the speed of its financial reforms slows down.

We control for a country's degree of democracy using the index called "polity2" from the Polity IV database.[11] In line with Giuliano et al. (2013) and Giavazzi and Tabellini (2005), democracy (polity2) has a positive impact on adopting financial reforms. If the value of polity2 (ranging from -10 to 10) increases by one, the country's liberalization norm increases by 0.035. For instance, the gap of this democracy index between Argentina and United States in 2014, which was 2, would imply their liberalization difference by 0.07.

We also control for currency, sovereign debt, and banking crises, whose dates are obtained from Laeven and Valencia (2020) and cover all countries and periods in our sample, and the global nominal interest rate provided by Schmelzing (2020). Each crisis indicator equals one in the three years after the onset of the crisis and zero in other years. The coefficients for currency and banking crises and the global interest rate are negative and statistically significant. Crises hinder financial reforms and the low interest rate encourages countries to further financial reforms in order to attract the international capital.

5.2 Model fit and the role of learning

How well our structural model fits the data is assessed by comparing the model's predictions with the observed dynamics of financial reforms over time *and* across countries. Figure 6 displays the

[11] The Polity IV database is publicly available and its manual can be found in Marshall et al. (2019).

average of financial reforms (black solid line) and the model's prediction (blue dashed line). The predicted series is a sequence of one-step-ahead predictions from the model. The model is capable of generating the S-curve dynamics of global financial reforms—a gradual increase in the early part of the sample, a rapid run-up in the 1990s, and a flattening after 2000. The model produces a good fit not just at the aggregate (average) level but at disaggregated levels as well. Figure 7 shows how the model fits to the path of actual reforms in each of the seven geographical regions.[12]

The dynamics of a country's financial liberalization path are determined by (i) the evolution of policymakers' beliefs ($\psi^{-1}\beta_{i,t|t-1}$) and (ii) the liberalization norm driven by a set of economic and political conditions ($\bar{r}_{i,t}$). To quantify the role of beliefs in our model, we decompose the dynamics of financial liberalization into contributions from the liberalization norm itself, learning over time from experiences of one's own country, and learning from experiences of other countries. The red and green dotted lines in Figure 8 show that a majority of observed S-curve dynamics (the rapid run-up in the 1990s) are contributed to cross-country learning.[13] The importance of learning from other countries is analyzed in Section 6.1.

If we remove the learning component in the model and re-estimate this alternative model (column labeled by "M2" in Table 1), the mean absolute error (MAE) of one-step predictions is 0.08, twice that of our baseline model. If we add the time fixed effect (column labeled by "M3" in Table 1), the fit is still worse with the MAE 0.068, about 1.7 times larger than the MAE of our baseline model. Including the time fixed effect is a reduced-form approach to capturing the learning component of our model. It cannot, however, capture the important effects of cross-country learning that is the key to explaining the S-curve dynamics of financial liberalization.[14]

Our learning model does not suffer from the overfitting problem common in many highly-parameterized models. To illustrate this point, we perform an out-of-sample forecasting exercise by estimating the model with the data up to 2002 and then generating forecasts of financial liberalization between 2003 and 2014. The model predicts the average financial liberalization between 2003 and 2014 very well (Figure 9). The out-of-sample MAE is 0.017. Models without learning fare much worse in out-of-sample predictions: the MAE is 0.061 for M2 and 0.035 for M3.[15]

[12] In fact, the model fits experience of each individual country remarkably well (Appendix D).

[13] The finding about the importance of cross-country learning is robust to alternative model specification for the DGP of growth (see Appendix E.1).

[14] An alternative model with each country learning only from its own experiences has a much worse fit to the data than does the baseline model both in sample and out of sample (Appendix E.2).

[15] For model M3, we assume that the time fixed effect in 2003-2014 is the same as its 2002 estimate, where 2002 is the end of the sample for our out-of-sample forecasting.

5.3 Belief evolution

The driving force behind the model's performance is the evolution of policymakers' beliefs. The evolution of heterogeneous beliefs over time and across countries is summarized in Figure 10 in which the red dashed line represents the average value and the blue shades represent 20% (40th to 60th), 50%(25th to 75th), and 80%(10th to 90th) probability intervals from dark to light colors. As one can see, a majority of policymakers' beliefs were below zero in 1980 and gradually increased over time with the average belief turning positive around early 1990s (Figure 10a). At the end of the sample, beliefs about the effects of financial liberalization on growth in a majority of countries were positive. The evolution of the average belief had S-curve dynamics: it fluctuated in the 1980s, rose up in the 1990s, and then flattened out. As information about the effects of financial liberalization accumulated from countries's own and other countries' experiences, the belief uncertainty (the standard deviation) and the dispersion of belief uncertainty declined over time (Figure 10b). The average belief uncertainty in 2014 was about one-third of that level in 1980, reflecting an increase in the belief precision. The correlation of beliefs across countries declined over time (Figure 10c), as countries accumulated their own experiences. But the dispersion of belief correlations remained substantial.

A belief deviation for country i, defined as $\beta_i - \beta_{i,t|t-1}$, measures the gap between the value of β_i estimated from the data generating process (DGP) represented by equation (1) and the country's belief about the value of β_i at time t. In early periods, most countries significantly underestimated the effects of financial liberalization on growth. The average of belief deviations converged to zero over time, and hovered around zero after 2000 (Figure 10d). That is, the average opinion about the effects of financial reforms after 2000 was close to the average value of β_i over i. The dispersion of belief deviations, however, remained substantial even at the end of our sample: some countries were over-optimistic or some were pessimistic about the effects of financial liberalization.[16]

6 Policy implications

In this section, we address a number of policy issues through the lenses of our estimated structural model and discuss the evidence of cross-country learning.

6.1 The importance of informational diffusion

To assess how financial reforms promote economic growth and how learning from other countries plays an important role in financial liberalization in the home country, we follow the IMF clas-

[16] Asymptotically, a belief deviation in every country converges to 0 as time increases.

sification to group countries into three categories: advanced countries, emerging economies, and low-income countries. We calculate contributions of each group of countries to the cumulative change in the belief averaged across all countries (Figure 11).[17] The contribution from advanced countries accounted for about 50% of cumulative changes since the late 1980s. The contribution from emerging countries accounted for $40 - 52\%$ of the run-up in the 1990s and $34 - 37\%$ of the cumulative belief change afterwards. The contribution from low-income countries was negligible at the beginning of the sample, grew gradually after 1990, and reached 15% by 2014.

How policymakers incorporate their learning experiences plays a vital role in a contribution to the average financial liberalization from each income group. If emerging economies and low-income countries had not used information from advanced countries through cross-country learning, their financial liberalization would have been on a different path from what we observe in the data. We run an experiment in which we remove cross-country learning for certain income groups and simulate counterfactual paths of financial liberalization and output growth.[18] To remove cross-country learning between advanced countries and emerging economies, we set the correlation coefficient to zero for an advanced country and an emerging economy at the beginning of our sample (the year 1980). We then allow policymakers to update their beliefs and make decisions about financial reforms. We consider three cases: (1) no learning between advanced countries and the rest of the world; (2) no learning between emerging economies and the rest of the world; and (3) no learning between low-income countries and the rest of the world.

For these three cases, we compares the average of counterfactual financial liberalization paths and the average of actual paths for each income group of countries in Figure 12, where each column represents one case and each row represents one income group. The diagonal graphs, AD-1, EM-2, and LI-3, display the paths of counterfactual financial liberalization with learning within each income group. Financial liberalization in emerging economies and low-income countries would have lagged behind considerably if they had learned among themselves within their own income group, while the counterfactual path of financial liberalization in advanced countries is very close to the actual path. Learning from other income groups of countries was not important for advanced countries; for emerging economies and low-income countries, however, it paid off for them to learn from advanced countries.

Indeed, the counterfactual path of financial liberalization in emerging countries when they had

[17] See Appendix F for details of the decomposition method for calculating contributions from different groups of countries.

[18] In our counterfactual simulation exercises, we keep all norm variables for financial liberalization the same as in the data, and growth and other shocks the same as their estimated values. The counterfactual level of financial liberalization is re-calculated with policymakers' counterfactual beliefs. The counterfactual GDP growth path and counterfactual GDP level are generated from equation (1) but with the counterfactual path of financial liberalization.

learned from advanced countries but not from low-income countries is close to the actual path (EM-3 of Figure 12); the counterfactual path of financial liberalization in low-income countries when they had learned from advanced countries but not from emerging countries is also close to the actual path (LI-2 of Figure 12). When the two income groups—emerging economies and low-income countries—had learned from each other but not from advanced countries, there would have been considerable gaps between counterfactual and actual paths of financial liberalization (EM-1 and LI-1 of Figure 12). Thus, learning from advanced countries was sufficient for emerging countries and low-income countries to advance their financial liberalization policy.

The informational diffusion from advanced countries to the rest of the world, as illustrated above, was vital for the progression of global financial liberalization. Since advanced countries had higher levels of financial liberalization and smaller uncertainty about their output growth than other countries, their economic performances served as informative signals to other countries about the effects of financial reforms, especially in the beginning of the sample where the level of financial liberalization in emerging economies and low-income countries was very low (see Section 7 for more discussions). Delayed financial reforms would have caused considerable losses of output. If other countries had not learned from advanced countries as Scenario 1 of Figure 12, average GDP growth would have decreased by 0.2% per year in emerging economies and 0.5% per year in lower income countries during the sample period and the average level of GDP would have been 8.3% in emerging countries and 18.1% in low-income countries lower than the actual level in 2014. The output loss would have been even larger if emerging economies and low-income countries had learned only from their own income group.

6.2 Impacts of the global financial crisis on financial reforms

The GFC raised a question of whether the crisis engendered a slowdown or even a reversal in the progress of financial reforms around the world, especially in emerging economies (Campos and Coricelli, 2012). The previous literature has found a "great reversal" of financial reforms in the aftermath of the great depression of the 1930s (Rajan and Zingales, 2003). Buera et al. (2011) conduct a counterfactual experiment with their model by imposing a severe worldwide recession in 2002 with the size of the Great Depression; they find that a substantial share (10%) of countries would have reverted from market-oriented policy to state-interventionist policy.

Since our sample covers the GFC period, we are able to quantify the effects of the GFC on changes in financial reforms and the economy. In our model, beliefs reversed course after the GFC. To quantify potential effects of the GFC on belief reversal, we study a counterfactual scenario in which no GFC had taken place and simulate growth shocks in 2008-2009 for all countries from the

estimated distribution of growth shocks (i.e., the scenario of no GFC) to compare the difference between our estimated beliefs (actual) and simulated beliefs (counterfactual). Based on 1,000 simulations, we calculate the mean and the 95% probability interval for the counterfactual path of average beliefs across countries. The belief reversal engendered by the GFC is statistically significant (panel (a) of Figure 13), and the average belief across countries would have been 0.126 higher in 2014 if we had not had the GFC, which corresponds to an increase of 0.017 in the index of average financial liberalization in 2014.

