Sovereign Default Risk and Migration

George Alessandria[a,b] Yan Bai[a,b] Minjie Deng[a]

[a] University of Rochester
[b] NBER

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Abstract

We study the role of migration in a sovereign debt crisis. Empirically, we document a large worker outflow accompanies a rise in sovereign debt spreads. We develop a model of sovereign default with an endogenous migration choice to understand how migration interacts with the default risk and propagates a debt crisis. In the model, the outflow of workers increases the government's debt burden by increasing debt-per-capita, further increasing default risk. As a result, the government decreases investment, which affects the consumption of the workers. Lower consumption, in turn, increases the probability of emigration. Compared with a model without endogenous migration, our model generates a higher default risk, lower investment, and deeper and more prolonged recession. The impact of the migration channel is even more substantial when the average migrant has higher levels of human capital relative to locals.

1 Introduction

The recent European debt crisis was characterized by high government indebtedness, rising bond spreads, and substantial cross-country labor mobility. The countries that were in debt crisis experienced massive outflows of workers. The migration pattern in Spain, for instance, was transformed entirely during the recent debt crisis: immigration booms present for years were replaced by net outflows. Country-level evidence also documents that high sovereign default risk is associated with discharges of workers. Motivated by these observations, we develop a sovereign default model with endogenous migration choice in which increases in

sovereign default risk lead to a higher probability of emigration, which in turn affects the default risk.

The key contribution of the model is that we allow endogenous migration choice in a sovereign default context. Our environment features a two-way loop. The workers affect the government through migration choices, and the government changes the workers' utility through lump-sum transfers. The workers choose the location that provides the highest utility, and the government makes default decision and conducts lump-sum transfers to maximize the utility of the workers. When the country is in a debt crisis, more workers choose to leave the country, further increasing the debt burden on the remaining workers, which raises the incentive to migrate. Increased debt burden depresses investment, leading to an even deeper and longer recession.

In the model, workers are heterogeneous in their idiosyncratic migration costs, and they decide whether to leave the country by comparing the value of staying and the value in another country minus migration costs. The workers provide labor and get paid by the government. The government borrows to finance investment. The government can default on its debt obligations, and its interest rate spreads compensate lenders for the default risk. It also internalizes that its borrowing affects interest rate spreads and hence output. The government transfers all remaining profit to the workers. The economic environment is perturbed by an aggregate shock that moves the productivity process of the government and an idiosyncratic shock that changes the migration cost of workers.

The default risk in our model responds to changes in the state of the economy as in Eaton and Gersovitz (1981). Specifically, the default probability in our model is a function of productivity, capital, borrowing, and labor. Given an exogenous negative productivity shock, the endogenous risk of a government default increases. Increased default risk raises the borrowing cost and thus depresses investment. Tightening financial constraints reduce the transfers to the workers. The workers emigrate because of higher welfare in another country. The emigration of workers not only reduce the labor of the country but also affects the government's decision of defaulting and investment in the next period.

We quantify our model and ask, how does the migration channel contribute to the crisis? We find that migration channel is magnifying the debt crisis in both size and persistence. To quantitatively evaluate the migration channel in reinforcing debt crisis, we compare our model against two reference models. Our benchmark model features both default risk and migration choices. In the first reference model *no-migration*, we shut down the migration choices. We re-calibrate it to ensure that the average spread is the same with our benchmark model. In the second reference model *no-default*, we further shut down the default risks. The

financial markets are nearly frictionless, and interest rate fluctuations are essentially null. We find that default risk accounts for part of decline and persistence of investment and output, and emigration provides further magnification by exaggerating the default risk. Following a one standard deviation negative productivity shock, the per-capita GDP in the benchmark model falls 2.9%. It drops 2.5% in the *no-migration* model and 2.3% in the *no-default* model. Until 20 periods after the shock, the fall in aggregate GDP in the benchmark model is still 2.3 times the decline in the no-migration model and 2.8 times the decline in the no-default model.

We apply our framework to the recent debt crisis in Spain, which featured increases in sovereign spreads together with a massive outflow of workers. We focus on the peak-to-trough dynamics of GDP, government spread, and migration from 2008 to 2012. During the event, output declines by 12.46%, spreads increased from 0.38% to 4.35%, and net migration rate drops from 0.95% to -0.3%. We feed in a path of productivity shocks such that the conditional mean aggregate output of the model reproduces the path of Spanish GDP from 2003 to 2012. Our model generates 80% of the increase in the interest rate spread and 35% of the decrease in migration rate during the peak-to-trough. We find that although the model without migration could generate a similar magnitude of the decline in output, it can't generate the persistence of the recession as in the data.

Related Literature. Our paper provides a framework that embeds migration choice into a sovereign default model. We also contribute to the literature that studies the role of migration in determining the business cycle dynamics.

Some recent papers in the sovereign default literature emphasize the connections between sovereign default and the private sector. Most of the papers focus on the link between the sovereign and the firm sector. Mendoza and Yue (2012) study a sovereign default model in which firms lose access to external financing conditional on a government default, and such a mechanism can generate substantial output costs of a sovereign default. Arellano, Bai, and Bocola (2017a) study the recessionary interplay between the government and heterogeneous firms during the sovereign debt crisis without actual default, and they find that interest rate hikes have more severe consequences for firms that are in need of borrowing and the increase of sovereign risk during the recent crisis in Italy was responsible for 50% of the observed decline in output. We share with these papers the emphasis on the interaction between the sovereign and the private sector during the debt crisis, but we depart from their analysis in focusing the interplay between the sovereign and the labor market. In our model, an increase in sovereign default risk affects the migration choice of the workers, and the migration decisions, in turn, change the state of the economy and thus the default risk of

the government.

Regarding the literature focusing on the interplay between the sovereign and the labor market, Balke (2016) studies the employment cost of default and shows that the persistence of unemployment produces serial defaults and rationalizes high debt-to-GDP ratios. The migration accompanied by the debt crisis in our paper can be viewed as another source of endogenous default cost. Furthermore, since migration involves population and human capital changes, it has a long run effect on the economy.

The amplification by financial friction has been extensively studied in the literature, which goes back to Bernanke, Gertler, and Gilchrist (1999) and Kiyotaki and Moore (1997). Our work shares a conclusion similar to Mendoza (2010) and Arellano, Bai, and Mihalache (2017b) in that financial frictions amplify the shocks and lead to a slow recovery. Our model differs from theirs in that not only financial frictions arise from endogenous default risk, but also amplified by emigration. Gordon and Guerron-Quintana (2018) shares with us the emphasize between debt and migration in that migration changes debt per person in each region, though their paper focuses on explaining declined migration rates among areas in the United States.

We also contribute to the literature that focuses on the effects of migration on business cycles. Using constructed working-age net migration data for the U.S. in a vector autoregression, Weiske (2017) finds that migration leads to real wages fall and investment increases in the destination country, but immigration only makes a modest contribution to the U.S. business cycle dynamics. Furlanetto and Robstad (2017) uses Norwegian data and find that positive migration shocks are expansionary and a significant driver of the dynamics of unemployment, though they are unimportant for house prices. Using a dynamic stochastic general equilibrium model of a small open economy estimated on data for New Zealand, Smith and Thoenissen (2018) finds that migration shocks account for a considerable proportion of the variability of per-capita GDP. An essential difference in our paper relative to all of the papers mentioned above is that we focus on the impact of migration on the source country rather than the destination country.

2 Migration during Debt Crises

In this section, we document migration during the debt crises. We show that during debt crises, the governments face increases in spreads on their borrowing, and many workers leave the countries. We also document that higher-educated and younger workers are more likely

to migrate.

2.1 Spreads

During late 2008, countries in Europe including Greece, Ireland, Italy, Portugal, and Spain experienced increases in their government bond yields and spread at which they were borrowing reflecting perceptions of higher default risks. Figure 1 plots the spread for these countries. Spread is defined as the gap between the 10-year government bond yield and that of Germany. The spreads peaked in 2012 for most countries, reaching, for example, 12% for Portugal and 27% for Greece.

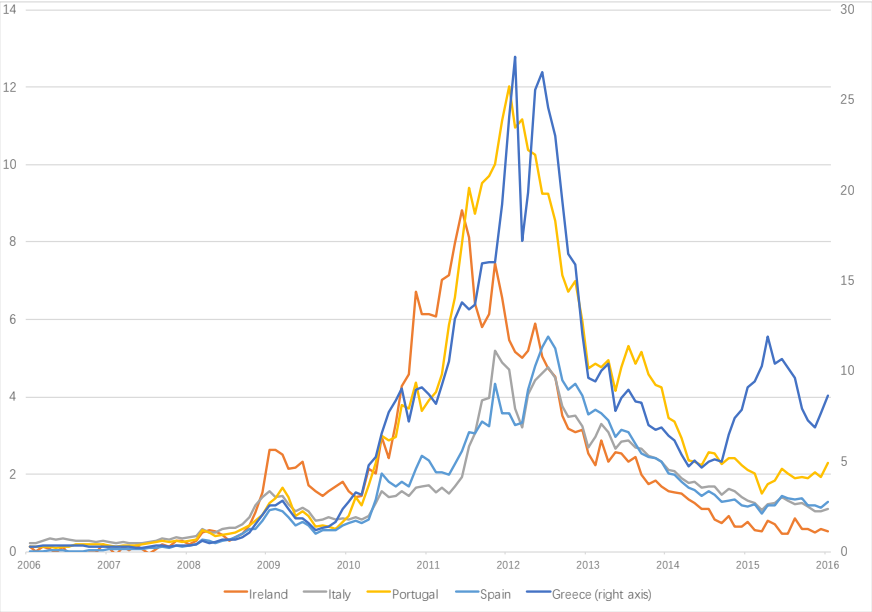


Figure 1: Spreads for EU countries

2.2 Migration in Debt Crises

During debt crises, massive workers left the countries in crisis. Figure 2 plots the government bond yield and net migration rate for Greece, Ireland, Portugal, and Spain during 1998-2015. The dashed blue line presents the net migration rate on the left axis, and the solid orange line presents government bond yield on the right axis. Net migration rate is defined as the ratio of net migration (inflows minus outflows) during the year to the average population in that year. Briefly speaking, a positive net migration rate means inflows outweigh outflows, while a negative net migration rate shows there are more substantial outflows than inflows. Figure 2 shows that the net migration rate drops when government bond yield rises

rapidly. It indicates that people tend to emigrate in debt crises. The Greek government bond interest rate, for instance, increased from 5.17% to 22.49% in 2009-2012. During this period, the net migration rate was decreasing rapidly. Before 2009, the average net migration rate was 0.3%. In 2012, the net migration rate was -0.6%, showing that there are more outflows than inflows. Compared with Greece, Spain experienced an even more massive emigration during the debt crisis if we consider previous large immigration inflows. The average annual net migration rate was 1.2% in 2000-2009 and drops to -0.13% in 2010-2015. We also plot government bond yield and net migration rate for a mostly immigrants receiver country – Germany (Appendix A.1). From 2008 to 2015, the government bond yield decreased from 1.4% to 0.5%, and the net migration rate increased from about -0.05% to 1.4%, which also indicates a negative correlation between government default risk and net migration. We also plot figures of government bond spread (which is the gap between government bond yield and that of Germany) for Greece, Ireland, Portugal, and Spain. They generate a similar pattern (Appendix A.2).

