Migration and Sovereign Default Risk*

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November 14, 2019

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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 erodes the tax base and 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 a 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.

Keywords: Sovereign default, European debt crisis, international migration

JEL classification: F22 F34 F41 F43 J61

*We appreciate comments from seminar participants at the Midwest Macro and SED.

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1 Introduction

Sovereign debt crises are typically associated with emigration. In the recent European crisis, Portugal, Greece, Ireland, and Spain all experienced massive outflows of workers. The migration pattern in Spain is perhaps the most striking. Before 2007, Spain experienced an economic boom with substantial immigration that expanded the labor force almost 2 percent per year. During the crisis, with a soaring spread, Spain's immigration declined dramatically, and the net migration rate became negative after 2011. Spain's economic activity has now fallen far below its pre-crisis trend. These observations are intertwined and bring up several important and unanswered questions. How does sovereign default risk affect migration choices? Does emigration worsen or lessen sovereign default risk? Does migration affect the persistence of the crises? What are the optimal migration and fiscal policies during a crisis?

In this paper, we study the interaction of sovereign default risk and migration. Default risk and emigration reinforce each other. Default risk increases a country's borrowing cost. Facing a high borrowing cost, the government borrows less, increases taxes and reduces transfers, which in turn lowers resident welfare and increases their incentive to migrate from the country. On the other hand, emigration decreases future capital returns reducing investment eroding the country's repayment capacity. Higher default risk ensues. During a recession, more workers choose to leave the country, further increasing the debt burden on the remaining workers. Incentives to migrate are further intensified. Meanwhile, the increased debt burden depresses investment, leading to an even deeper and longer recession. Our quantitative analysis shows emigration helps explain the persistence of Spain's crisis.

These effects work in reverse when a country is expected to receive a future inflow of workers. We show that migration was important in the lead up to the crisis as this was a period with substantial changes in mobility barriers within Europe with EU enlargement (Klein and Ventura [2009], and Caliendo et al. [2017]). Likewise, we consider how policies in the aftermath of the crisis exacerbated the crisis.

We incorporate a migration decision and capital accumulation into a standard sovereign default model. The economy consists of a continuum of firms, families, and a central government. Firms rent capital and hire workers to produce. Families accumulate capital, send out workers to firms, and pay lump-sum tax to the government. Workers make migration choices in the presence of a stochastic migration cost. A worker leaves the country when either the staying value or the migration cost is low. The government collects taxes from the private economy and borrows internationally. It enforces capital controls so that only itself can borrow and lend internationally.[1] The government can also default on its bond under the cost of low productivity and some period of exclusion from the international financial market. The bond prices, therefore, incorporates a risk premium to compensate international lenders for their default losses. The economic environment is perturbed by an aggregate productivity shock.

The country is more likely to default if it has a higher debt, larger emigration, lower capital, or a worse productivity shock. In particular, a negative productivity shock increases the default risk, which in turn pushes up the borrowing cost and depresses investment. Tightened financial constraints reduce the transfers to the workers and increase their incentive to migrate out of the country. More emigration happens. The emigration of workers not only reduces the labor of the country but also affects the government's decision of defaulting and investment in the next period. Hence, there is a two-way feedback loop between default risk and emigration.

We quantify our model with Spanish data and ask how much the migration channel contributes to the recent crisis in Spain. We find that the migration channel magnifies and elongates the debt crisis. To evaluate the role of migration, we compare our model against two reference models. Our model features both default risk and migration choices. In the first reference model, *no-migration*, we shut down the migration choices. We re-calibrate the model to ensure that the average default risk is comparable with our benchmark case. In the second reference model, *no-default-no-migration*, we shut down both migration and default choices. In this case, the government still borrows state uncontingently but faces a natural borrowing limit as in Aiyagari [1994] and Bai and Zhang [2010].

We find that default risk amplifies a bad productivity shock and generates a deeper and longer decline in investment and output. Default risk makes the bond price schedule elastic, which reduces the incentive to invest during the recovery period. Emigration provides further magnification by exaggerating the default risk. After a one standard deviation negative productivity shock, the per-capita GDP falls 2.9% in the benchmark model, 2.5% in the *no-migration* model, and 2.3% in the *no-default-no-migration* model. Event 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-no-migration*

[1] Alternatively, private agents can borrow and default internationally. In this case, due to pecuniary externality, the government has the incentive to impose taxes or subsidies to international capital flows to implement the allocations in the centralized borrowing and default case as in our current model. See Jeske [2006], Kehoe and Perri [2004], Wright [2006], and Kim and Zhang [2012] for discussions on private versus public borrowing and 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. In the data, output declines by 12.46%, spreads increased from 38 basis point to 435 basis point, and net migration rate drops from 0.95% to *negative* 0.3%. We feed in a path of productivity shocks such that the model reproduces the path of Spanish aggregate GDP from 2003 to 2012. Our model generates 80% of the increase in the sovereign spread and 35% of the decrease in migration rate during the peak-to-trough periods. The *no-migration* model could generate a similar magnitude of the output decline; it, however, fails to produce the observed persistence of the recession.