The dynamic impacts of the GFC on average beliefs for advanced countries, emerging economies, and low-income countries are reported in panels (b)-(d) of Figure 13. Although advanced countries suffered the largest negative shocks to their output growth, the GFC did not change their belief much; there was not much uncertainty around their belief in these countries and their belief was well anchored. For low-income countries, the magnitude of negative shocks to their output growth was the smallest among all income groups, so that the impact of the GFC on their belief was limited. Emerging economies, however, suffered large negative shocks to their output growth shocks and there was large uncertainty around their belief. Because belief in emerging economies was not anchored, the GFC had the largest negative impact on their belief (panel (c) of Figure 13).

The belief reversal had negative effects on global financial liberalization as well as economic growth around the world. We use each simulated path of beliefs to calculate a counterfactual path of the average financial liberalization for each country. We then calculate both level and growth of counterfactual output for each country from the output growth equation. We find that the belief reversal reduced an average growth rate of output by 0.025% per annum in 2010-2014, which is equivalent to a loss of GDP per capita by 0.082% on average in 2014.

6.3 IFIs and catch-up

There are two prevailing views in the literature about the progression of worldwide financial liberalization. One view, put forth by a number of studies, emphasizes the leverage used by IFIs in advancing worldwide financial reforms (Krueger 1993????). According to these studies, IFIs such as the IMF, the World Bank, and the United States Department of the Treasury have pushed for the "standard" reform package that promotes the expansion of market forces, macroeconomic stability, and trade opening within a country's domestic economy. Although financial reforms in certain countries were imposed as a condition for receiving loans from the IMF and World Bank, there is no evidence that domestic financial reforms were coerced by IFIs. In fact, policymakers in one's own country often arrived at reform packages based on their own analyses (Yergin and Stanislaw, 2002). In their book "The Commanding Heights," Yergin and Stanislaw (2002) argue

that the policy prescriptions described in the Washington Consensus were actually "developed in Latin America, by Latin Americans, in response to what was happening both within and outside the region."

Reform recommendations put forth by the IMF were primarily based on its extensive research drawn from experiences of other countries. In this aspect, IFIs served as a conduit for cross-country learning (informational facilitator) and allowed nations to learn new lessons from participating jointly in international organizations (Hass 1959?????). The IMF has been recognized for its prominent research function as informational facilitator to disseminate the knowledge learned from the success of reform leaders to the rest of the world (Quirk et al., 1994). According to our data, the top 10 countries and territories with the highest levels of financial liberalization in 1985 were United States, Switzerland, United Kingdom, Germany, Netherlands, Singapore, France, Canada, Ireland, and Hong Kong. They are all classified as advanced countries by the IMF. From the lenses of our structural model, informational diffusion from experiences of advanced countries (reform leaders) to the rest of the world is the key model mechanism in explaining the S-curve path of worldwide financial reforms. Without this learning process, less developed countries would have suffered a significant loss of output (Section 6.1).

The other view, proposed by Abiad and Mody (2005), states that a country advances its financial reforms by catching up with reform leaders through policy emulation. According to this view, the gap between the levels of a country' financial liberalization and reform leaders' financial liberalization is an important determinant of worldwide financial reforms. This reduced-form analysis, however, does not address the most important issue in hand: the timing, speed, and magnitude of narrowing gaps observed in the sample. Our model offers a structural interpretation of this reduced-form view. Section 7, below, presents evidence that learning from economic effects of advanced countries' financial reforms played a critical role in the dynamic evolution of narrowing gaps between advanced and other countries throughout the sample. It demonstrates that the existence of the gap by itself is insufficient to account for the observed S-curve path of worldwide financial reforms.

7 Understanding the S-curve mechanism

The S-curve dynamics of belief evolution, discussed in the preceding sections, are the most important feature of our data. They have three distinct phases: (i) a slow change in the beginning, (ii) a rapid run-up in the second phase, and (iii) a flatterning-out in the final period of our sample. These observed S-curve dynamics are more pronounced for countries other than developed ones.

To gain insights into how our learning model can endogenously generate S-curve dynamics of global financial liberalization and the important role of learning from other countries in these dynamics (Figure 8), we assume no correlation in the growth shock covariance so that one can obtain a closed-form solution.[19] Under this assumption, the covariance matrix Ω is a diagonal matrix

$$\Omega = \begin{bmatrix} s_1^2 & \cdots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \cdots & s_n^2 \end{bmatrix}.$$

With the optimal Bayesian updating, we have

$$\begin{aligned}
\beta_{t+1|t} &= \beta_{t|t-1} + \Sigma_{t+1|t}^{-1} R_t' \Omega^{-1} \left(z_t - R_t \beta_{t|t-1} \right) \\
&= \beta_{t|t-1} + \Sigma_{t+1|t}^{-1} \begin{bmatrix} r_{1t} & & \\ & \ddots & \\ & & r_{nt} \end{bmatrix} \begin{bmatrix} s_1^2 & & \\ & \ddots & \\ & & s_n^2 \end{bmatrix}^{-1} \begin{bmatrix} z_{1t} - r_{1t}\beta_{1,t|t-1} \\ \vdots \\ z_{nt} - r_{nt}\beta_{n,t|t-1} \end{bmatrix} \\
&= \beta_{t|t-1} + \Sigma_{t+1|t}^{-1} \begin{bmatrix} \frac{r_{1t}^2}{s_1^2} \left(\beta_1 - \beta_{1,t|t-1} + \frac{\xi_{1t}}{r_{1t}} \right) \\ \vdots \\ \frac{r_{nt}^2}{s_n^2} \left(\beta_n - \beta_{n,t|t-1} + \frac{\xi_{nt}}{r_{nt}} \right) \end{bmatrix}.
\end{aligned}$$

Since

$$\Sigma_{t+1|t}^{-1} = \begin{bmatrix} \sigma_{1,t+1|t} & & \\ & \ddots & \\ & & \sigma_{n,t+1|t} \end{bmatrix} \begin{bmatrix} 1 & \cdots & \rho_{1n,t+1|t} \\ \vdots & \ddots & \vdots \\ \rho_{n1,t+1|t} & \cdots & 1 \end{bmatrix} \begin{bmatrix} \sigma_{1,t+1|t} & & \\ & \ddots & \\ & & \sigma_{n,t+1|t} \end{bmatrix},$$

one can write a change of belief for country i as

$$\begin{aligned}
\Delta\beta_{i,t+1|t} &= \sigma_{i,t+1|t} \left[\sum_{j=1}^{n} \frac{1}{s_j^2} \rho_{ij,t+1|t} \sigma_{j,t+1|t} \cdot r_{jt}^2 \cdot (\beta_j - \beta_{j,t|t-1} + \frac{\xi_{jt}}{r_{jt}}) \right] \\
&= \underbrace{\frac{1}{s_i^2} \sigma_{i,t+1|t}^2 r_{it}^2 (\beta_i - \beta_{i,t|t-1} + \frac{\xi_{it}}{r_{it}})}_{\text{own learning}} + \underbrace{\sigma_{i,t+1|t} \left[\sum_{j \neq i} \frac{1}{s_j^2} \rho_{ij,t+1|t} \sigma_{j,t+1|t} \overbrace{r_{jt}^2}^{\text{liberalization}} (\overbrace{\beta_j - \beta_{j,t|t-1}}^{\text{belief signal}} + \overbrace{\frac{\xi_{jt}}{r_{jt}}}^{\text{noise}}) \right]}_{\text{learning from other countries}}.
\end{aligned}$$

[19] This assumption is reasonable because the average correlation for growth shocks across countries is estimated to be 0.0189 for equation 1.

As discussed in the preceding sections, an updating of policymakers' belief in country i was influenced mostly from cross-country learning. We find that while belief updating depends on country j's belief uncertainty $\sigma_{j,t+1|t}$ (a square root of the j^{th} diagonal element of the matrix $\Sigma^{-1}_{t+1|t}$) and belief correlation $\rho_{ij,t+1|t}$ between country i and j (the element in the i^{th} row and j^{th} column of the matrix $\Sigma^{-1}_{t+1|t}$, divided by $\sigma_{i,t+1|t}$ and $\sigma_{j,t+1|t}$), it is an inner product of financial liberalization $\left(r^2_{jt}\right)$ and belief deviation $\left(\beta_j - \beta_{j,t|t-1}\right)$ that drives the observed S-curve dynamics of financial liberalization. Policymakers' belief in country i adjusts mostly to the value of this product, partly because a belief deviation in one country is seen as a signal for the effect of financial liberalization on growth and partly because the level of financial liberalization determines how informative that signal is. The higher the level of neighbors' financial liberalization, the larger the impact of a belief deviation on changes of belief.

For each country i, we calculate the distance-weighted average of r_{jt} in all other countries $j \neq i$ (called "neighbors' financial liberalization") and the distance-weighted average of $\left(\beta_j - \beta_{j,t|t-1}\right)$ in all other countries $j \neq i$ (called "neighbors' belief signal"). The weight for neighbor country j is a decreasing function of distance between countries j and i.[20]

Figure 14a shows the estimated time series for neighbors' financial liberalization and their belief signal. In the 1980s, neighbors' financial liberalization was at a low level, which kept slow adjustments of the country's own belief in financial reforms. At the same time, however, neighbors' belief signal—a signal for belief in the success of reforms—was very high, causing the country's own belief to increase gradually. In the late 1980s, an increase in the level of neighbors' financial liberalization began to gain momentum, while neighbors' belief signal fell but nonetheless remained strong. As a result, an inner product of liberalization level and belief signal was very large during the 1990s and through cross-country learning, policymakers in country i accelerated their belief updating process. This accelerated updating accounted for the large and rapid increase of observed financial liberalization globally in the 1990s, especially in less advanced countries. After 2000, neighbors' belief signal gradually fell around zero. The signal, therefore, was very weak, and the value of the inner product of liberalization level and belief signal in other countries became very small as well, despite the high level of neighbors' financial liberalization. As a result, adjustments of the country's own belief were small and the level of belief flattened out.

As panels EM-1 and LI-1 of Figure 12 in Section 6.1 show, financial liberalization in emerging economies and low-income countries would have delayed considerably if these countries had not learned from advanced countries. To understand this result, we conduct a counterfactual exercise in which we exclude advanced countries when calculating neighbors' belief signal and financial lib-

[20] This function is proportional to $\exp(-d_{ij}/2500)$ as in our reduced-form regression (Appendix A).

eralization. As one can see in Figure 14b, although neighbors' belief signal for emerging economies and low-income countries had been strong in the beginning, the level of neighbors' financial liberalization had been so low that policymakers in each country would have essentially learned little about the effects of their financial reforms on their own. Indeed, the value of an inner product of liberalizations and belief signals in other countries had been very small in the early period, implying a slow updating process of policymakers' belief. This slow update would have led to a continuing low level of financial liberalization for these countries. The interaction between slow belief update and low level of financial liberalization in other countries had prolonged the first phase of the S-curve with a very slow increase in financial liberalization. Without learning from advanced countries, therefore, emerging economies and low-income countries would have delayed reforms of their domestic financial sectors for a long time.