Figure 2: Government Bond Yield and Net Migration Rate

Notes: Net migration rate is defined as the ratio of net migration during the year to the average population in that year (dashed blue line, left axis). Government bond yield is long-term interest rates of government bonds maturing in ten years (solid orange line, right axis).

To further confirm the correlation between sovereign default risk and net migration, we regress the net migration rate on government bond spread and other control variables. Our empirical specification is:

$$m_{jt} = \alpha_j + \beta sp_{jt} + \gamma y_{jt} + \Phi' Z_{jt} + \phi y_{us,t} + \epsilon_{jt} \tag{1}$$

where m_{jt} is the net migration rate of country j in time t. α_j is the country fixed effect. sp_{jt} is the government bond spread in country j in time t. y_{jt} is the per-capita real GDP in country j in time t. Z_{jt} is a vector of country-level controls including exchange rate, unemployment rate, and price level. We also include per-capita real GDP of the United States $y_{us,t}$ to control for the world economy. ϵ_{jt} is the residual. Our net migration data comes from Eurostat, spanning from 2008 to 2016. The definition of migrants is consistent across countries during this period. For government bond interest rate, we use data of government bonds maturing

in ten years (% per annum) from OECD database and spread is then defined as the difference between the interest rate in the country j and that in Germany. Data of GDP, exchange rate and price level are from Penn World Table 9.0 and unemployment rate data is from IMF. We logged and HP-filtered all variables except the net migration rate and spread.

Table 1 presents the regression results of empirical specification (1). The results show that high spread significantly associated with low net migration. Column (5) is the result when we add both country-level controls and GDP in the United States as the world economy control, as well as country fixed effect. Spread increases by one percentage point associated with net migration rate decrease by 0.03 percentage point. For example, if spread increased from 2% to 3%, then we could expect the net migration rate decrease from 0.2% to 0.17%. In Appendix B, we also show the results when we lag all variables to take into account the fact that it takes time to migrate. The results are consistent with our findings in the main text.

Table 1: Regression of Net Migration on Government Bond Spread

	(1)	(2)	(3)	(4)	(5)
spread	-0.11***	-0.03**	-0.11***	-0.11***	-0.03**
	(0.02)	(0.01)	(0.02)	(0.02)	(0.01)
GDP	2.25	4.65***	-4.64	-4.61	-1.22
	(1.85)	(1.05)	(3.65)	(3.80)	(2.02)
unemployment			-1.18*	-1.19*	-1.21***
			(0.61)	(0.63)	(0.32)
exchange rate			1.61	1.57	0.11
			(3.50)	(3.66)	(1.91)
price			2.23	2.21	0.40
			(3.51)	(3.60)	(1.88)
U.S. GDP				-0.17	-1.81
				(5.14)	(2.67)
N	159	159	159	159	159
R^2	0.261	0.215	0.284	0.284	0.301
country FE		yes			yes
country controls			yes	yes	yes
US GDP				yes	yes

Standard errors in parentheses

* p<.1, ** p<0.05, *** p<0.01

2.3 Profiles of Emigrants

We document the profiles of emigrants by combining survey data by Gallup and information in Database on Immigrants in OECD and non-OECD Countries (DIOC-E).

Table 2 shows the desire to emigrate is generally stronger for younger, higher educated and wealthier people. Gallup collects the information in a survey conducted in more than 160 countries from 2007 to 2013. The study covers all adults (aged 15 and over) and includes information on their socio-demographic characteristics and labor market outcomes. It also consists of a series of questions related to the intention to emigrate. The plan to migrate considerably varies with gender, age, education, income, and other features. Men and persons below age 44 are more likely to express an intention to emigrate. Persons between 15 and 24 years old express a greater desire to migrate, but they are less likely to be making preparations (32%) than those aged 25-44 (41%). Intention to emigrate strongly depends on the education level. The share of persons with high levels of education who would like to migrate (19%) is ten percentage points higher than that of persons with low levels of education. More top educated persons are also more likely to be actively preparing their emigration. Labor market outcomes and job opportunities in the home country are also important factors determining potential emigration intention. Persons who are "employed at capacity," that is those who are either working full-time or are employed part-time, but they do not wish to work full-time, are less likely to express their wish to emigrate than those who are either under-employed or unemployed (13% versus 21%). However, persons who are "employed at capacity" are more likely to be actively preparing their emigration (40% versus 33%). Among the employed, persons in professional occupations are more likely to report their desire to emigrate (19%) than those in other professions (14%), and they are also more likely to have started making preparations. The intention to emigrate is positive correlates with the income level. 12% of persons in the lowest income quintile report their desire to emigrate, versus 17% for those in the highest quintile. Moreover, wealthier individuals are more likely to have already started preparing their emigration. Migrant networks also play an essential role in people's decision to emigrate. Those correlations between income, education, age, and intentions to migrate indicate nature of selection for migration. In general, the evidence on the plan to emigrate suggests that the persons who are young, highly educated, wealthier are more likely to migrate.

We document some evidence for the emigrants' characteristics using information in Database on Immigrants in OECD and non-OECD Countries (DIOC-E). This dataset contains 100 destination countries and more than 200 countries of origin. It includes information on demographic characteristics (age and gender), duration of stay, labor market outcomes (labor

Table 2: Persons who wish, plan and make preparations to emigrate among different population groups, 2007-2013

	Desire to migrate	Of which: Plan to move in the next 12 months	Of which: Making preparations
Gender			
% among men	15	10	37
% among women	12	8	35
Age			
% among 15-24	22	10	32
% among 25-44	14	10	41
% among 45-64	9	6	36
% among 65+	5	7	42
Education			
% among low-educated	9	9	30
% among median-educated	18	9	36
% among highly-educated	19	10	54
Employment status			
% among employed at capacity	13	8	40
% among underemployed/unemployed	21	13	33
% among not in workforce	12	8	35
Employment			
% among professionals	19	9	49
% among others	14	9	38
Networks			
% among those who have someone to count on in another country	27	15	43
% among those who have no one to count on in another country	11	6	25
Income			
% among the poorest 20%	12	8	29
% among the second 20%	13	9	33
% among the middle 20%	13	8	31
% among the fourth 20%	15	9	42
% among the richest 20%	17	11	45

Notes: The population of reference is adult population aged 15 and above. Gallup classifies respondents as "employed at capacity" if they are employed full-time or are employed part-time but do not want to work full-time. Respondents are "underemployed" if they are employed part-time but want to work full-time. *Source*: Gallup World Poll Survey 2007-2013. *Table Source*: Connecting with Emigrants by OECD (2012)

market status, occupations, sectors of activity), fields of study, educational attainment and the place of birth, which makes it possible to calculate emigration rates by skill level. The limitation of this dataset is that it only contains information around 2000/01, 2005/06, and 2010/11, so it would be impossible for us to get time series information. Another limitation particular to our paper is that although the sources for DIOC-E 2010 are primarily census data from the 2010 round, which spans 2005-2014, the majority of the data were recorded at the turn of the decade. It means that we could not get the same detailed information for the years after 2012 for most countries. Nevertheless, we could still get some information on the profile of emigrants.

We focus on emigration rate using 2010/2011 dataset. Emigration rates show the extent of emigration to the population of the country of origin. The total emigration rate of the OECD area is 4.1%. Ireland has the highest emigration rate (17.4%) of all OECD countries. Portugal has a relatively high emigration rate of 15.4%. Countries with the lowest emigration rates (less than 1%) were the United States and Japan. By comparing the emigration rate of highly skilled and the total emigration rate, we can infer whether emigrants have higher or lower human capital than locals. Table 3 shows the emigrants characteristics of Spain. For OECD and selected non-OECD destinations, the total emigration rate is 2.3%, and emigration rate of the highly educated is 2.7%. For OECD destinations, the emigration rate of the highly educated is 2.4%, which is higher than the total emigration rate (1.9%). Appendix A.3 provides information for more OECD countries. For the majority of OECD countries, the emigration rate of the highly skilled is usually higher than the total emigration rate. It reflects the selective nature of migration because of migration costs and immigration policies. For other non-OECD countries, the difference between total and high-skilled emigration rates is even more enormous. Sub-Saharan Africa, for example, 13% of all highly educated persons emigrate. It reflects the problem of "brain drain" for some countries.

Table 3: Emigrants of Spain, 2010/11

	OECD and selected non-OECD destinations			OECD destinations		
	Men	Women	Total	Men	Women	Total
Emigrant population (thousands)	424.4	494.6	919.0	350.1	417.7	767.8
15-24 (%)	6.1	5.7	5.9	6.7	6.2	6.4
25-64 (%)	62.3	57.4	59.7	67.0	62.0	64.3
65+ (%)	31.5	36.9	34.4	26.2	31.8	29.3
Total emigration rates (%)	2.1	2.4	2.3	1.8	2.0	1.9
Emigration rates of the highly educated (%)	2.7	2.7	2.7	2.3	2.5	2.4

Data Source: Database on Immigrants in OECD and non-OECD Countries (DIOC-E) 2010/11.

Although there are significant variations among countries for the profile of emigrants, it is necessary to consider the potential effects that emigration could have. Emigration of young and highly educated persons signifies a loss of valuable workforce, which could negatively affect economic growth and development. This loss is not only in the current period but also in the long run. Emigration of youth also accelerates aging, which is critical especially for countries facing rapid population aging.

In Figure 3, we plot an effective emigration rate by considering the education levels of emigrants. We define effective emigration rate as $(wE_H + E_L)/(H + L)$, where E_H is the number of high-skilled workers who migrate out and E_L is the number of low-skilled emigrants. $(H + L)$ is the total population in the country. w is the wage premium of high-skilled workers. We use 80th percentile of the whole wage distribution as the proxy for the wage of high-skilled and 20th percentile as the proxy for the wage of low-skilled following Grogger and Hanson (2011). The wage premium is the ratio between the wage of the high-skilled and that of low-skilled. The effective emigration rate is higher than the emigration rate, echoing the fact that higher educated workers are more likely to emigrate.