Our model builds on the sovereign default model pioneered by Eaton and Gersovitz [1981], Arellano [2008], Aguiar and Gopinath [2006], and Yue [2010]. Most works in the literature study an endowment economy and abstract from capital and migration choices. Gordon and Guerron-Quintana [2018b] incorporates capital accumulation into a default model. Our contribution lies in providing a framework that embeds these two choices into a sovereign default model. The endogenous capital choice affects future value, default risk, and borrowing cost; it, therefore, has a significant impact on migration choices. Migration choices also shape future capital returns and determine the current investment, production, and default incentive. It is, therefore, important to incorporate both into the model.

Some recent papers in the sovereign default literature emphasize the connections between sovereign default and the private sector. Most existing works focus on the link between sovereign spreads and firm behaviors. 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 [2017] measures the aggregate implications of sovereign risk with both aggregate and cross-section firm and bank-level data. They find that sovereign default risk accounts for one-third of the output decline during the Italian debt crisis. We share with these papers and emphasize the interaction between the sovereign and private sectors during the debt crisis. We, however, focus on the interplay between the sovereign and labor migration.

Our paper also relates to the literature on the interaction of sovereign default risk and labor market frictions. 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. In our paper, migration generates another source of endogenous default cost during a debt crisis. Furthermore, migration has a long-run effect on the economy.

The amplification effect of 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 mechanism similar to Mendoza [2010] and Arellano, Bai, and Mihalache [2018] 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 they are amplified by emigration. Gordon and Guerron-Quintana [2018a] studies debt and migration at the regional level of the U.S. The key mechanism is migration changes debt per person in each region.

We also contribute to the literature that focuses on the effects of migration on business cycles. Using a constructed working-age migration data for the U.S., Weiske [2017] finds that migration leads to a fall in real wages but an increase in investment in the destination country. Immigration, however, only makes a modest contribution to the U.S. business cycle dynamics. Furlanetto and Robstad [2017] uses Norwegian data and finds that positive migration shocks are expansionary, migration shocks are a significant driver for unemployment dynamics but not housing 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. Our paper differs in that we focus on sovereign default risk.

2 Spreads and Migration during European Debt Crises

During late 2008, countries in Europe including Greece, Ireland, Italy, Portugal, and Spain experienced an dramatic increase in their government spreads. At the same time, more workers migrate out of those countries. Figure 1 plots the government bond spreads and net migration rate for Greece, Ireland, Portugal, and Spain during 2008-2015. The dashed blue line presents the net migration rate on the left axis, and the solid orange line presents government bond spread on the right axis. Spread is defined as the difference between the government ten-year bond yield and that in Germany. Bond yields are from OECD data base. Our migration data comes from Eurostat. The definition of migrants is consistent across countries during this period. 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 1 shows that the net migration rate drops when government bond spreads rise. It indicates that people tend to emigrate in debt crises. The Greek spread, for instance, increased by more than 20% 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.

In summary, debt crises are featured with both high government spreads and larger outflow of workers. In the next section, we present a theory of migration and sovereign default risk.

To further confirm the correlation between sovereign default risk and net migration, we regress the net migration rate on government bond spreads 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. 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 C, 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.

3 Model

We now describe our model of sovereign default and migration. The model extends the canonical sovereign default model Arellano [2008] to include both capital accumulation and migration. We consider a small open economy with a continuum of households, firms, and a benevolent government. Households supply labor to firms and make decisions to emigrate after paying a stochastic and idiosyncratic migration cost δ_m. Firms produce with capital K and labor L with the production function $Y = zK^{\alpha}L^{1-\alpha}$ where z is the stochastic productivity.

We follow the literature and assume that only the government can borrow and lend internationally and that the government rebates all the proceeds back to the households in a lump-sum fashion. While this implies the government makes all consumption and investment decisions, we assume that individuals make migration decisions. International financial markets are incomplete in that the government only issues a state-uncontingent bond and can default on these obligations. Default involves a persistent cut in productivity to $z_d(z) \leq z$. Following a default, the country is excluded from capital markets. With probability λ, a government in default regains access to international borrowing and lending and is no longer subject to lower productivity.