In summary, our learning model is capable of explaining the observed S-curve path of global financial liberalization as a result of cross-country learning; and the joint force of liberalization level and belief signal in other countries drives the timing and shape of financial liberalization in one's own country.

8 Conclusion

Using our new dataset, we document the S-curve path of average financial liberalization worldwide and in different income groups of countries. We develop and estimate a structural model with learning to explain the evolution of financial reforms. We find that the 2008 global financial crisis reversed the progress of financial liberalization. We show the importance of informational diffusion in the learning process. While cross-country learning accounted for most of the dynamics of financial reforms we observe in every country, learning from advanced countries about the effects of their financial reforms was essential for the shape and timing of financial liberalization in emerging economies and low-income countries throughout the sample.

It would be informative to study how subindices of the financial liberalization series interacted among themselves and with other series of reforms (e.g., product market reforms and external sector reforms) across countries and how governments decided on these various reforms. The methodology developed in this paper allows one to model multiple series of reforms in one single framework. Estimating such a large structural model would increase the scale of parameterization considerably, a major task that is computationally infeasible at the present time. We hope, however, that both our findings and our framework will serve as a first step toward this ambitious project.

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Table 1: Estimation results for the structural model and two reduced form models

Coefficients	M1	M2	M3
	Learning	No Learning	
Correlation			
Geographic distance (γ)	0.0100		
	(0.0011)		
Political cost			
Deviation from norm (ψ)	7.2631		
	(0.1732)		
Liberalization norm			
Relative GDP (ϕ_1)	-1.0238	-0.2233	0.0606
	(0.0945)	(0.0444)	(0.0653)
Polity2 (ϕ_2)	0.1428	0.0244	0.0016
	(0.0124)	(0.0041)	(0.0036)
Currency crisis (ϕ_3)	-0.1953	-0.1021	-0.0428
	(0.0987)	(0.0396)	(0.0364)
Debt crisis (ϕ_4)	-0.2975	-0.1466	-0.0818
	(0.1606)	(0.0681)	(0.0687)
Banking crisis (ϕ_5)	-0.4982	-0.0095	-0.0435
	(0.0863)	(0.0430)	(0.0403)
Global interest rate (ϕ_6)	-0.4563	-0.3235	
	(0.0232)	(0.0057)	
Country fixed effect	Yes	Yes	Yes
Time fixed effect	No	No	Yes
Mean absolute error (MAE)	0.040	0.080	0.068

Note: M1 denotes our structural model, M2 a model without the learning mechanism, and M3 a model with the time fixed effect. When the time fixed effect is included, the time series of the global interest rate is removed for the M3 model. Standard errors are reported in parentheses. The MAE is an average of the absolute errors of one-step predictions from the model within the sample.

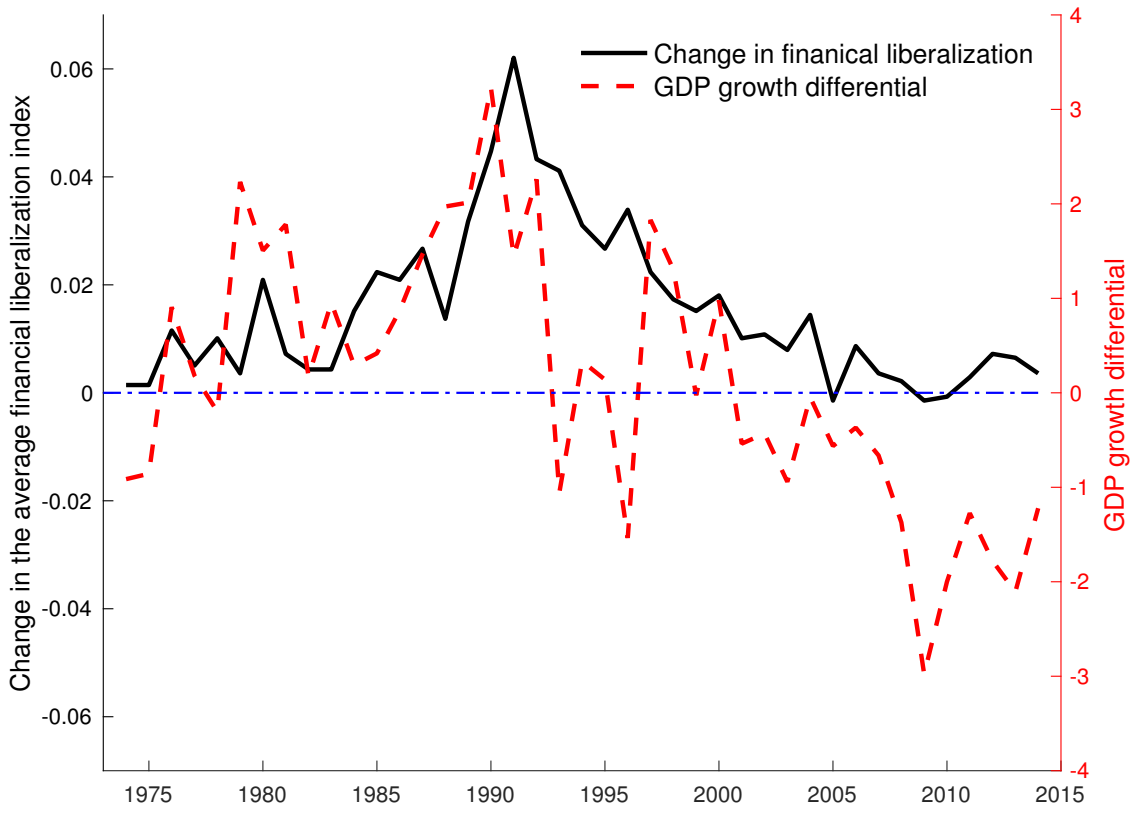


Figure 1: Global financial reform versus GDP growth differential

Note: The variable on the left y-axis is a change in the average financial liberalization index over all countries. GDP growth differential on the right y-axis is the difference between the average growth rate in financially liberalized countries and the average growth rate in financially repressed countries. The financial liberalization index in a financially liberalized country is above the median index; the financial liberalization index in a financially repressed country is below the median index.

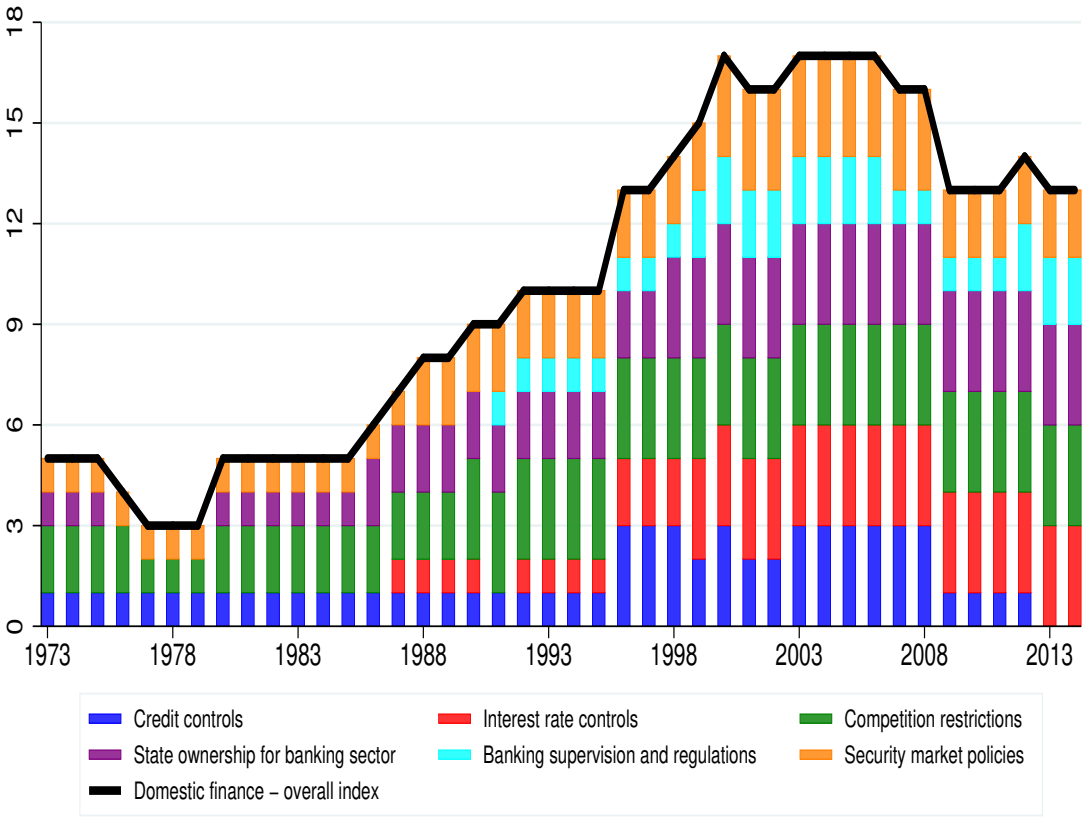
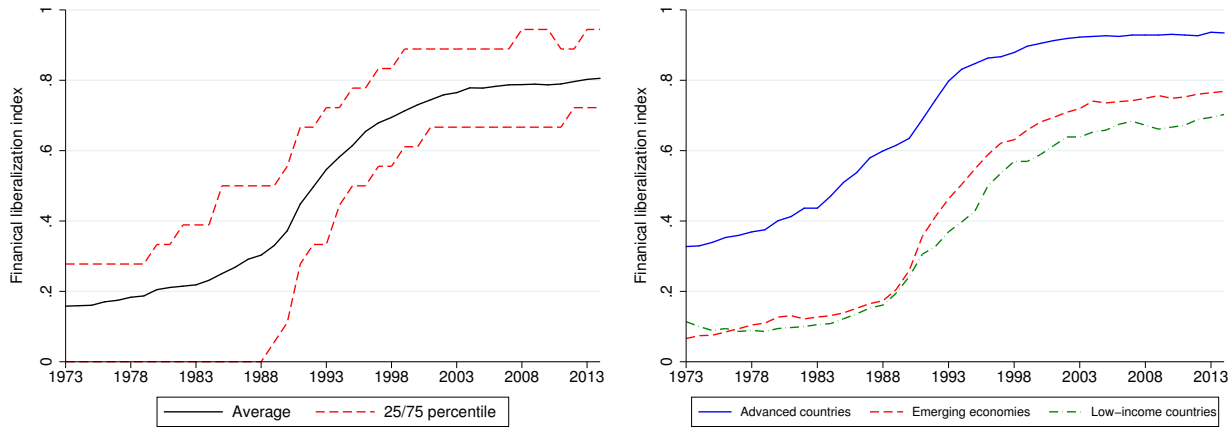


Figure 2: Nigeria: the unnormalized index of financial liberalization and its six subcomponents

Note: Each subcomponent receives a score from zero to three. Adding all the six components, the overall score ranges from zero to eighteen. The aggregate index of domestic financial liberalization, used for estimation of our structure model, normalizes the score between zero and one.