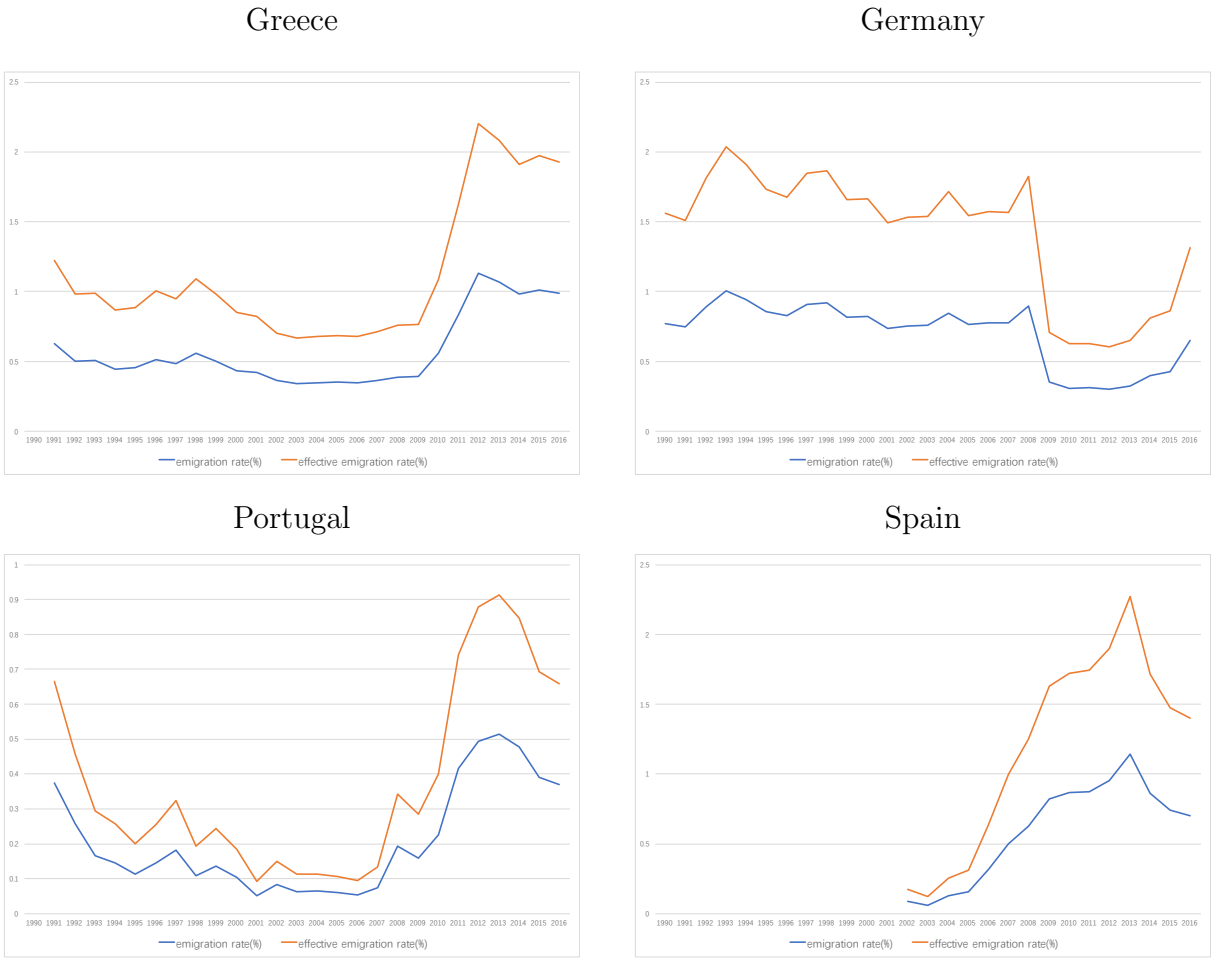


Figure 3: Effective Emigration Rate

Notes: Calculated by authors. The effective emigration rate is $(wE_H + E_L)/(H + L)$, where E_H is the number of high-skilled emigrants and E_L is the number of low-skilled emigrants. $(H + L)$ is the total population in the country. w is the wage premium of high-skilled workers. We use 80th percentile of the whole wage distribution as the proxy for the wage of high-skilled and 20th percentile as the proxy for the wage of low-skilled. The wage premium is the ratio between wage of the high-skilled and that of low-skilled.

3 Model

To understand how migration interacts with sovereign default risk and recession, we build a sovereign default model with endogenous migration choice. We consider a small open economy. There are L workers who consume and work. The number of workers may change due to migration. The government is benevolent. It can issue state-uncontingent bond internationally and may default. Default comes with the cost of productivity losses $z_d(z) \leq z$. With probability λ, the defaulted government can resume international borrowing and lend-

ing. The government puts capital controls and only it can borrow and lend internationally. There are no government spending or distortionary taxes. All government revenue transfer to consumers in a lump-sum fashion.

There is a measure one of the firms in the government, who produce with productivity z, capital K and labor L with production function: $Y = zK^{\alpha}L^{1-\alpha}$. In the following subsections, we will first describe the timing of our model and then describe the workers' problem and the government's problem respectively.

3.1 Timing

Let B be the aggregate public debt. The state variable of the economy is $S = (z, K, L, B, h)$ where $h = 0$ denotes normal phase, $h = 1$ denotes penalty phase, which means the government defaulted and hadn't been forgiven by lenders. Denote idiosyncratic migration cost shock of workers by δ_m. We omit the time subscript t to simplify notation, and we use x' to denote variable x in the next period. After illustrations on the notations, the timing of the model is as follows:

- At time t, aggregate shock z and idiosyncratic shock δ_m for each household realized.
- Households decides on whether to emigrate based on z and δ_m. The aggregate state in this stage is (S, h) where $S = (z, K, L, B)$. Each household's state is $s^h = (S, h, \delta_m)$. After the migration choice, the total population becomes L'.
- At the beginning of period $t + 1$, the households have made their migration choices. The state variable is $\tilde{S} = (z, K, L', B)$ for the government. The government in the normal phase chooses whether to default, new investment and new borrowings. The government in the penalty phase chooses the new investment.

3.2 Migration Choice

Consider a representative worker. The worker chooses whether to stay or migrate to another country by maximizing the value of staying in the home country and the value of emigration. If staying in the home country, the worker receives transferred consumption from the government every period. If moving to other countries, the worker gets utility from other countries, but have to pay an idiosyncratic migration cost. The value of a worker is:

$$W(S, h, \delta_m) = \max\{W^s(S, h), \quad W^m - \delta_m\}$$

where W^s denotes the value if stays in the home country and W^m the value if he or she migrates to another country. δ_m is the cost of migration, which has exponential distribution over workers: $F(x) = 1 - e^{-\zeta_m x}$. If the worker stays in the home country, her value function is:

$$W^s(S,h) = \{u(c(S,h)) + \beta EW(S', h', \delta'_m)\}$$

Where $c(S,h)$ is the consumption transferred by domestic government. If the worker migrates, she gets utility in the foreign country in that period and every period after. We assume the foreign country value is constant and is given by W^m.

For a worker, she will choose to stay in the home country if and only if:

$$W^s(S,h) \geq W^m - \delta_m$$

Otherwise she will migrate to another country. The probability of staying in the home country is given by:

$$Pr(\delta_m \geq W^m - W^s(S,h)) = e^{-\zeta_m(W^m - W^s(S,h))}$$

Thus, the measure of workers at the beginning of next period is given by :

$$L'(S,h) = e^{-\zeta_m(W^m - W^s(S,h))}L$$

3.3 Government

The government owns the firms and makes default and borrowing decisions. Government transfers all revenue to the workers within the country. The government in the normal phase chooses whether or not to default to maximize the stayers' welfare:

$$V(z,K,L',B) = \max\left\{V^c(z,K,L',B), V^d(z,K,L')\right\}$$

where V^c denotes the non-defaulting value and V^d the default value. Let $D(z,K,L',B) = 1$ denote default.

If not default, the government can choose both investment and new international borrowings B' by solving the following problem:

$$V^c(z,K,L',B) = \max_{C,B',K'} \quad L'u\left(\frac{C}{L'}\right) + \beta E[V(z',K',L''(z',K',L',B'),B')]$$

subject to the budget constraint and law of motion of labor:

$$C + B = zK^\alpha(L')^{1-\alpha} - K' + (1-\delta)K - \frac{\theta}{2}\left(\frac{K'}{K} - 1 + \delta\right)^2 K + Q(z,K',L',B')B',$$

$$L''(z', K', L', B') = e^{-\zeta_m(W^m - W^s(z', K', L', B', h'))} L'$$

where $Q(z, K', L', B')$ is the bond price. If default, the economy suffers a loss in productivity from z to z_d and enters into penalty phase. The government can't borrow internationally and can only choose investment to maximize stayers' utility. With probability λ, the government comes back to the international borrowing market. The default value is given by:

$$V^d(z, K, L') = \max_{C_d, K'} L' u\left(\frac{C_d}{L'}\right) + \beta E[\lambda V(z', K', L''_0, 0) + (1-\lambda) V^d(z', K', L''_1)]$$

subject to

$$C_d = z_d(z) K^\alpha (L')^{1-\alpha} - K' + (1-\delta)K - \frac{\theta}{2}\left(\frac{K'}{K} - 1 + \delta\right)^2 K,$$

$$L''_0 = e^{-\zeta_m(W^m - W^s(z', K', L', 0, h=0))} L',$$

$$L''_1 = e^{-\zeta_m(W^m - W^s(z', K', L', h=1))} L'$$

where C_d is the consumption under penalty phase, $L''_0 = e^{-\zeta_m(W^m - W^s(z', K', L', 0, h=0))} L'$ is the law of motion of labor in normal phase and $L''_1 = e^{-\zeta_m(W^m - W^s(z', K', L', h=1))} L'$ is the law of motion in penalty phase.

3.4 International financial intermediary

The competitive financial intermediaries charge bond price to break even,

$$Q(z, K', L', B') = \frac{1}{1+r} E[1 - D(z', K', L''(z', K', L', B'), B')]$$

where $D(z, K, L', B) = 1$ denotes default.

3.5 Transformed problem: per-capita term

We want to show that the solution in the benchmark economy is the same as the following transformed problem, all in per capita terms. For a variable X, we define the per-capita term as

$$x = \frac{X}{L}$$

Suppose the worker's welfare is given by

$$u(c) = \frac{c^{1-\sigma}}{1-\sigma}$$

Let the state be (s, h) with $s = (z, k, b)$ where k and b is per-capita capital and debt respectively.