Each period the economy starts with a level of exogenous productivity, z, capital, K, stock of workers, L, public debt, B and being in or out of the punishment phase. Specifically, the aggregate state of the economy is (S, h) where $S = (z, K, L, B)$, $h = 0$ denotes the normal phase, and $h = 1$ denotes the penalty phase. The penalty phase means the government previously defaulted, remains incapable of borrowing, and is subject to an exogenous productivity loss. Individual agents differ only in their idiosyncratic migration cost, which we denote by δ_m. We omit the time subscript t to simplify notation, and we use x' to denote variable x in the next period. The timing of the model is as follows. At the beginning of each period, the aggregate shock z and the idiosyncratic shock δ_m for each household are realized. Given the aggregate state (S, h) and idiosyncratic shock δ_m, households decide on whether to emigrate. Let a household's state be $s^h = (S, h, \delta_m)$. After the migration choice, the total population becomes L'. The government then chooses whether or not to default. It it repays then it chooses new borrowing and its state becomes (S_g, h) with $S_g = (z, K, L', B')$.

3.1 Migration Choice

Consider a representative worker with idiosyncratic moving cost of δ_m. The worker makes a discrete choice to stay or emigrate. If the worker moves, she receives an exogenous and constant value W^m but must also pay her idiosyncratic migration cost. If she stays in the home country, she receives transferred consumption from the government and starts the next period as a home resident. The value of a worker is:

$$W(S, h, \delta_m) = \max\left\{W^s(S, h), \quad W^m - \delta_m\right\} \tag{2}$$

where W^s denotes the value if she stays in the home country and W^m is the value if she emigrates. We assume the migration cost is drawn from an exponential distribution: $F(x) = 1 - e^{-\zeta_m x}$. If the worker stays in the home country, her value function is:

$$W^s(S, h) = \left\{u(H_c(S, h)) + \beta \mathbb{E} W(S', h', \delta'_m)\right\}$$

where $H_c(S, h)$ is the consumption transferred by the domestic government after migration and the government's choice on default and new borrowings. If the worker migrates, she gets utility in the foreign country in that period and every period thereafter. We assume the foreign country value is constant and is given by W^m. Let the optimal migration choice be $\iota(S, h, \delta_m) = 1$ if the value of staying is higher than migrating out of the country, i.e., $W^s(s, h) \geq W^m - \delta_m$, and $\iota(S, h, \delta_m) = 0$ otherwise.

A worker stays in the home country if the value of doing so is higher, i.e., $W^s(S, h) \geq W^m - \delta_m$. The probability of staying in the home country is then given by

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

The law of large number holds here so that the fraction of stayers is the same as the probability of a worker leaving the country. Hence, the measure of workers after migration choices L' is the product of initial labor force L and the fraction of staying, $L' = H_L(S, h)$ where $H_L(S, h) = e^{-\zeta_m (W^m - W^s(S,h))} L$.

3.2 Government and International Lenders

The government makes default and borrowing decisions. It 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:

$$V(z,K,L',B) = \max\left\{V^c(z,K,L',B), V^d(z,K,L')\right\} \tag{3}$$

where V^c denotes the non-defaulting value and V^d the default value. Let $D(z,K,L',B) = 1$ denotes default. If there is no default, the government can choose both investment and new international borrowing, B', by solving the following dynamic programming problem:

$$V^c(z,K,L',B) = \max_{C,B',K'} \quad L'u\left(\frac{C}{L'}\right) + \beta\mathbb{E}[V(z',K',H_L(S',h'=0),B')] \tag{4}$$

subject to the budget constraint:

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

where $Q(z,K',L',B')$ is the bond price.

If the government defaults, the economy suffers a loss in productivity from z to z_d and enters into the penalty phase. The government cannot borrow internationally and can only choose investment to maximize stayers' utility. With probability λ, the government returns to the international borrowing market and the productivity penalty from default is removed. The default value is given by:

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

subject to the budget constraint

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

International lenders are competitive and risk neutral. They face a constant world risk free rate r. The break-even conditional implies the bond price schedule satisfies

$$Q(z,K',L',B') = \frac{1}{1+r}\mathbb{E}[1 - D(z',K',H_L(S',h'=0),B')].$$

Hence the bond price compensates lenders for their losses during sovereign default. As in the standard sovereign default literature, these prices depend on the country current shock z, level of capital, K', and debt, B'. In our setup, the bond price schedule is also a function of current population, L'.