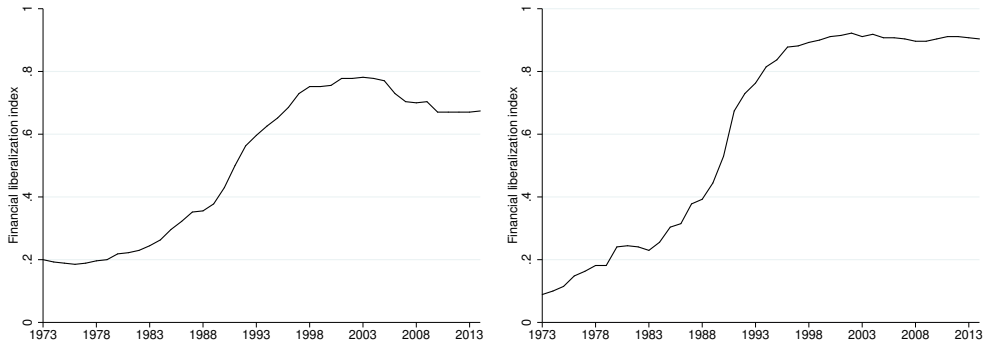


(a) Average across all countries

(b) By income group

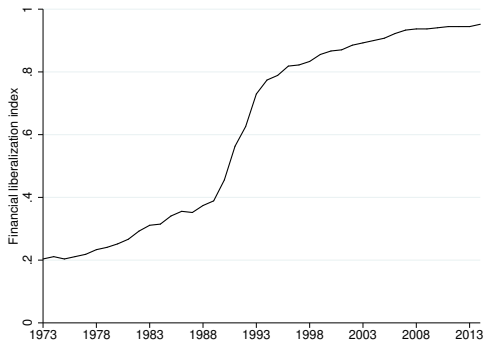
Figure 3: Financial liberalization over time

Note: Panel (a) displays the evolution of the cross-country average of financial liberalization indices over time (black line) with the 25th and 75th percentiles (dashed lines); Panel (b) displays this evolution by income group.

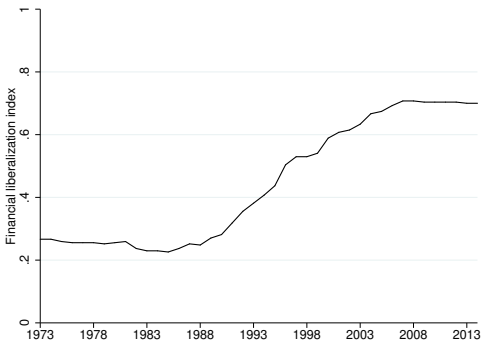


(a) Credit controls

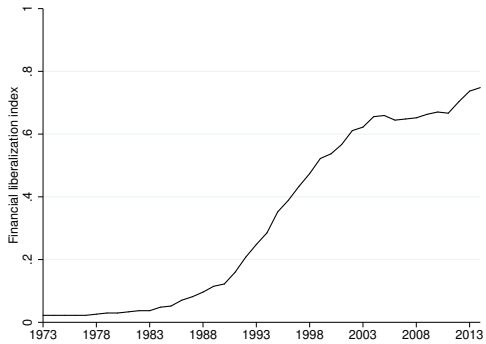
(b) Interest rate controls



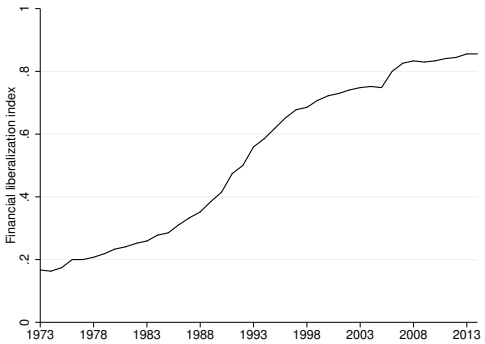
(c) Competition restrictions



(d) State ownership in the banking sector



(e) Banking supervision and regulation



(f) Securities market policies

Figure 4: Sub-indicators of financial liberalization

Note: The evolution of financial liberalization over time is reported for each sub-indicator.

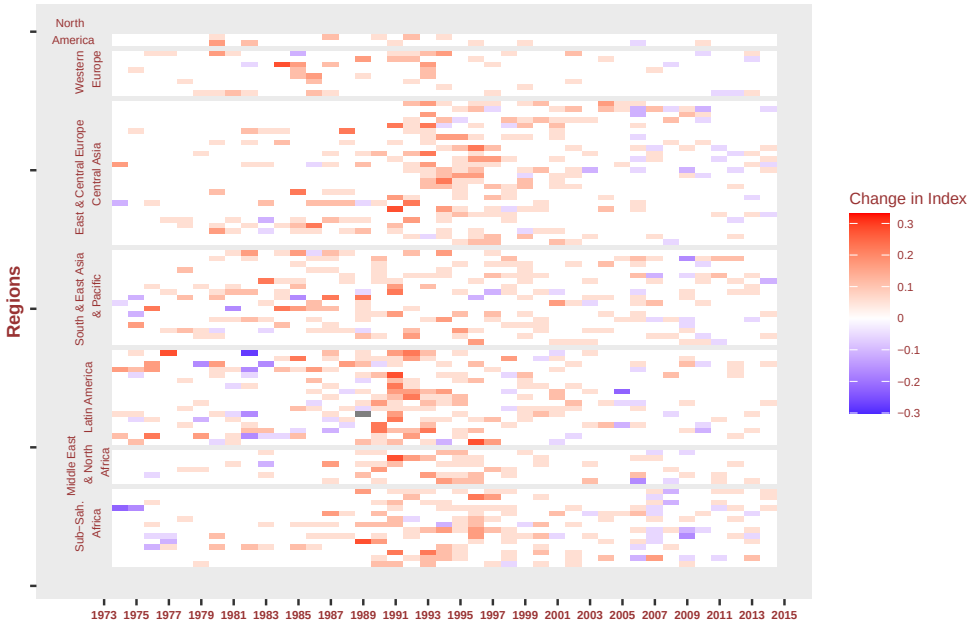


Figure 5: Heatmap: magnitude of changes in financial reforms by regions

Note: This heatmap represents annual changes in the level of financial liberalization (financial reforms) in each country over time. Countries are grouped into different geographic regions: North America, East and Central Europe, South/East Asia and Pacific, Latin America, Middle East and North Africa, and Sub-Saharan Africa. The color indicates the size and direction of changes; the red color signals an advancement of liberalization while blue a reversal.

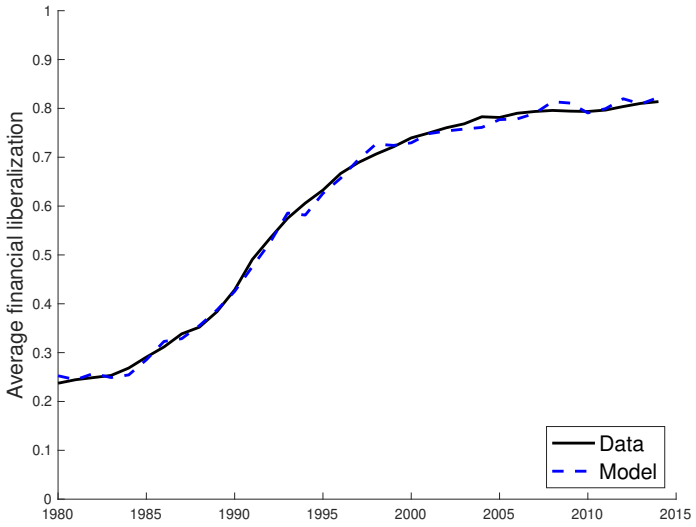


Figure 6: Actual versus model-predicted average level of financial reforms across countries

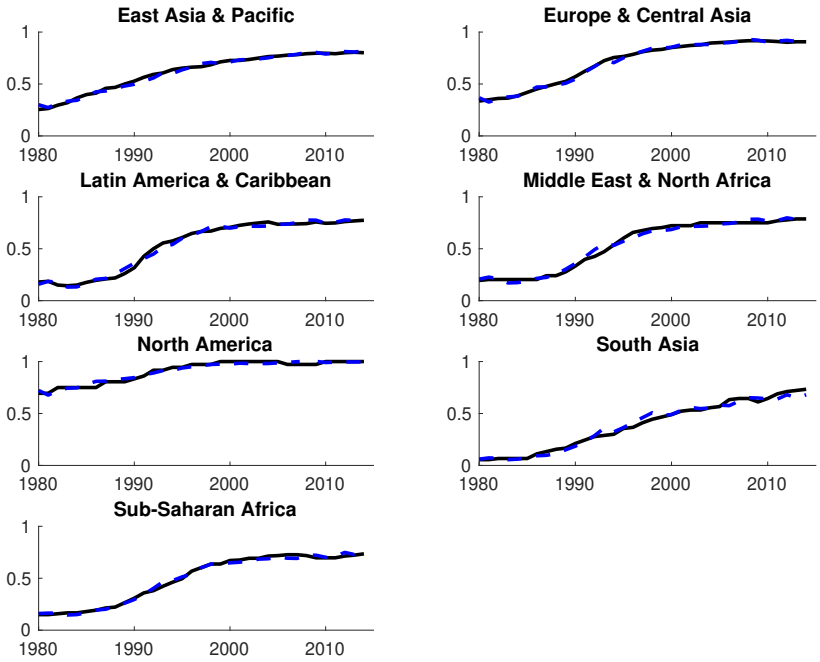


Figure 7: Actual versus model-predicted average level of financial reforms across regions within each region

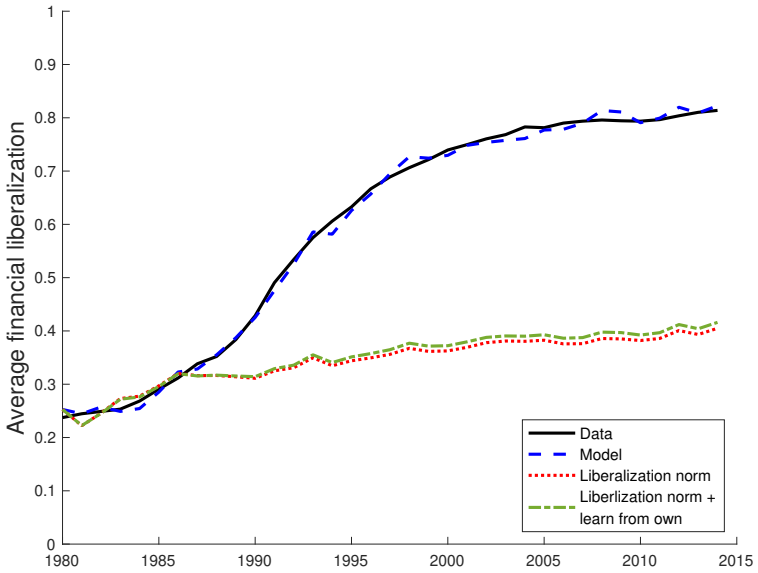


Figure 8: Decomposition of financial liberalization over time: the role of cross-country learning