Worker's transformed problem The value of a worker is:

$$w(s,h,\delta_m) = \max\left\{w^s(s,h), \quad w^m - \delta_m\right\}$$

If the worker stays in home country, his value function is:

$$w^s(s,h) = \frac{c^{1-\sigma}}{1-\sigma} + \beta E w(s',h',\delta_m')$$

The growth rate of measure of workers is then given by:

$$g(s,h) = e^{-\zeta_m(w^m - w^s(s,h))}$$

Government's transformed problem The government first chooses whether or not to default depending on the per-capita value of not defaulting $v^c(s)$ and defaulting $v^d(s)$, i.e.

$$v(s) = \max\left\{v^c(s), v^d(z,k)\right\}$$

Let the default decision be $d(z,k,b) = 1$ if $v^c(s) < v^d(z,k)$. The repaying value is given by

$$v^c(s) = \max_{c,b',k'} \quad g(s,0)\left[\frac{c^{1-\sigma} g(s,0)^{\sigma-1}}{1-\sigma} + \beta E v(s')\right]$$

subject to

$$c + b = z k^\alpha g(s,0)^{1-\alpha} - \left[g(s,0)k' - (1-\delta)k + \frac{\theta}{2}\left(\frac{k' g(s,0)}{k} - 1 + \delta\right)^2 k\right] + q(z,k',b') g(s,0) b'$$

The defaulting value is given by

$$v^d(z,k) = g(s,h)\left[\frac{c_d^{1-\sigma} g(s,h)^{\sigma-1}}{1-\sigma} + \beta E[\lambda v(z',k',0) + (1-\lambda) v^d(z',k')]\right]$$

subject to

$$c_d = z_d(z) k^\alpha g(s,h)^{1-\alpha} - \left[g(s,h)k' - (1-\delta)k + \frac{\theta}{2}\left(\frac{k' g(s,h)}{k} - 1 + \delta\right)^2 k\right]$$

where $g(s,h) = g(s,0)$ if the government defaults in the current period, i.e. $h = 0$ and $d = 1$; $g(s,h) = g(s,1)$ if the government defaulted in the previous periods and is still in the penalty phase.

Bond price schedule

$$q(z,k',b') = \frac{1}{1+r} E\left[1 - d(z',k',b')\right]$$

3.6 Equivalence

We show that the per-capita solution implied by the benchmark economy is equivalent to the solution in the transformed problem. Recall that $S = (z, K, L, B)$ and $s = (z, k, b)$ with $k = K/L$ and $b = B/L$. We claim the following relations hold:

$$\frac{L'}{L} \equiv g(S,h) = e^{-\zeta_m(w^m - W^s(S,h))} = e^{-\zeta_m(w^m - w^s(s,h))} \equiv g(s,h)$$

$$\frac{1}{L}V(z,K,L'(S),B) = v(s)$$
$$\frac{1}{L}V^c(z,K,L'(S),B) = v^c(s)$$
$$\frac{1}{L}V^d(z,K,L'(S)) = v^d(z,k)$$
$$D(z,K,L'(S),B) = d(z,k,b)$$
$$W^s(S,h) = w^s(s,h)$$
$$Q(z,K',L'(S),B') = q\left(z, \frac{K'}{L'(S')}, \frac{b'}{L'(S')}\right) = q(z,k',b')$$
$$c(s) = c(S)$$

Note that

$$\frac{K'}{L} = \frac{K'}{L'}\frac{L'}{L} = k'e^{-\zeta_m(W^m - W^s(S,h))} = k'e^{-\zeta_m(w^m - w^s(s,h))} = k'g(s,h)$$

Divide L for both sides of the default decision:

$$V(z,K,L'(S),B) = \max\left\{V^c(z,K,L'(S),B), V^d(z,K,L'(S))\right\}$$

$$\frac{1}{L}V(z,K,L'(S),B) = \max\left\{\frac{1}{L}V^c(z,K,L'(S),B), \frac{1}{L}V^d(z,K,L')\right\}$$

which implies

$$v(z,k,b) = \max\left\{v^c(z,k,b), v^d(z,k)\right\}$$

Thus the default decisions satisfy

$$D(z,K,L'(S),B) = d(z,k,b)$$

Divide L for both sides of the non-defaulting value:

$$V^c(z,K,L',B) = L'u\left(\frac{C}{L'}\right) + \beta E[V(z',K',L''(z',K',L',B'),B')]$$

$$\frac{1}{L}V^c(z,K,L',B) = \frac{L'}{L}u\left(\frac{C}{L'}\frac{L}{L}\right) + \beta\frac{L'}{L}\frac{1}{L'}E[V(z',K',L''(z',K',L',B'),B')]$$

$$\frac{1}{L}V^c(z,K,L',B) = g(s,h)u\left(cg(s,h)^{-1}\right) + \beta g(s,h)\frac{1}{L'}E[V(z',K',L''(z',K',L',B'),B')]$$

$$\frac{1}{L}V^c(z,K,L',B) = g(s,h)\frac{c^{1-\sigma}g(s,h)^{\sigma-1}}{1-\sigma} + \beta g(s)\frac{1}{L'}E[V(z',K',L''(z',K',L',B'),B')]$$

which implies

$$v^c(z,k,b) = g(s,h)\left[\frac{c^{1-\sigma}g(s,h)^{\sigma-1}}{1-\sigma} + \beta E[v(z',k',b')]\right]$$

Divide L for both sides of budget constraint:

$$\frac{C}{L} + \frac{B}{L} = \frac{1}{L}zK^{\alpha}(L')^{1-\alpha} - \frac{K' - (1-\delta)K + \frac{\theta}{2}\left(\frac{K'}{K} - 1 + \delta\right)^2 K}{L} + \frac{Q(z,K',L',B')B'}{L}$$

which implies

$$c + b = \quad zk^{\alpha}g(s,h)^{1-\alpha} - \left[g(s,h)k' - (1-\delta)k + \frac{\theta}{2}\left(\frac{g(s,h)k'}{k} - 1 + \delta\right)^2 k\right] + q(z,k',b')g(s,h)b'$$

Finally, for bond price schedule, we have:

$$\begin{aligned} Q(z,K',L'(S),B') &= \frac{1}{1+r}E\left[1 - D(z',K',L''(S'),B')\right] \\ &= \frac{1}{1+r}E\left[1 - d(z',k',b')\right] \\ &= q(z,k',b') \end{aligned}$$

4 Quantitative Results

4.1 Parameterization

We set the length of a period to one year. The preference is given by $u(c) = \frac{c^{1-\sigma}}{1-\sigma}$. The productivity loss after default take a form similar to that in Chatterjee and Eyigungor (2012): $z_d(z) = z - \max\left\{\chi_1 z + \chi_2 z^2, 0\right\}$. The investment is: $i(s,h) = g(s,h)k' - (1-\delta)k + \frac{\theta}{2}\left(\frac{g(s,h)k'}{k} - 1 + \delta\right)^2 k$, where $\frac{\theta}{2}\left(\frac{g(s,h)k'}{k} - 1 + \delta\right)^2 k$ is the quadratic capital adjustment cost. Finally, the productivity shock z follows an AR(1) process:

$$\log(z_t) = \rho_z \log(z_{t-1}) + \eta_z \varepsilon_t$$

where ϵ has a standard normal distribution.

There are two groups of parameters. The first is taken directly from the literature, and the second group of parameters is jointly chosen to match empirical moments (see Table 4). The first set of parameters includes $\{\alpha, \delta, \sigma, \lambda, r\}$. We set the capital share α to 0.34,

Table 4: Calibration

Parameter	Benchmark	Target	Realized
Assigned parameters			
Capital share α	0.34	National accounts	
Capital depreciation rate δ	0.08	Standard business cycle model	
Risk aversion σ	2	Standard business cycle model	
Risk-free rate r	4%	Standard business cycle model	
Return probability λ	0.25	Gelos et al. (2011)	
Moment-matching parameters		*Spanish Data*	
Productivity persistence ρ_z	0.9	Spanish Data, 1980-2017	
Productivity volatility η_z	0.016	Spanish Data, 1980-2017	
Discount factor β	0.8	mean(spread)=3.0%	3%
Penalty parameter χ_1	-0.78	vol(spread)=2.8%	2.2%
Penalty parameter χ_2	0.85	vol(c)/vol(y)=0.96	0.96
Capital adjustment cost θ	3.8	vol(i)/vol(y) = 3.5	4.9
Migration cost distribution ζ_m	0.01	vol(net migration rate)=0.6%	0.25%
Exogenous inflow $\bar{m}$	0.076	mean(net migration rate)=0.38%	0.36%

and the depreciation rate is 8% annually, which is standard. We set the risk aversion σ to 2 and the yearly net risk-free rate r to 4%. The return parameter λ is chosen to be 0.25 so that defaulting countries are excluded from financial markets for four years, consistent with Gelos, Sahay, and Sandleris (2011). The second group of parameters includes eight parameters: productivity process ρ_z and η_z, the discount factor β, the default cost parameters χ_1 and χ_2, capital adjustment cost θ, and the migration parameters ζ_m and $\bar{m}$. Productivity parameters are calculated from Spanish data. Other parameters are jointly calibrated to target the following moments: the mean spread of 3%, the volatility of spread of 2.8%, the relative consumption volatility of 0.96, the relative investment volatility of 3.5, volatility of net migration rate of 0.6% and the mean of net migration rate of 0.38%. Most moments are closely matched.

Our model characterizes an interplay between workers and the government. The migration decision of workers will change the number of workers in the next period, and the default decision of the government will enter into the migration decision of workers. Appendix C details the computational algorithm employed to solve for the model's equilibrium.

4.2 Bond Spread and Capital Inflows

To illustrate the model mechanisms, we start by presenting how the bond spread changes with productivity, bond level, and capital shock. Then we show that high default risk limits capital inflows and migration accompanied with higher default risk further restricts capital inflows.

In our model, given a shock realization this period of z, each combination of levels of per-capita borrowing and capital choices is associated with a different bond price, encoded in the bond price function $q(z, k', b')$. Spread is defined as the inverse of bond price schedule relative to the risk-free rate, $sp = 1/q(z, k', b') - (1 + r)$. Figure 4 plots the bond spread as a function of bond with different levels of productivity and capital. The solid blue line plots for median productivity and median capital. The dash-dot orange line plots for low productivity and median capital and the dotted green line plots for median productivity and low capital. Spread increase in the borrowing level. The bond spread is higher when productivity is low or when capital stock is low. Lower productivity or lower capital stock associated with a lower debt repayment capacity, which increases default risk today.