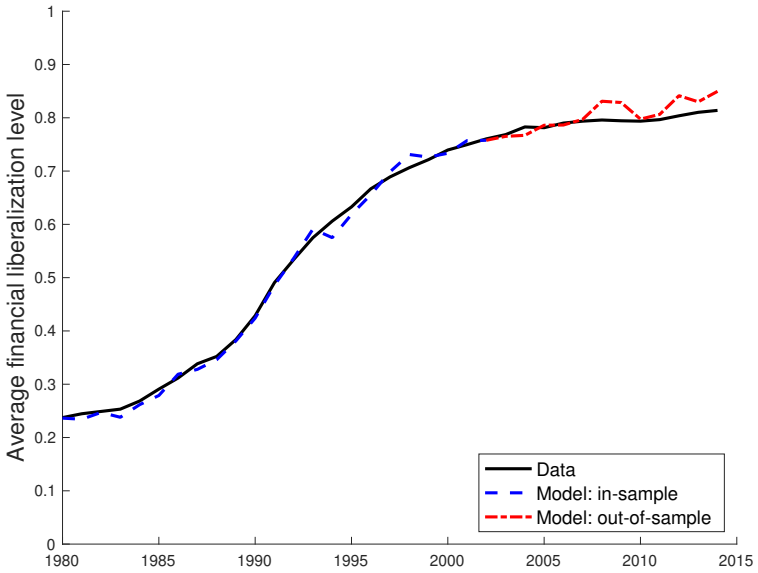
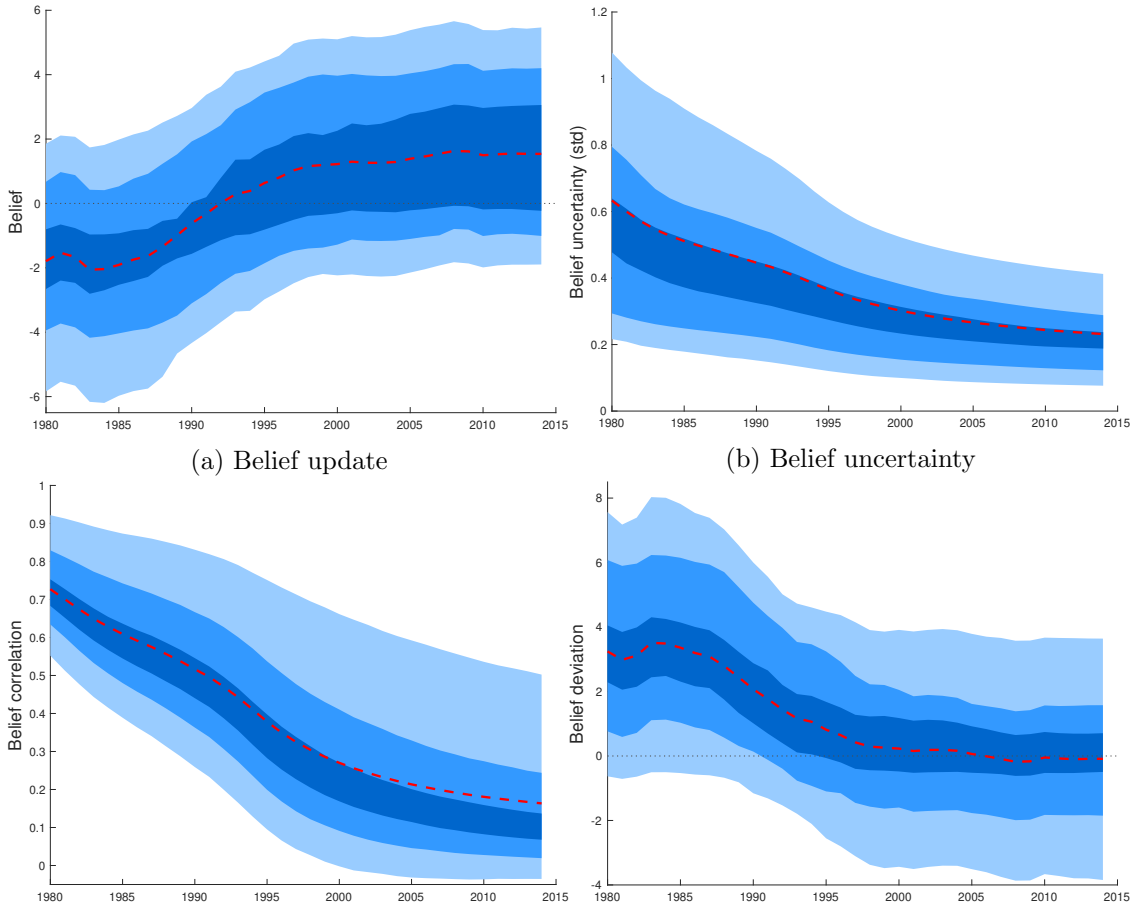


Figure 9: Actual versus model-predicted average financial liberalization

Note: The in-sample prediction (blue dashed line) is from 1980 to 2002; the out-of-sample prediction (red dot-dashed line) is from 2003 to 2014.



(a) Belief update (b) Belief uncertainty

(c) Belief correlation (d) Belief deviation

Figure 10: The evolution of heterogeneous beliefs across countries

Note: The red dashed line represents the average value across countries. The blue shades represent 10% to 90%, 25% to 75%, and 40% to 60% probability intervals from light to dark colors.

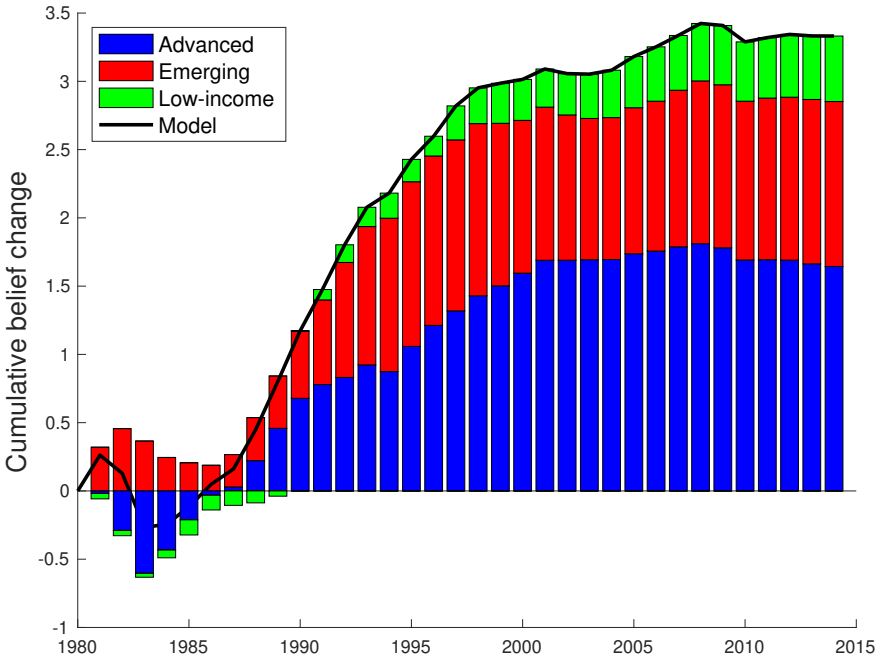


Figure 11: Contributions to cumulative belief changes over time by income groups

Note: For cumulative changes of belief from the estimated model, the belief at each time is computed as the average across all countries.