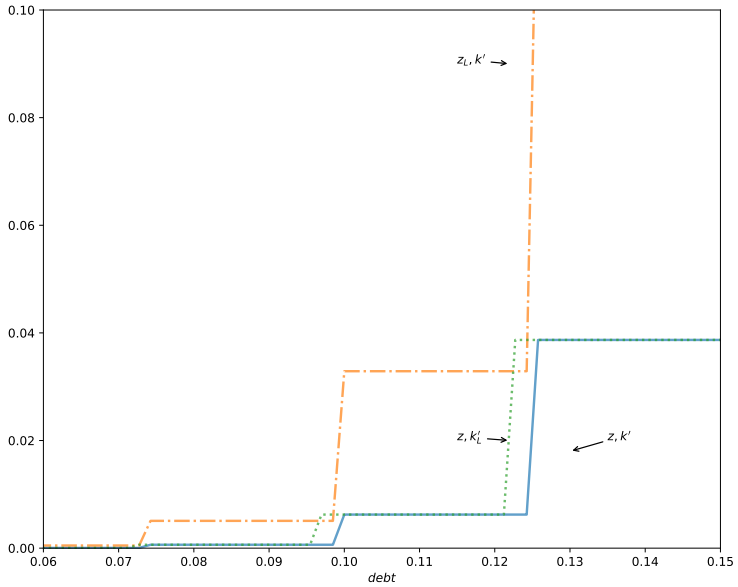


Figure 4: Bond Spread Schedule

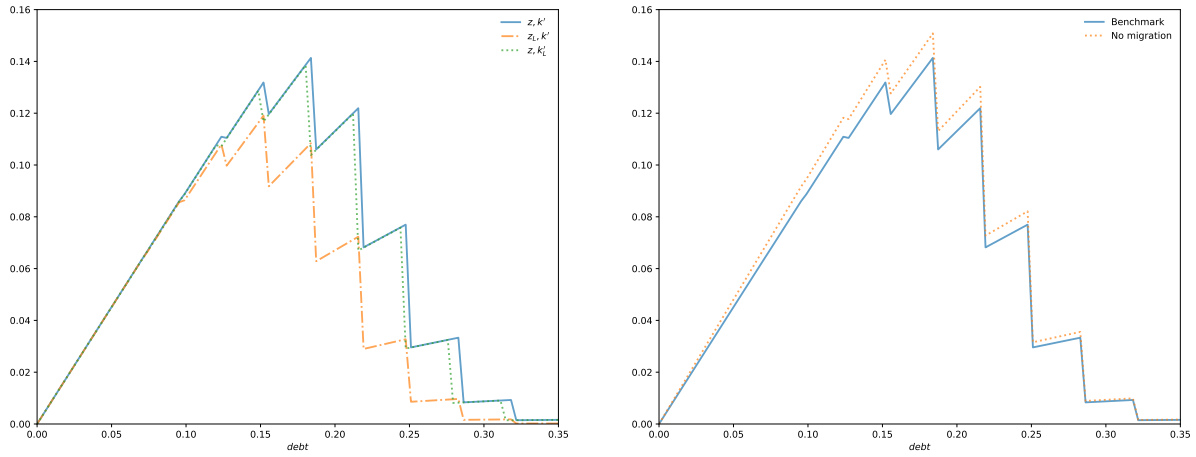
Notes: The x-axis is debt level, and the y-axis is the bond spread. The solid blue line plots for median productivity and median capital. The dash-dot orange line plots for low productivity and median capital and the dotted green line plots for median productivity and low capital.

Given a negative shock, the debt burden of the sovereign is higher than the model without migration choice. Recall the budget constraint of the government in normal phase:

$$c+b = zk^{\alpha}g(s,0)^{1-\alpha} - \left[g(s,0)k' - (1-\delta)k + \frac{\theta}{2}\left(\frac{k'g(s,0)}{k} - 1 + \delta\right)^2 k\right] + q(z,k',b')g(s,0)b'$$

where $s = (z,k,b)$ and $g(s,0)$ is the probability of staying in the home country. When more workers leave, $g(s,0)$ goes down. It decreases the amount of borrowing the sovereign could get in the current period $q(z,k',b')g(s,0)b'$.

In Figure 5, we plot the capital inflow schedule $q(z,k',b')g(s,0)b'$. Capital inflows are restricted by default risk and bounded by the peak of the Laffer curve. Panel (a) of Figure 5 plots the capital inflows schedule under different levels of productivity and capital. Again, the solid blue line plots for median productivity and median capital. The dash-dot orange line plots for low productivity and median capital and the dotted green line plots for median productivity and low capital. Lower productivity and lower capital associated with higher default risk, which restricts capital inflows. Panel (b) plots the capital inflows for our benchmark and the *no-migration* reference model. Without migration choice, the maximum capital inflows are larger. It means that emigration accompanied with higher default risk further restricts capital inflows.



(a) Capital Inflows (b) Benchmark and Reference Model

Figure 5: Capital Inflows Schedule

Notes: The x-axis is debt level, and the y-axis is the capital inflows schedule. Panel (a) plots capital inflows under different productivity and capital. Panel (b) plots for our benchmark model and a reference model without migration.

4.3 Impulse Responses: Benchmark

We now describe the time series dynamics of our model by presenting impulse response functions of aggregates to a negative productivity shock. We simulate 3,000 paths for the model for 500 periods. From periods 1 to 400, the productivity shock follows its underlying Markov chains so that the cross-sectional distribution of debt and capital converges to the limiting distribution of endogenous states. In period 401 (period 1 in the plots), we introduce a negative productivity shock. From period 401 on, the productivity shocks follow the conditional Markov process. The impulse responses plot the average, across the 3,000 paths, of the variables conditional on the economy not defaulting.

Figure 6 plots the impulse responses to the productivity declines for the productivity z, spread, capital, GDP, consumption, and growth rate of population. Panel (a) shows the productivity falls for 2.3%. After the impact period, the shock follows its Markov process. Panel (b) shows that the spread increases from 2.7% to 3.4% on impact following the decline in productivity. Panel (c) plots the impulse response for per-capita capital. It falls for 3.2% on impact and continues to be depressed for more than 20 periods. In Panel (d), we plot the response for per-capita GDP and aggregate GDP. Aggregate GDP decrease for 3.3% and recovers very slowly. After 20 periods, aggregate GDP is still more than 2% below the mean. Here aggregate GDP is more persistent because of the novel migration channel. In a model without migration, per-capita GDP changes coincide with aggregate GDP changes. Per capita consumption falls for 4.9% in Panel (e), and the growth rate of the population decreased for 0.15% in Panel (f).

Figure 6 shows that our model generates a sizeable endogenous persistence. Sizeable persistence generates even if there's no capital adjustment cost for two reasons. First, the financial frictions that arise in the model because of default risk make recessions more persistent. When there's a negative productivity shock, financial frictions tighten, and the economy reduces investment in response to lower external financing. Second, with endogenous migration choice, workers emigrate more when the productivity is low. Emigration increases the debt burden of the sovereign, leading to further reduction of investment.

4.4 Impulse Responses: Reference Models

We assess the endogenous amplification that our model generates by comparing its dynamics to two reference models. The first reference model is a *no-migration* reference model, where endogenous migration choice is not allowed. We re-calibrate the model to match the

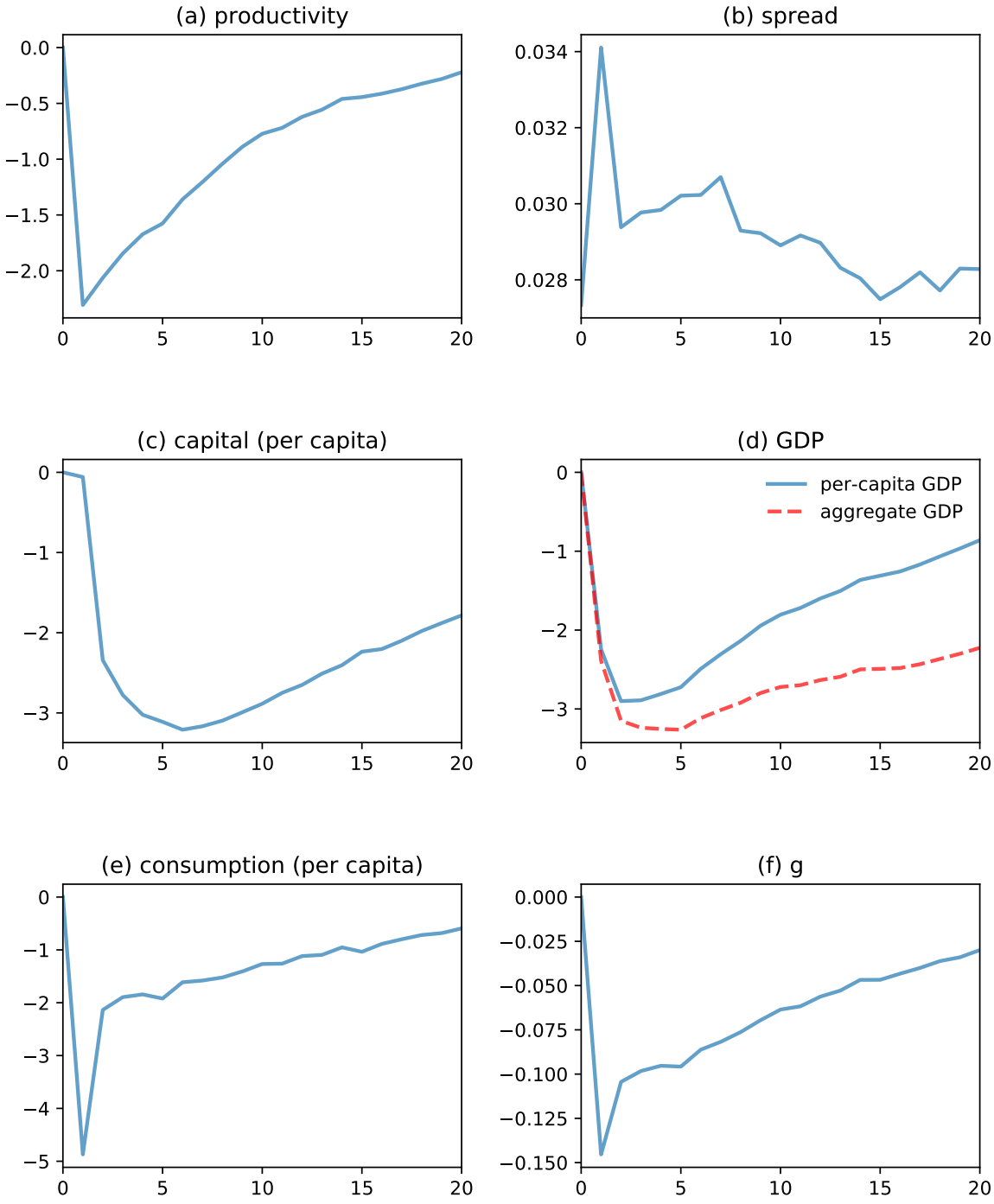


Figure 6: Impulse Response Functions to a Decline in Productivity

Notes: The x-axis is time, and the y-axis presents for percentage changes except for spread.

average spread in the benchmark model. The second reference model is *no-default*. In this reference model, we further shut down the default risks. By comparing the *no-default* model and the *no-migration* model, we know how much default risks contribute to the recession. The *no-migration* reference model mimics the classical model in standard sovereign default literature where there are default risks but does not consider migration. By comparing the *no-migration* model and the *benchmark* model, we can figure out how much migration channel contributes to the recession.

We found that our benchmark model generates a large endogenous amplification of shocks relative to two reference models. In Figure 7, we plot the impulse response functions for the spread, capital, GDP, consumption and population growth rate to a decline in productivity for three models. The orange dashed lines show for the *no-default* model which features no default and no migration. The green dotted lines show for the *no-migration* model which embeds default risks compared with the no-default model. The solid blue lines plot the responses of the *benchmark* model, in which both default risks and migration choices are allowed. We re-calibrate the no-migration model to make it have the same average spread as in the benchmark model. Following a one standard deviation decline of productivity, the spread goes up except in the no-default model. Capital decreases for 1.2% in the no-default model, drops for 2.1% in the no-migration model, and falls the most (3.2%) in the benchmark model. Both no-migration and no-default models have a much more muted and less persistent recession than the benchmark model. The decline of per capita GDP in the benchmark model is 0.4% larger than that in the no-migration model and 0.6% larger in the no-default model. Until 20 periods after the shock, the fall in aggregate GDP in the benchmark model is still 2.3 times the decline in the no-migration model and 2.8 times the decline in the no-default model.