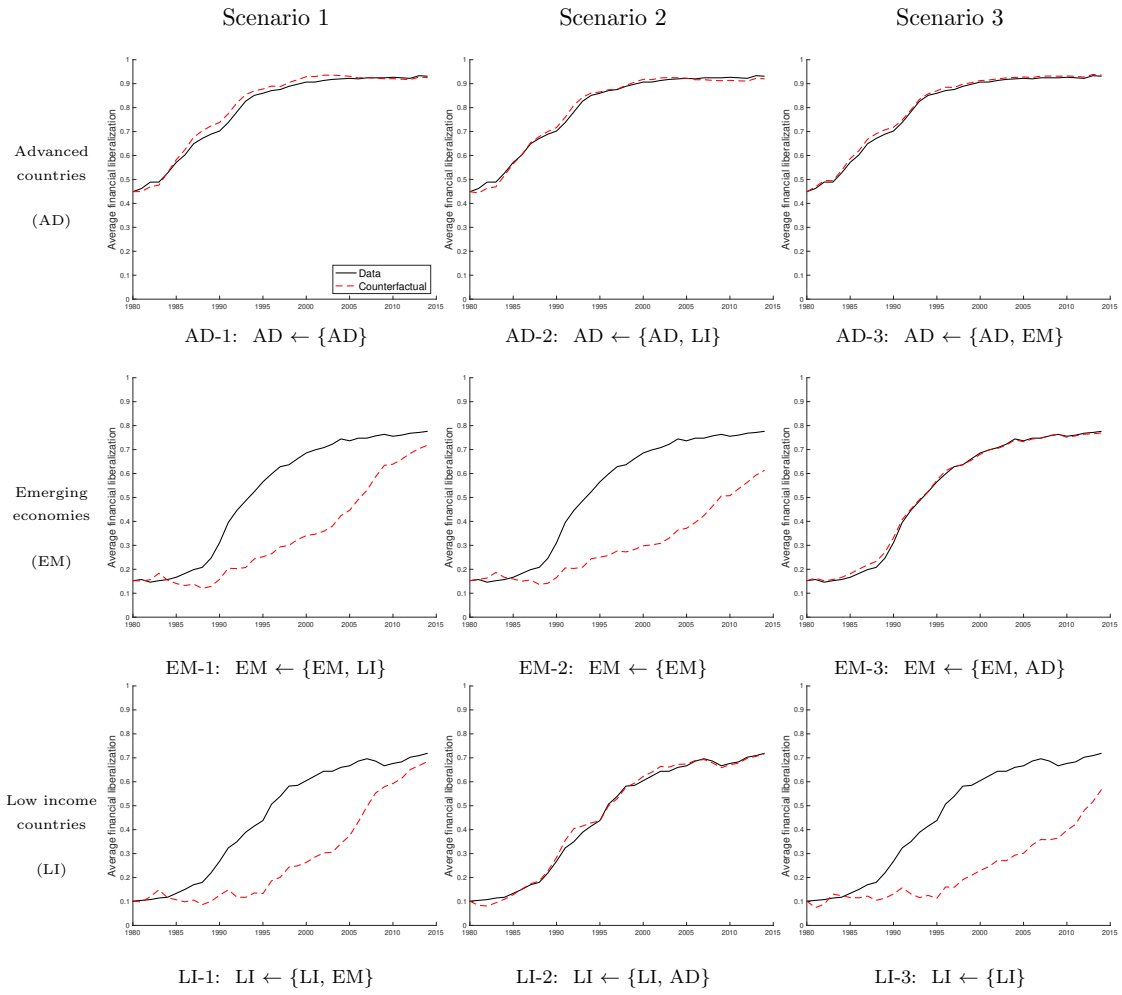
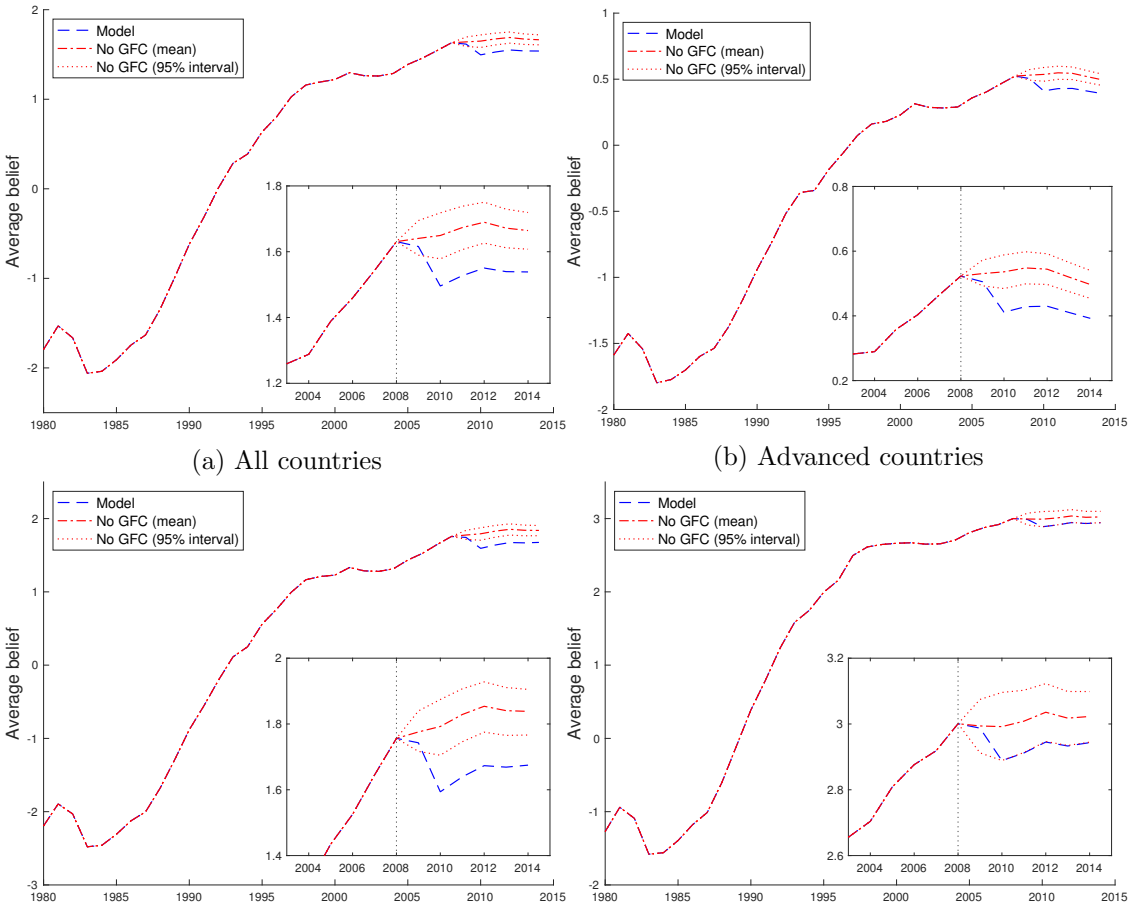


Figure 12: Learning across income groups

Note: The solid line represents the average of actual financial liberalization levels across all countries (data). The dashed line represents the average of counterfactual financial liberalization levels across certain countries under the following scenarios. Scenario 1 refers to no learning between advanced countries and the rest of the world. In this scenario, for example, AD ← {AD} indicates that AD learns from AD only, and EM ← {EM, LI} indicates that EM learns from EM and LI but not AD. Scenario 2 refers to no learning between emerging economies and the rest of the world. In this scenario, for instance, LI ← {LI, AD} indicates that LI learns from LI and AD but not from EM. Scenario 3 represents no learning between low-income countries and the rest of the world.



(a) All countries

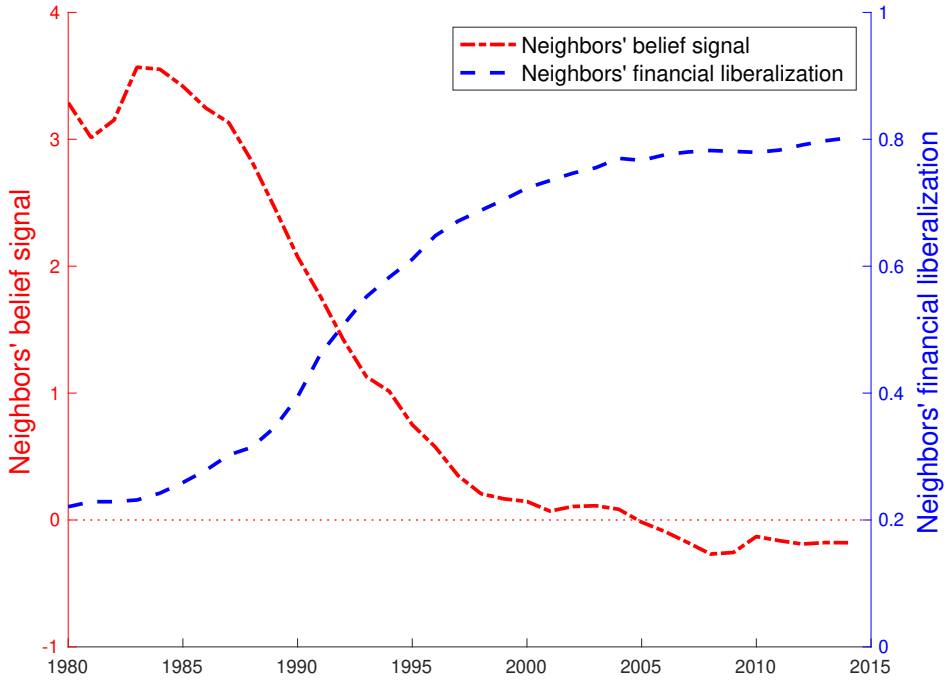
(b) Advanced countries

(c) Emerging countries

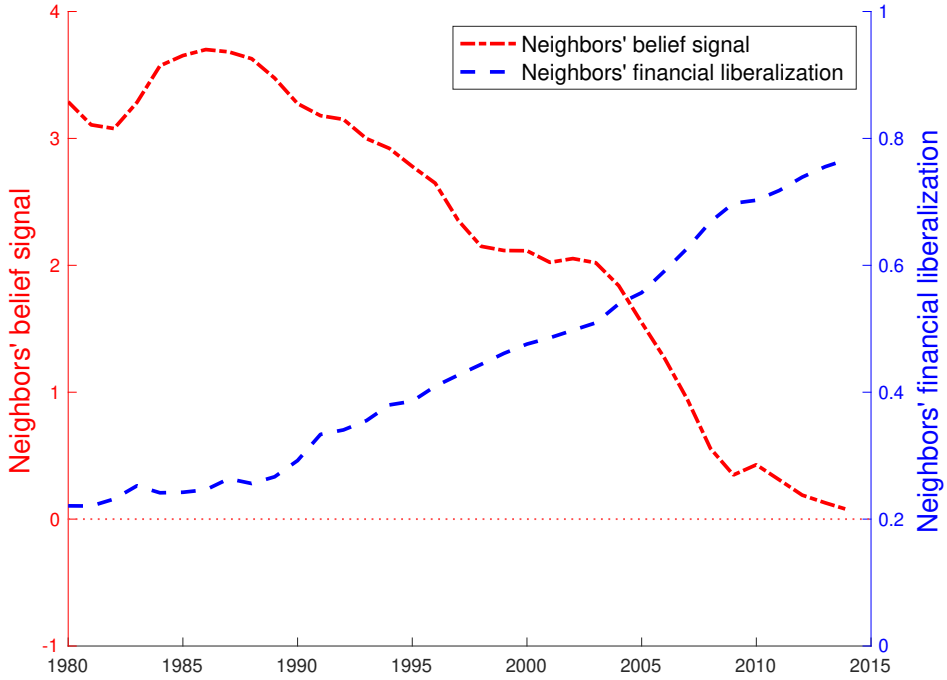
(d) Low-income countries

Figure 13: The effects of the GFC on policymakers' beliefs

Note: The blue dashed line represents the model estimation. The red dashed line represents the counterfactual belief, and the two red dotted lines around the red dashed line represent the 95% probability band generated from the simulations. The counterfactual experiment assumes that countries had not had suffered the GFC.



(a) Benchmark learning model



(b) Without learning from advanced countries

Figure 14: Neighbors' belief signal and financial liberalization

Note: The top panel is our benchmark model, which includes all countries when calculating neighbors' belief signal and financial liberalization. The bottom panel reports the counterfactual results for the case in which emerging economies and low-income countries had not learned from advanced countries. In this case, we exclude advanced countries when calculating neighbors' belief signal and financial liberalization.

Appendices

A Reduced-form evidence for learning

In this section, we provide reduced-form evidence for the learning component in our structural model. This reduced-form approach is common in the previous literature (Abiad and Mody 2005; Giuliano et al. 2013).