Figure 8 plots the impulse response functions to a one-period exogenous decline in population. We compare the benchmark model with a model that allows for migration but with no default. In both two models, we decrease g for 0.5% in period 1. In the benchmark model, the decline in the population increases the default rate, leading to lower debt. It depresses investment, leading to a decrease in GDP.

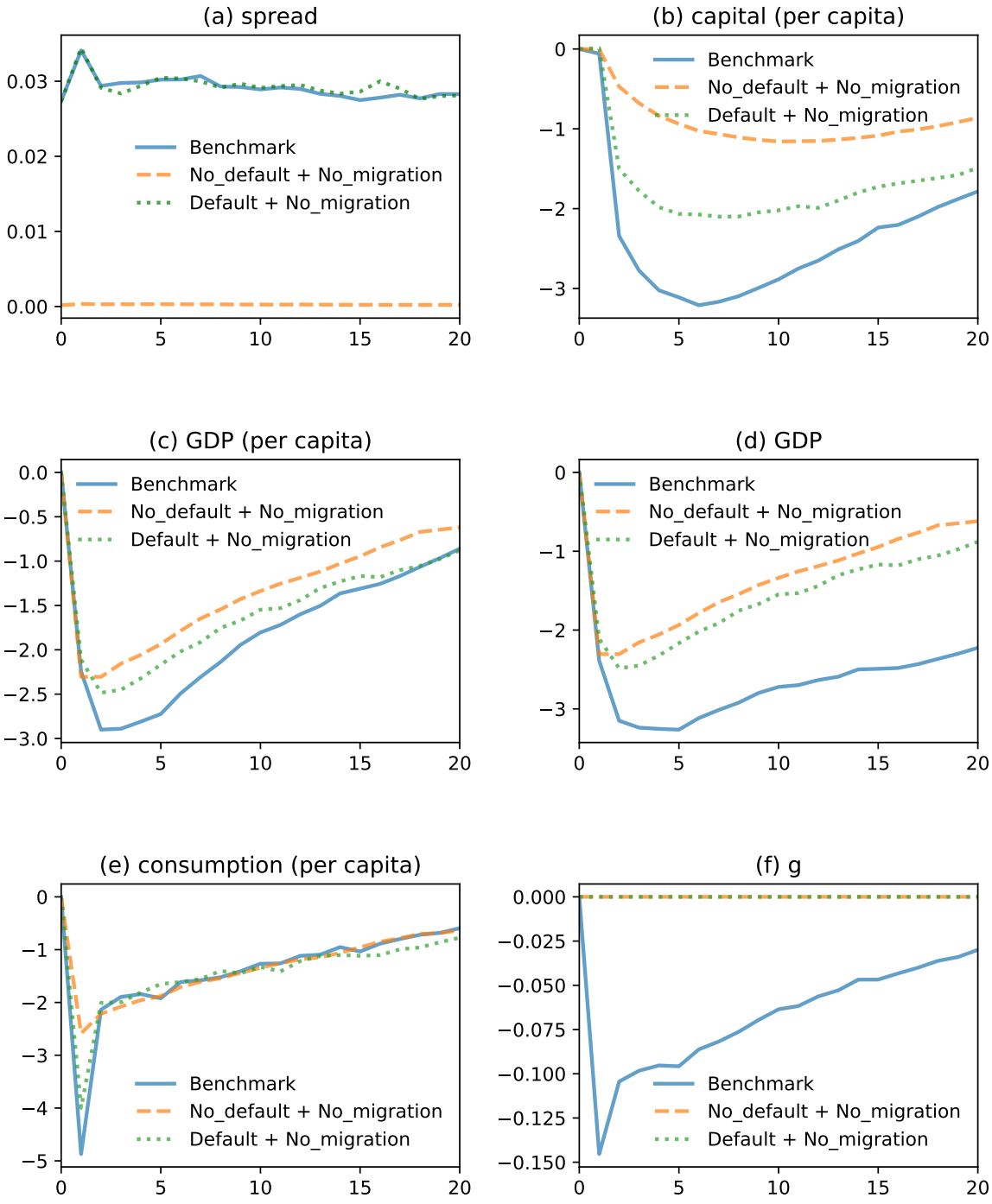


Figure 7: Impulse Response Functions to a Decline in Productivity: Benchmark and Reference Models

Notes: Impulse response functions to a decline in productivity in benchmark model and reference models. The solid line, dashed line and dotted line presents for benchmark model, no default model and no migration model respectively.

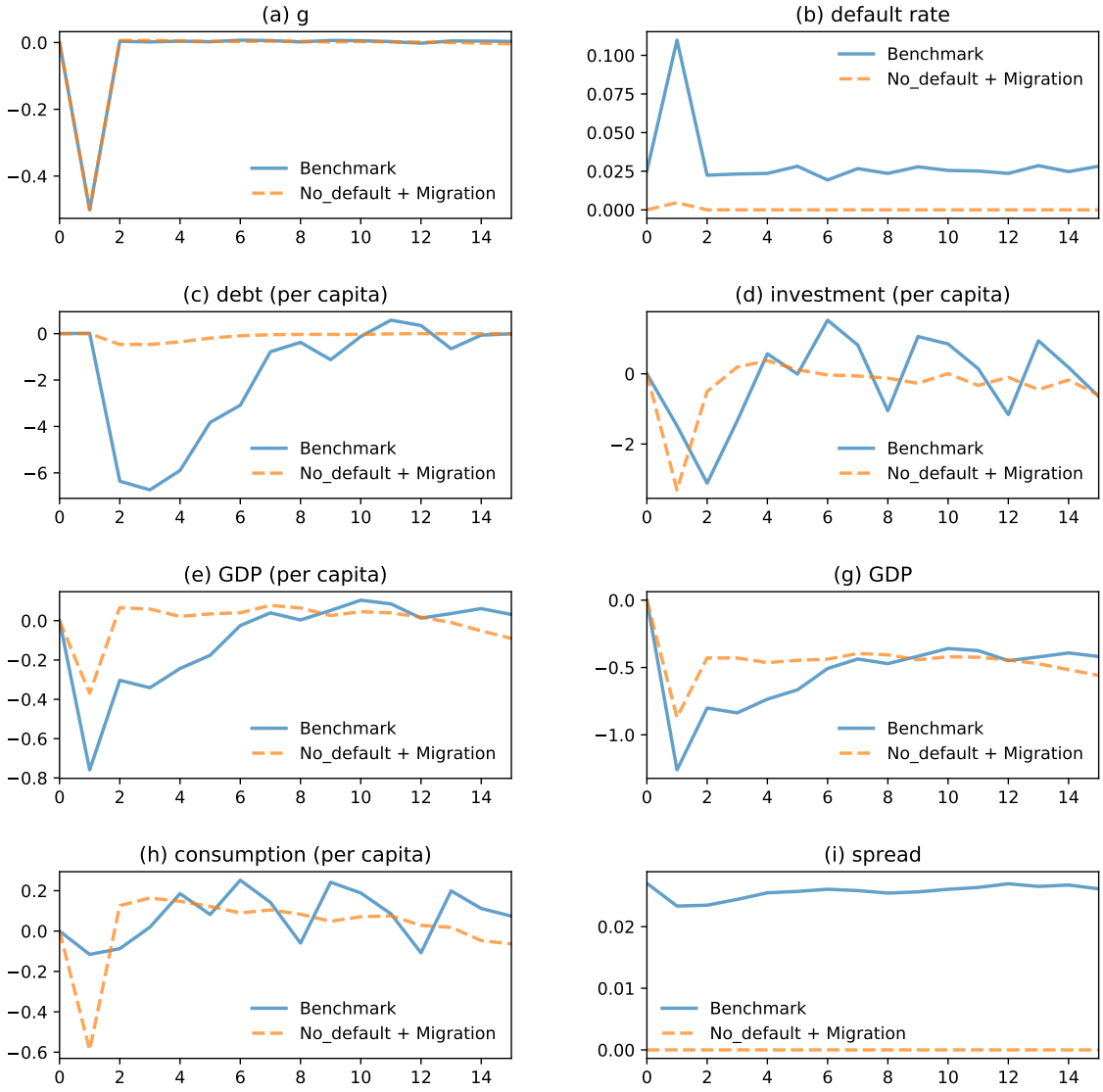


Figure 8: Impulse Response Functions to One-period Decline in Population

Notes: Impulse response functions to a one-period decline in population. The solid blue presents for the benchmark model. The dashed orange line shows for a model allows for migration, but there's no default risk.

5 Event Analysis for Spain

5.1 Recession in Spain

Began in 2008 during the financial crisis of 2007–08, Spain experienced an economic downturn. In 2012, it made Spain a late participant in the European sovereign debt crisis when the country was unable to bail out its financial sector and had to apply for a 100 billion Euros rescue package provided by the European Stability Mechanism (ESM). Figure 9 plots recession in Spain using real GDP data. We fit a log-linear trend over 1995-2008 and then extrapolate. It shows a massive output loss that persists for a long time. In the previous section, we have demonstrated that the interaction between default risk and migration provides a powerful channel in explaining the depth and persistence of recession. In this section, we apply our model to Spanish data to understand and explain the persistent depression.

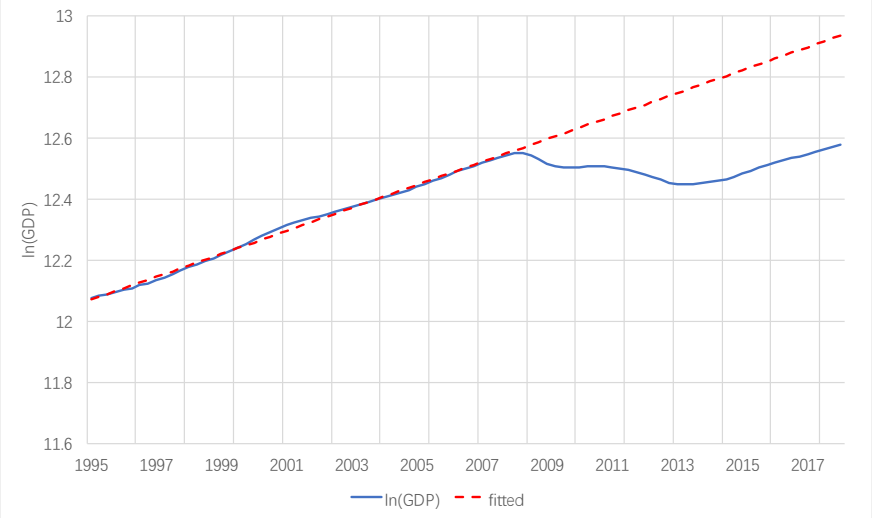


Figure 9: Recession in Spain

5.2 Migration in Spain

Migration Policy. During the process of European Union (EU) enlargement, labor migration issues have gained special attention. The Accession Treaty of 2003 (European Union (2003)) allowed the "old" member states to temporarily restrict (for a maximum of 7 years) the access to their labor markets to citizens from the accessing countries, except Malta and Cyprus. In 2006, Spain lifted restrictions on workers from EU-8 countries. Although we do not observe a huge net migration flow increase around 2006, the composition of the migrants by nationality indeed change[data here]. In general, immigration to Spain increased

significantly at the beginning of the 21st century.

Migration Flows. The recent debt crisis and the economic downturn has transformed migration patterns in Spain. Net outflows replaced impressive immigration boom which persists for years. Those leaving include both immigrants returning home or moving to a third country, and Spanish-born emigrants. Before the crisis, there's large scale immigration. The foreign-born population multiplied between 2000 and 2008, quadrupling from 1.5 million to 6 million. The primary driver of the immigration boom was the sustained economic growth between 1995 and 2007. In 2008, the financial crisis hit Spain and housing market collapse. Although immigration has not ceased, it has been overshadowed by the emigration by both immigrants and natives. Emigrants of native-born Spaniards has risen rapidly since 2010. Net migration was slightly negative in 2012, and more clearly contrary in 2013. Huge emigration captures public attention and calls for efforts to quantify its effects.

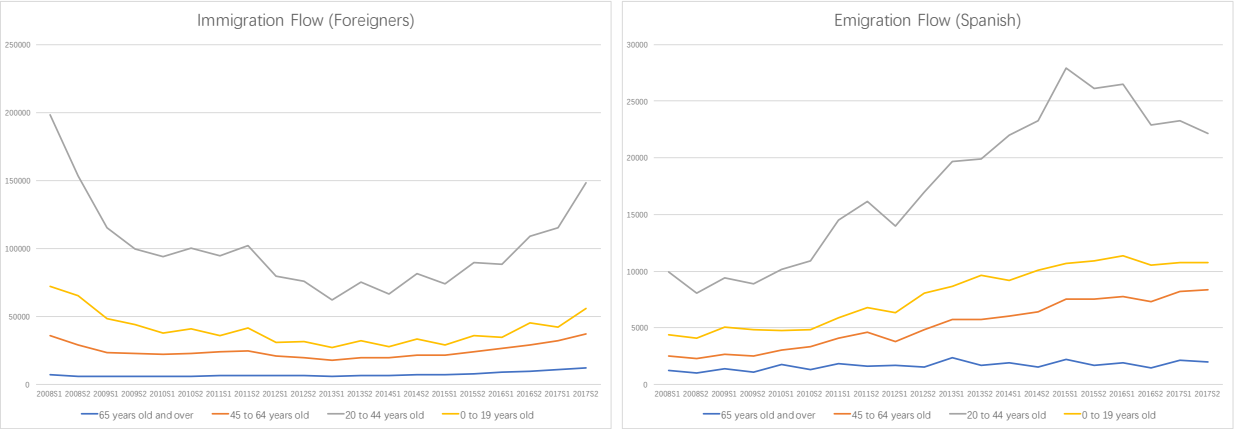
Though limited data on education levels of immigrants and emigrants, evidence from DIOC-E (also see Domingo and Sabater (2013)) suggests that most native-Spaniards who leave are ages 25 to 35 and are relatively higher-educated. The impact of emigration is not in one direction. For instance, some emigrants are jobless, and migration leads to an increase in remittances to Spain, which may benefit the labor market in Spain. In the following quantitative implications, we assume the average immigrant has the same level of human capital with the locals. If assuming the average immigrant is relatively higher-educated, our mechanism of the model is even more powerful in explaining the depth and persistence of recession.

Figure 10 shows migration flows of Spain from 2008 to 2017 by age group. Data is available from the National Statistics Institute after 2008. For both immigration and emigration, those who age 20 to 44 years old are the most active ones. The migration flows decrease in general for all age groups between 2008 and 2014, especially for people aged 20 to 44. Around debt crisis period, the emigration of young Spaniards has risen rapidly.

5.3 Model to Spanish Data

We now compare the quantitative implications of the model to Spanish data. We quantify our model against the peak-to-trough data in Spain during the debt crisis. We deflate the nominal output series with the GDP deflator and detrend the annual time series for GDP (1960-2013) by logging the series and filtering with the Hodrick-Prescott filter, using a smoothing parameter of 100.[1] Then we get 7.89% as the peak in 2008 and -4.57% as the

[1]GDP and deflator data are from the World Bank.



(a) Immigration Flows (b) Emmigration Flows

Figure 10: Inflows and Outflows of Spain

Notes: Migration flows of Spain by age group. Panel (a) shows immigration flows by foreigners and panel (b) shows emmigration flows by Spaniards. Unit is migratory flows. Data source: National Statistics Institute.

trough in 2012 during debt crisis. The spread is defined as the gap between government interest rate and that of Germany. The spread is 0.38% in 2008 and increased to 4.35% in 2012. The net migration rate is 0.95% in 2008 and becomes -0.3% in 2012.[2]

We conduct the numerical experiment in the model with a procedure similar to the impulse responses. We simulated 3,000 paths for 400 periods. We use the resulting limiting distribution of capital, debt, migration rate, and productivity shocks in period 400 as the initial condition for the event. We then feed in a path of shocks such that the conditional mean aggregate output of the model reproduces the path of Spanish GDP from 2003 to 2012. We choose the year 2003 as the start year because Spain's GDP in that year is close to the trend. The shocks during the event are parallel deviations across all the 3,000 paths.

We focus on the peak-to-trough dynamics of GDP, government spread, and net migration. Table 5 reports the difference in the time series between 2008 and 2012, with the corresponding levels of these two years, for the data and the model. In the data, GDP declines by 12.46%, varying from 7.89% above the trend and 4.57% below the trend. The government spread increases from 0.38% to 4.35% during 2008-2012. The net migration rate drops from 0.95% to -0.3%, turning Spain from a net inflow country to a net outflow country. The benchmark model generates a sizable decline in output and increase in government spread, and 35% of the decline in net migration during 2008-2012.

The event dynamics is driven by productivity shocks, endogenous financial frictions that

[2]The net migration rate troughs in 2013, with a value of -0.54%.

Table 5: Spain from 2008 to 2012

	GDP	gov spread	net migration
2008-2012 Difference (%)			
Data	-12.46	3.97	-1.25
Benchmark	-10.35	3.14	-0.43
2008 Levels (%)			
Data	7.89	0.38	0.95
Benchmark	6.13	0.66	1.01
2012 Levels (%)			
Data	-4.57	4.35	-0.3
Benchmark	-4.22	3.80	0.58

arise due to default risk, and endogenous migration choice, as well as the interaction between default risk and migration. To decompose the results into these forces and explore the role of migration channel, we contrast the performance of our model with the reference model without migration in the event. By comparing the results from the reference model to those from the benchmark model, we can evaluate the importance of migration channel contributing to aggregate dynamics. In this reference model, the mechanisms driving the dynamics are productivity and default risk without migration. We feed in the mean productivity shock recovered from the event analysis of the benchmark model, which implies that the mean productivity paths in the benchmark model and reference model are by construction identical. [in progress]

6 Conclusion

We incorporate cross-border migration into sovereign debt crises literature. Empirical evidence show that large outflows of labors accompany debt crises. In the model, this observation arises as the endogenous response to tightening financial conditions and high bond spreads. Adverse domestic shock increases the likelihood of default and bond spreads. Households react to this by moving to foreign countries, which increases the debt burden of the government. The interaction between migration by workers and borrowing decision by the government can rationalize the persistent recession during debt crises.

The connection between sovereign default and the private sector starts to receive attention in recent sovereign default literature. Different from focusing on a firm sector, this paper

contributes to this literature by making sovereign conditions affect migration decisions of the household sector. It provides an essential link between sovereign default and the households.

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Appendix A More Stylized Facts

A.1 Government Bond Yield and Net Migration in Germany

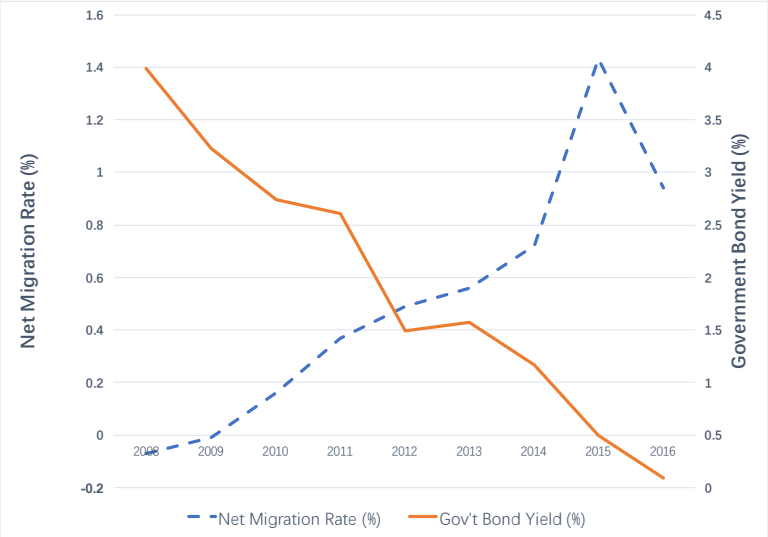

Figure 11: Government Bond Yield and Net Migration Rate in Germany

Notes: Net migration rate is defined as the ratio of net migration during the year to the average population in that year (dashed blue line, left axis). Government bond yield is long-term interest rates of government bonds maturing in ten years (solid orange line, right axis).