We hypothesize that governments may learn from past"success" (policies that induce growth) from economic reference groups (geographic neighbors or trading partners). That is, if the recent experiences in reference countries show that a higher level of financial liberalization increases economic growth, the government is likely to update their beliefs about the impact of these polices and deregulate their financial market further. And if the evidence is overwhelmingly the opposite, the government is likely to tighten its financial regulation. Following this narrative, we estimate the following regression specification:

$$r_{i,t} = \alpha_1 r_{i,t-1} + \alpha_2 r_{-i,t-1} + \alpha_3 g^{+}_{i,t-1} + \alpha_4 g^{-}_{i,t-1} + \boldsymbol{\gamma} \boldsymbol{X}_{i,t} + \varepsilon_{i,t}, \tag{A.1}$$

where the dependent variable, $r_{i,t}$ stands for the domestic financial liberalization index of country i at time t. To allow for persistence in the degree of liberalization, the lagged index, $r_{i,t-1}$, is included as the first control variable. The second term, $r_{-i,t-1}$, is the (distance-weighted) average level of liberalization of all other countries.[21] It captures policy emulation, which is another mechanism of policy diffusion but a distinct concept from learning as it does not require evaluating whether the emulated policy has shown success. The third and fourth controls capture the concept of learning about the growth effect of financial liberalization and their coefficients are of particular interest here. Specifically, $g^{+}_{i,t-1}$ denotes the (distance-weighted) average growth rate over the previous three years of all countries that have more liberalized domestic financial market than country i. Similarly, $g^{-}_{i,t-1}$ denotes the (distance-weighted) average growth in countries that have tighter regulation or state controls than country i over the past three years.[22]

A set of country characteristics, $\boldsymbol{X}_{i,t-1}$, are progressively controlled for in various specifications to absorb other time-varying determinants of reforms as suggested by the existing studies. This includes a country's initial economic conditions captured by log GDP relative to the U.S., the degree of democracy (Giuliano et al., 2013; Giavazzi and Tabellini, 2005), post-economic crises indicators (Abiad and Mody, 2005; Mian et al., 2014; Rancière and Tornell, 2016), global interest rates (Bartolini and Drazen, 1997; Abiad and Mody, 2005), and political structural factors (Alesina

[21] We have also used exports and imports as a ratio of GDP as weight.

[22] Formally, $R_{-i,t-1} = \frac{\sum_{j \neq i} \exp(-d_{ij}/\delta) R_{j,t-1}}{\sum_{j \neq i} \exp(-d_{ij}/\delta)}$, $\bar{g}_{-i,t-k|R_{-i,t-k,} > R_{i,t-k}} = \frac{\sum_{s=1}^{k} \sum_{j:R_{-i,t-k,} > R_{i,t-k}} \exp(-d_{ij}/\delta) g_{j,t-s}}{\sum_{s=1}^{k} \sum_{j:R_{-i,t-k} > R_{i,t-k}} \exp(-d_{ij}/\delta)}$ and $\bar{g}_{-i,t-k|R_{-i,t-k} \leq R_{i,t-k}} = \frac{\sum_{s=1}^{k} \sum_{j:R_{-i,t-k,} \leq R_{i,t-k}} \exp(-d_{ij}/\delta) g_{j,t-s}}{\sum_{s=1}^{k} \sum_{j:R_{-i,t-k} \leq R_{i,t-k}} \exp(-d_{ij}/\delta)}$. We set $\delta = 2500$ (as in Buera et al. 2011).

and Roubini, 1992; Persson and Tabellini, 2002). We also control for country fixed effects and time trend to absorb time-invariant determinants of reforms of a given country and aggregate trends of reform.

The OLS estimates of Equation (A.1) are reported in Table A.1. Across all specifications, the coefficients of lagged financial liberalization index are positive and statistically significant, implying a strong policy inertia or bias towards status quo. This is consistent with the stylized facts that majority (about 75 percent) of country-year observations are associated with no changes in the financial liberalization index. The coefficient of lagged neighbors' liberalization index is also significantly positive in Column (1)-(3), reflecting the strong desire to imitate neighbor's policy or prevailing practices. More importantly, turning to the effect of learning, we find that α_3 is positive and α_4 negative, and both are statistically significant. That is, a country's own financial liberalization effort improves if its more liberalized neighbors grow faster and reverses its course following periods of more rapid growth of its financially more restrictive neighbors. This finding is consistent with our hypothesis that policy makers, in making financial sector reform decisions, are influenced by the past growth performance of different policy regimes.

The results are robust to including other covariates, each of which is of interest on its own merit. In Column (2)-(5), we account for a country's degree of democracy using the polity2 index sourced from the Polity IV database and the stage of development measured by log real GDP (at current PPP) relative to the world average. In line with Giuliano et al. (2013) and Giavazzi and Tabellini (2005), democracy has a positive impact on the adoption of financial sector reforms. Since the lagged index is controlled for, the negative coefficient of log relative GDP should be interpreted as as a country's income rises, its speed of reforms slows down (larger $\Delta r_{i,t}$). Column (3)-(5) add additional controls of post-crises indicators which equals one in the three years following the initial onset year of respective crises. Currency, sovereign debt and banking crises dates are obtained from Laeven and Valencia (2020) which covers all our sample countries and periods. Column (4)-(5) further controls for inflation crises obtained from the updated database of Reinhart and Rogoff (2009), and global nominal interest rate sourced from Schmelzing (2020). Inclusion of the inflation crises reduced the sample by 1/3. Our results suggest that inflation crises are an impetus to financial reform, whereas external debt crises set back the reforms as governments may resort to financial repression as a way to draw down debt accumulation.[23] In addition, when the global interest rate is low, countries may engage more in domestic financial liberalization to attract international capital. Finally, Column (5) show that political factors do not really play a significant role.

[23]The effect of crises on reform is inconclusive in the literature. Crises induce reform are argued in earlier literature Drazen and Grilli (1993); Fernandez and Rodrik (1991). Abiad and Mody (2005) find only balance-of-payments crises improves financial liberalization. Mian et al. (2014) provide tentative evidence of an adverse effect.

Table A.1: Evidence for learning: reduced-form regression estimates

	(1)	(2)	(3)	(4)	(5)
$r_{i,t-1}$	0.908***	0.892***	0.892***	0.900***	0.899***
	(0.011)	(0.011)	(0.011)	(0.013)	(0.014)
$r_{-i,t-1}$	0.091***	0.069***	0.068***	0.026	0.027
	(0.015)	(0.015)	(0.015)	(0.022)	(0.023)
$g^{+}_{i,t-1}$	0.225***	0.219***	0.216***	0.208**	0.205**
	(0.073)	(0.075)	(0.076)	(0.101)	(0.102)
$g^{-}_{i,t-1}$	-0.535***	-0.447***	-0.442***	-0.514***	-0.506***
	(0.061)	(0.061)	(0.061)	(0.084)	(0.084)
Democracy$_{i,t-1}$		0.001***	0.001***	0.001***	0.001***
		(0.000)	(0.000)	(0.000)	(0.000)
Relative GDP$_{i,t-1}$		-0.014***	-0.014***	-0.013***	-0.013***
		(0.004)	(0.004)	(0.005)	(0.005)
Post-currency$_{i,t}$			0.011**	0.008	0.008
			(0.004)	(0.006)	(0.006)
Post-debt$_{i,t}$			-0.011*	-0.016**	-0.016**
			(0.006)	(0.006)	(0.006)
Post-banking$_{i,t}$			-0.006	-0.015***	-0.015***
			(0.005)	(0.005)	(0.005)
Post-inflation$_{i,t}$				0.012***	0.011***
				(0.004)	(0.004)
Global interest rate$_{i,t-1}$				-0.002	-0.002*
				(0.001)	(0.001)
New government$_{i,t-1}$					0.003
					(0.003)
Left$_{i,t-1}$					-0.001
					(0.003)
Presidential$_{i,t-1}$					0.003
					(0.007)
Observations	3269	3014	3014	1955	1922

Note: The dependent variable is the financial liberalization index $r_{i,t}$. All regressions control for country fixed effects and time trend. Robust standard errors are denoted in parentheses. *, ** and *** denote significant at the 10, 5 and 1 per cent, respectively.

B True data generating process

We assume that the true DGP is a hierarchical linear model, that is, the GDP growth per capita for country i follows

$$g_{i,t} = c_i + \alpha_i y_{i,t-1} + \beta_i r_{i,t} + \xi_{i,t},\ t = 1, \ldots, T,$$

where $g_{i,t}$ is the per capita GDP growth in country i at time t, $y_{i,t-1}$ is the log of a one-year lag of per capita GDP, and $r_{i,t}$ is the financial liberalization level. The vector of growth shocks across countries is $\xi_t \equiv [\xi_{1,t}, \ldots, \xi_{n,t}]' \sim \mathcal{N}(0, \Omega)$, which is uncorrelated across time. The structure for the covariance matrix is $\Omega = S \cdot Q \cdot S$, where $S = diag(s_1, \ldots, s_n)$ and $Q_{ij} = \exp[-d_{ij} \cdot \tau]$.

Each country's coefficients are drawn from a population with the following distribution

$$\begin{aligned} c &\sim N(1_n \cdot \bar{c},\ \Omega_c), & \Omega_c &= \zeta_c^2 \cdot W_c. \\ \alpha &\sim N(1_n \cdot \bar{\alpha},\ \Omega_\alpha), & \Omega_\alpha &= \zeta_\alpha^2 \cdot W_\alpha. \\ \beta &\sim N(1_n \cdot \bar{\beta},\ \Omega_\beta), & \Omega_\beta &= \zeta_\beta^2 \cdot W_\beta. \end{aligned}$$

The population mean and standard deviation for the coefficients of financial liberalization (β) are $\bar{\beta}$ and ζ_β, respectively. The correlation matrix W_β is modeled as $W_{\beta,ij} = \exp[-d_{ij} \cdot \tau_\beta]$ for country i and j, which allows for potentially spatial correlation. The setup is similar for c and α.

The estimation results are in the Table B.1. First, the growth shocks are not closely correlated in the spatial distance, and the average correlation across countries is 0.02. The average standard deviation for growth shocks is 3.51. Second, increase in financial liberalization by 0.1 would on average increase the country's growth rate by about 0.18 percentage point, but there exists large heterogeneity across countries. And the correlation is approximately 0.56 for countries with a distance of 1000km. Third, the effect of GDP level on growth is overall negative, and the average correlation for this effect across countries is about 0.07. Fourth, the dispersion of country-specific growth component is large. The correlation for this country-specific growth component is about 0.83 for countries that are 1000km apart and 0.39 for those with 5000km apart.

Table B.1: Estimates of the hierarchical linear model for the true DGP

τ	$\bar{\beta}$	ζ_β	τ_β	$\bar{\alpha}$	ζ_α	τ_α	$\bar{c}$	ζ_c	τ_c
1.7958	1.8429	1.9499	0.5789	-0.9249	0.6122	0.6823	1.4677	2.1333	0.1882
(0.0896)	(0.6005)	(0.4256)	(0.2787)	(0.2837)	(0.2660)	(0.3878)	(0.9357)	(0.5413)	(0.1261)

Note: The standard errors for the estimates are in the parentheses.

C Estimation methodology

The task is to fit the model to the data and thereby to estimate the model's parameters, including those governing the policymakers' beliefs. The unknown coefficients are (1) expectation of initial beliefs about the effect of financial liberalization, $\{\beta_{i,1|0}\}_{i=1}^{n}$; (2) standard deviation of initial beliefs about the effect of financial liberalization, $\{\sigma_{i,1|0}\}_{i=1}^{n}$; (3) coefficient parameterizing the correlation of initial beliefs, γ; (4) coefficient for political cost, ψ; (5) country-specific component of financial liberalization norm, $\{\delta_i\}_{i=1}^{n}$; (6) coefficients of time-varying liberalization norm, ϕ; (7) variance of financial liberalization implementation shocks, $\{\lambda_i\}_{i=1}^{n}$.