A.2 Government Bond Spread and Net Migration

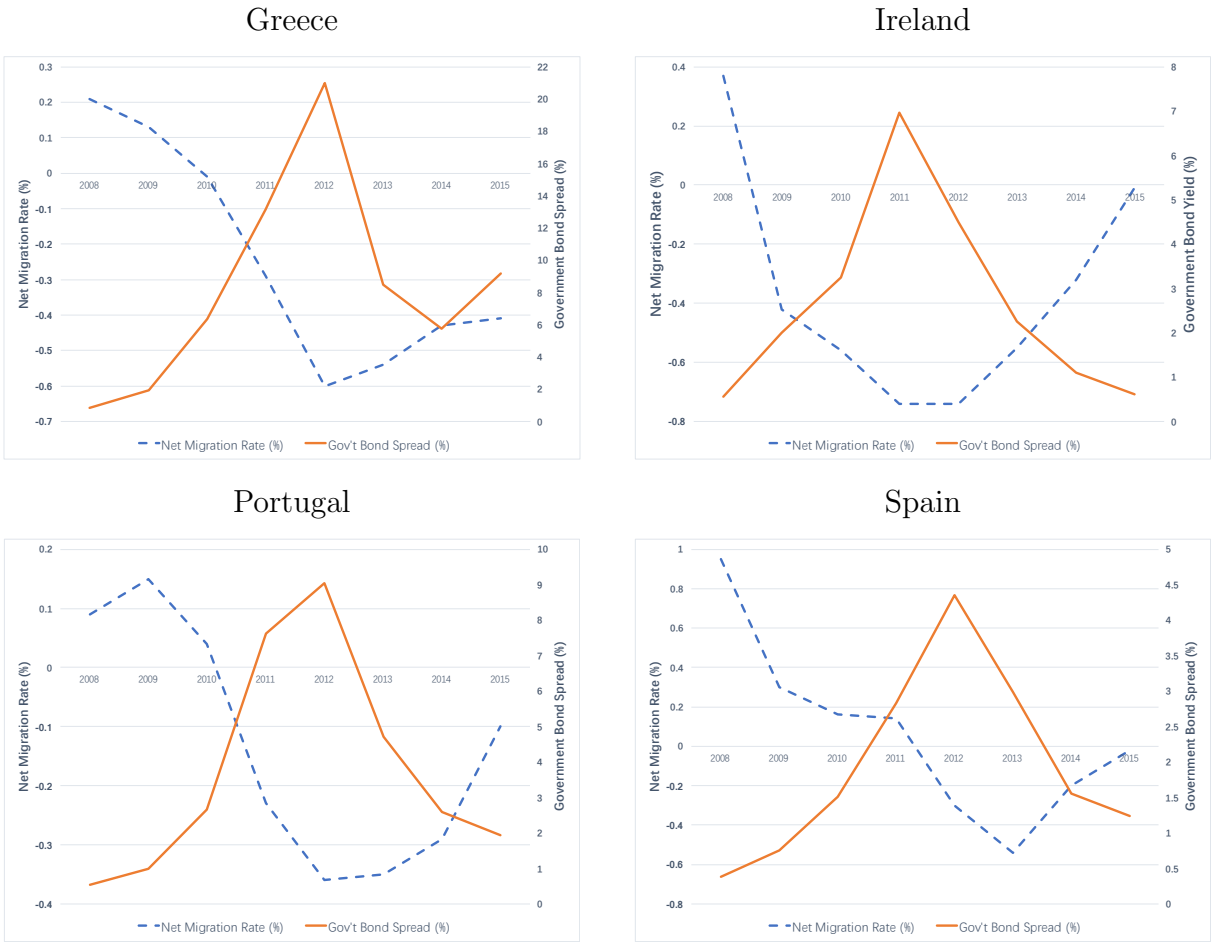

Figure 12: Government Bond Spread and Net Migration Rate

Notes: Net migration rate is defined as the ratio of net migration during the year to the average population in that year (dashed blue line, left axis). Government bond spread is the gap between long-term interest rates of government bonds maturing in ten years and that of Germany (solid orange line, right axis).

A.3 Two Emigration Rates

Table 6 provides total emigration rates and emigration rates of the highly skilled for OECD countries. By comparing the two rates, we infer the characteristics of the emigrants. For most OECD countries, the emigration rate of highly skilled is larger than the total emigration rate, suggesting that highly skilled workers are more likely to emigrate. It is not hard to understand because the migration policy is selective and in favor of people with a higher education level in most countries.

Table 6: Total emigration rates and emigration rates of the highly skilled, by country of origin (OECD countries), 2010/11

	Emigration (total)	Emigration (high-skilled)
Australia	2.2	3.3
Austria	5.8	12.9
Belgium	4.6	7.5
Canada	4	5.4
Chile	3.7	3.4
Czech Republic	4.1	11.7
Denmark	4.3	8.9
Estonia	11.3	14.8
Finland	5.8	7.3
France	2.7	5.8
Germany	5	9.5
Greece	6.9	6
Hungary	5.3	12.3
Iceland	11.8	15.5
Ireland	17.4	20.3
Israel	4.3	6.8
Italy	4.7	8.9
Japan	0.7	1
Luxembourg	12	22.6
Mexico	12.1	6.3
Netherlands	5.3	8.3
New Zealand	13.8	9.5
Norway	3.5	5.5
Poland	9.3	17.5
Portugal	15.4	15.4
Slovak Republic	10.1	17.6
Slovenia	7.8	8.3
Spain	2.3	2.7
Sweden	3.3	6.8
Switzerland	7.5	13
Turkey	4.8	4
United Kingdom	7	11.9
United States	0.6	0.6

Notes: The population refers to persons aged 15 and above. Data Source: Database on Immigrants in OECD and non-OECD Countries (DIOC-E) 2010/11.

Appendix B Robustness Check

Table 7, 8 and 9 provide robustness checks for empirical specification (1). Table 7 shows the result with lagged independent variables. Table 8 shows the result with both current and lagged independent variables. Table 9 presents the result when we substitute spread with lagged spread in Table 8.

Table 7: Lagged Independent Variables

	(1)	(2)	(3)	(4)	(5)
lagged spread	-0.13***	-0.07***	-0.13***	-0.13***	-0.07***
	(0.02)	(0.01)	(0.02)	(0.02)	(0.01)
lagged GDP	-2.12	-0.78	-3.27	-4.22	0.16
	(1.95)	(1.09)	(3.87)	(4.07)	(2.25)
lagged unemployment			-0.25	-0.17	0.24
			(0.65)	(0.66)	(0.36)
lagged exchange rate			1.78	2.71	0.50
			(3.72)	(3.92)	(2.15)
lagged price			1.34	2.00	-0.71
			(3.73)	(3.84)	(2.10)
lagged U.S. GDP				4.09	3.81
				(5.37)	(2.90)
N	136	136	136	136	136
R^2	0.311	0.178	0.313	0.316	0.208
country FE		yes			yes
country controls			yes	yes	yes
US GDP				yes	yes

Standard errors in parentheses

* p<.1, ** p<0.05, *** p<0.01

Table 8: Current and Lagged Independent Variables

	(1)	(2)	(3)	(4)	(5)
spread	-0.10***	-0.02	-0.10***	-0.10***	-0.00
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)
GDP	6.26**	5.69***	-1.87	-2.31	1.17
	(2.52)	(1.46)	(4.18)	(4.46)	(2.45)
lagged GDP	3.41*	1.80*	2.30	2.73	2.66
	(1.89)	(1.03)	(3.84)	(4.00)	(2.07)
unemployment			-1.60**	-1.74**	-1.48***
			(0.74)	(0.83)	(0.44)
exchange rate			5.45	4.73	2.75
			(4.11)	(4.47)	(2.32)
price			5.19	4.65	2.00
			(4.10)	(4.33)	(2.25)
lagged unemployment			-0.12	-0.15	0.36
			(0.66)	(0.69)	(0.35)
lagged exchange rate			3.08	2.61	0.12
			(3.95)	(4.15)	(2.14)
lagged price			2.02	1.79	-1.52
			(3.84)	(3.94)	(2.03)
U.S. GDP				-2.12	-5.37
				(8.67)	(4.67)
lagged U.S. GDP				-2.91	2.24
				(6.53)	(3.46)
N	136	136	136	136	136
R^2	0.302	0.205	0.340	0.341	0.330
country FE		yes			yes
country controls			yes	yes	yes
US GDP				yes	yes

Standard errors in parentheses

* p<.1, ** p<0.05, *** p<0.01

Table 9: Current and Lagged Independent Variables, and Lagged Spread

	(1)	(2)	(3)	(4)	(5)
lagged spread	-0.12***	-0.05***	-0.12***	-0.12***	-0.05***
	(0.02)	(0.01)	(0.02)	(0.02)	(0.02)
GDP	6.60***	5.07***	-0.66	0.01	0.32
	(2.40)	(1.33)	(4.03)	(4.25)	(2.22)
lagged GDP	-1.36	0.03	-3.39	-4.35	0.57
	(1.93)	(1.05)	(3.80)	(3.98)	(2.09)
unemployment			-1.73**	-1.42*	-1.20***
			(0.71)	(0.81)	(0.43)
exchange rate			-0.61	0.67	1.30
			(4.07)	(4.34)	(2.29)
price			-1.45	-0.53	0.43
			(4.08)	(4.23)	(2.21)
lagged unemployment			-0.23	-0.20	0.26
			(0.64)	(0.66)	(0.34)
lagged exchange rate			3.22	4.17	1.29
			(3.83)	(4.04)	(2.08)
lagged price			2.21	2.69	-0.42
			(3.71)	(3.82)	(1.96)
U.S. GDP				5.00	0.18
				(8.59)	(4.72)
lagged U.S. GDP				5.53	4.06
				(6.40)	(3.31)
N	136	136	136	136	136
R^2	0.348	0.274	0.381	0.384	0.380
country FE		yes			yes
country controls			yes	yes	yes
US GDP				yes	yes

Standard errors in parentheses

* p<.1, ** p<0.05, *** p<0.01

Appendix C Computation Algorithm

We compute the worker's problem and the sovereign's problem in Section 3 using value function iteration. In sovereign's problem, the state space for periods with financial market access is given by (z, k, b), whereas during default(or penalty phase) it is (z, k, h). In worker's problem, the state space is (z, k, b, h). We discretize the AR(1) process for the z shock using 40 equally spaced grid points with Tauchen's method. For the bonds, we use a grid with 120 equally spaced points on $b \in [0, 0.6]$, and for capital, we use a grid with 120 equally spaced points on $k \in [0.1, 1.0]$. The sovereign makes investment decision b' and k' for the next period (k' only, if in default or penalty phase). We restrict these choice variables to be on the grid. Then, given an optimal savings policy, the workers decide whether to migrate. The decision of workers changes the number of workers in the next period, thus changing the states the sovereign face in the next period. For each iteration, we update the value of the sovereign and value of workers. We stopped when both value functions of sovereign and workers converged. Rather than value function iteration until convergence, and then updating the price and then repeating, we update the bond price at every value function iteration step. The method of updating the bond price at every iteration is faster than updating the price after the convergence of value function iteration, and the two different procedures deliver very similar results.

Here is a more detailed description of our algorithm:

1. Create grids for capital k, bond b, and economy phase indicator h; Create grids and discretize Markov process for productivity z.
2. Guess for the value function of sovereign $V_0(z, k, b, h)$, value function of workers $V_0^w(z, k, b, h)$, and price function $q_0(z, k, b)$.
3. Update the value of non-defaulting $V_c(z, k, b)$.
4. Update the value of defaulting $V_d(z, k, h)$.
5. Compare $V_c(z, k, b)$ and $V_d(z, k, h)$, update the default rule, price function, and the value function of sovereign $V(z, k, b, h)$.
6. Compute the optimal savings policy of government with and without access to the international borrowing market.
7. Given optimal savings policy, update workers' value of staying in home country $V_s(z, k, b, h)$.
8. Compare $V_s(z, k, b, h)$ and V_m, update the value function of workers $V^w(z, k, b, h)$.

9. Check the distance $dist_g$ between updated value function of sovereign and the one from last iteration, and the distance $dist_w$ between updated value function of workers and the one from last iteration. If either of distances larger than tolerance, then go back to 3. Otherwise, stop.