Group all the unknown parameters in the vector Θ. Denote the entire financial liberalization data by $R \equiv \{r_{1,t}, \ldots, r_{n,t}\}_{t=1}^{T}$, and the entire data on growth component and countries' political and economic characteristics by $D \equiv \{z_{1,t}, \ldots, z_{n,t}, \nu'_{1,t}, \ldots, \nu'_{n,t}\}_{t=1}^{T}$. The Bayes rule delivers

$$p(\Theta \mid R, D) \propto \mathcal{L}(R \mid \Theta, D)\pi(\Theta),$$

where $p(\Theta \mid R, D)$, $\mathcal{L}(R \mid \Theta, D)$, and $\pi(\Theta)$ represent the posterior pdf, likelihood, and prior pdf respectively.

C.1 Priors

Since our model has many parameters, we use informative priors to prevent overfitting problems, as in Buera, Monge-Naranjo, and Primiceri (2011).

The prior distribution of ψ takes the Gamma form. We choose the shape hyperparameter to be 1 so zero reform cost is allowable. We pick the scale hyperparameter as 4.3429 so that the probability of $\psi > 10$ is about 10% for the prior distribution. In this way, the prior distribution covers a relatively wide range.

The prior distribution of $\beta_{i,1|0}$ takes the Gaussian form. We set the prior mean at 0 and the prior standard deviation at 2 to be agnostic. If all coefficients related to financial liberalization norm are zero, this prior distribution implies an average liberalization level of 0.5 with standard deviation of around 0.5.

The prior distribution of $\sigma_{i,1|0}$ follows inverse Gamma distribution. From the estimated growth process, the average standard deviation for growth shocks across countries is about 3.5. Consider the case that we have 25 observations for $z_{i,t} = 0.5 \cdot \beta + \xi_{i,t}$, the standard deviation of estimate for β is $(3.5/0.5)/\sqrt{25} \approx 1.4$. Thus, we set both the prior mean and standard deviation of $\sigma_{i,1|0}$ as 1.5 to be consistent with the estimate while remaining diffuse, and this gives the shape and scale hyperparameters as 3 and 3 respectively.

The prior distribution of λ_i also follows inverse Gamma distribution. From the construction method of financial liberalization index, the gap between two nearby levels is $1/18 \approx 0.055$. Based on this, we set the prior mean and standard deviation for the implied standard deviation of implementation shocks both to 0.025, which gives the shape and scale hyperparameters for λ_i as 1.2945 and 0.004 respectively.

Lastly, we use flat priors for γ, δ_i, and ϕ, about which we do not have much prior information.

C.2 The likelihood function

From equation (3), the likelihood function can be derived from the joint probability density of liberalization implementation shocks as

$$\mathcal{L}(R \mid \Theta, D) = \frac{1}{(2\pi)^{nT/2}} \prod_{i=1}^{n} \left[\lambda_i^{-\frac{T}{2}} \prod_{t=1}^{T} \exp\left(-\frac{\eta_{i,t}^2}{2\lambda_i} \right) \right],$$

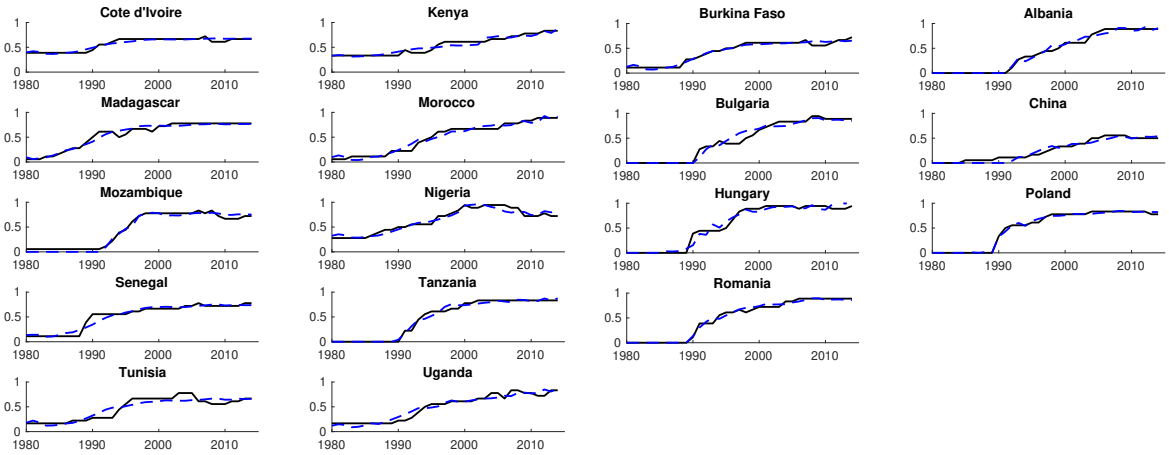
where $\eta_{i,t}$ is a function of unknown parameters

$$\eta_{i,t} = r_{i,t} - (\bar{r}_{i,t} + \psi^{-1}\beta_{i,t|t-1}).$$

C.3 The estimation procedure

We divide the whole sample into two parts, training sample ($1973 \sim 1979$) and estimation sample ($1980 \sim 2014$). While parameters are estimated only using the estimation sample, policymakers' beliefs are updated with observed growth components and financial liberalization data in the training sample period. The role of training sample is to help alleviate overfitting problem and discipline policymakers' initial beliefs at the beginning of estimation. For instance, the model can fit data well, but policymakers' initial beliefs are implausible. With training sample, policymakers update their beliefs with true growth and financial policy data for seven years before the estimation period. In this way, training sample imposes a fair amount of information on policymakers' beliefs, and the estimation does not start from arbitrary beliefs. Besides, we exclude 12 former Soviet Union countries due to lack of growth information before 1990 and Zimbabwe due to growth outlier observation, so we use 77 countries in our estimation.

D Model fit for each country


Cote d'Ivoire
Kenya
Burkina Faso
Albania
Madagascar
Morocco
Bulgaria
China
Mozambique
Nigeria
Hungary
Poland
Senegal
Tanzania
Romania
Tunisia
Uganda
0
0.5
1
1980
1990
2000
2010

E Robustness

E.1 Alternative specification of the DGP for growth

We consider an alternative specification of the DGP for growth, where the effects of financial liberalization on growth are common across countries (common β).[24] The learning part of the model is the same as our baseline model, where policymakers believe each country has its own β_i and they are potentially correlated. With this alternative specification of the DGP for growth, we re-estimate our model with the same priors for the parameters. The decomposition of the model's fit for financial liberalization is in the Figure 19. We can see that most increase in the fitted financial liberalization still comes from the cross-country learning, which shares a similar pattern as our baseline model. This shows that the learning mechanism (especially learning across countries) is robust for different specifications in the data generating process for growth.

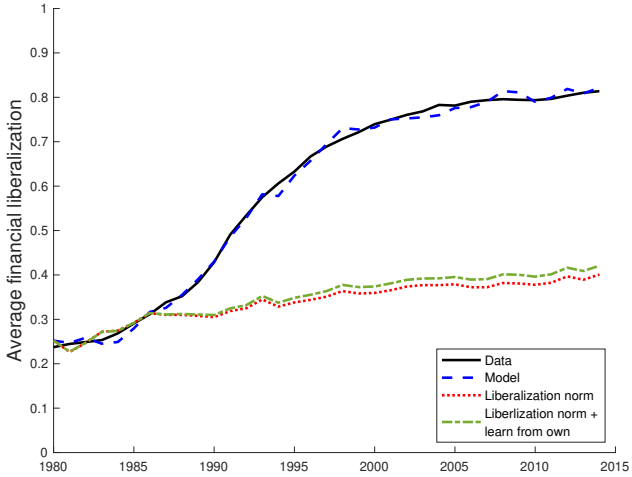


Figure 19: Decomposition of the estimated model with common-β growth specification

E.2 Model with only learning from own country's experiences

We explore an alternative specification of the model to emphasize the importance of cross-country learning. Specifically, we consider the case where countries believe their effects of financial liberalization on growth are uncorrelated, so they do not learn from other countries' economic performances. To shut down cross-country learning, we fix the correlation of initial beliefs across countries to zero (equivalent to setting the parameter γ to infinity) and re-estimate the rest of parameters following the same estimation method as the baseline model. The MAE in this estimated model is 0.055, and it is about 1.4 times larger than that in the baseline model. This shows that the model

[24] The rest of the growth equation are the same as the true DGP, i.e. heterogenous coefficients for country specific component (c_i) and level of GDP (α_i).

with only learning from own country's experiences cannot fit the data well. Also, we conduct the out-of-sample forecast exercise for this model, and the out-of-sample MAE for average financial liberalization level in this model is 0.026, which is much higher than that value (0.017) in our baseline model. In summary, this exercise fortifies the claim that cross-country learning is vital to explain the dynamics of global financial liberalization.

F Belief decomposition

In this section, we decompose belief changes into the contribution of different group of countries based on the Bayesian update formula. We can re-write equation (8) as

$$\Delta\beta_{t+1|t} = \Sigma_{t+1|t}^{-1} R_t' \Omega^{-1} \left(z_t - R_t \beta_{t|t-1} \right), \tag{F.1}$$

where $\Delta\beta_{t+1|t} \equiv \beta_{t+1|t} - \beta_{t|t-1}$. Since $z_t - R_t\beta_{t|t-1}$ is a vector with the ith element equal to $z_{i,t} - \beta_{i,t|t-1} r_{i,t}$, we define

$$\tilde{z}_t^g \equiv \begin{bmatrix} (z_{1,t} - \beta_{1,t|t-1} r_{1,t}) \cdot \mathcal{I}_{\{1 \in g\}} \\ \vdots \\ (z_{i,t} - \beta_{i,t|t-1} r_{i,t}) \cdot \mathcal{I}_{\{i \in g\}} \\ \vdots \\ (z_{n,t} - \beta_{n,t|t-1} r_{n,t}) \cdot \mathcal{I}_{\{n \in g\}} \end{bmatrix}, \tag{F.2}$$

where g denotes different group of countries, and $\mathcal{I}_{\{i \in g\}}$ is an indicator function, which equals one if country i is in the group g and zero otherwise. Define the contribution of group g to belief change in the period t as

$$\Delta\tilde{\beta}_{t+1|t}^g \equiv \Sigma_{t+1|t}^{-1} R_t' \Omega^{-1} \tilde{z}_t^g. \tag{F.3}$$

It is easy to see that $\Delta\beta_{t+1|t} = \sum_g \Delta\tilde{\beta}_{t+1|t}^g$. Then the contribution of group g to cumulative belief change until time T is $\sum_{t=1}^{T} \Delta\tilde{\beta}_{t+1|t}^g$.