Recursive equilibrium The equilibrium consists of the private migration choice $\iota(S, h, \delta_m)$, the government's decisions $D(z,K,L',B)$, $B'(z,K,L',B)$, $K'(z,K,L',B)$, $C(z,K,L',B)$, $C^d(z,K,L',B)$, $K^{d\prime}(z,K,L',B)$, consumption function $H_C(z,K,L,B,h)$, and migration function $H_L(z,K,L,B,h)$, value function $V(z,K,L',B)$, $V^c(z,K,L',B)$, $V^d(z,K,L')$, and $W^s(z,K,L,B)$ such that

- Taking as given the consumption function $H_C(z,K,L,B,h)$, a worker's migration choice $\iota(S,h,\delta_m)$ and value function $W^S(S,h,\delta_m)$ solve the worker's problem (2).
- Taking as given the migration function $H_L(z,K,L,B,h)$, the government's choice of $D(z,K,L',B)$, $B'(z,K,L',B)$, $K'(z,K,L',B)$, $C(z,K,L',B)$, $C^d(z,K,L',B)$ and $K^{d\prime}(z,K,L',B)$ and its value functions V, V^c, V^d solve the government's problem (3).
- Consistency. The per-capita consumption function is consistent with the government's optimal choice, $H_C(S,h=0) = C(z,K,H_L(z,K,L,B,h=0))/H_L(S,h=0)$ if the country is in the normal phase and the government chooses not to default, $H_C(S,h=1) = C^d(z,K,H_L(S,h=0))/H_L(S,h=0)$ if the country is in the normal phase and the government chooses to default, and $H_C(S,h=1) = C^d(z,K,H_L(S,h=1))/H_L(S,h=1)$ if the country is in the penalty phase. The migration function $H_L(S,h)$ is consistent with the workers' migration choices.

3.3 Transformed Problem

We normalize the aggregate variables in per-capita terms. For a variable X, we define its per-capita term as $x = X/L$. Let the worker's per-period utility given by $u(c) = \frac{c^{1-\sigma}}{1-\sigma}$. Let the state be (s,h) with $s = (z,k,b)$ with k and b the per-capita capital and debt, respectively.

Workers' transformed problem The value of a worker is given by

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

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

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

We can write the growth rate of the measure of workers accordingly $h_g(s,h) = e^{-\zeta_m(w^m - w^s(s,h))}$.

Government's transformed problem Taking as given the current population growth g after migration, the government first chooses whether or not to default depending on the per-capita value of not defaulting $v^c(s,g)$ and defaulting $v^d(s,g)$, i.e.

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

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

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

subject to the budget constraint

$$c + b/g = z(k/g)^\alpha - \left[k' - (1-\delta)(k/g) + \frac{\theta}{2}\left(\frac{k'}{(k/g)} - 1 + \delta\right)^2 (k/g)\right] + q(z,k',b')\ b', \tag{5}$$

and the bond price schedule $q(z,k',b') = \frac{1}{1+r}E\left[1 - d(z',k',b',g')\right]$. The future state of growth is given by $g' = h_g(z',k',b',h'=0)$ where h_g is consistent with workers' optimal migration choices.

The defaulting value is given by

$$v^d(z,k,g) = \max_{c_d,k'} \quad g\left[\frac{c_d^{1-\sigma}}{1-\sigma} + \beta\mathbb{E}[\lambda v(z',k',0,g_0') + (1-\lambda)v^d(z',k',g_1')]\right]$$

subject to the budget constraint during autarky

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

where $g_0' = h_g(z',k',0,h'=0)$ if the country regains access to the international financial markets and $g_1' = h_g(z',k',b',h'=1)$ if the country remains in autarky in the future.

The consumption function h_c is consistent with the government's choice of consumption, i.e., $h_c(s,0) = c(z,k,b,h_g(z,k,b,0))$ and $h_c(s,1) = c_d(z,k,h_g(z,k,b,1))$.

Migration and Default To understand the role of migration on the government's default choices, we rewrite the budget constraint (5) in the normal phase with a zero capital adjustment cost $\theta = 0$,

$$c = z(k/g)^\alpha + (1-\delta)(k/g) - (b/g) - k' + q(z, k', b')b'$$

where $b/g = B/L'$ and $k/g = K/L'$ are the per-capita debt and capital after the migration choices. The government chooses k', b', and consumption per capita c to maximizes its value (4). Migration has two effects here. On the one hand, higher immigration, or higher g leads to a lower capital per capita, which further reduces output per capita. This effect is standard as in a Solow growth model. It is also similar to the congestion effect when there are public goods, as discussed in Guerreiro et al. [2019]. On the other hand, When more workers move in, g goes up, the debt burden per capita $b/g = B/L'$ is lower, the average repayment capacity is higher. Hence under the congestion effect, immigration increases the government's default incentive, whereas, under the debt burden effect, immigration reduces the government's default incentive. When the country has a large debt burden, i.e., high B/K, emigration worsens the debt burden and pushes up the sovereign spreads. The debt burden effect is unique to our model with a sovereign default.

4 Quantitative Analysis

We conduct a quantitative analysis in this section. We first parameterize our model to the Spanish economy. To illustrate the mechanism, we show the bond price schedules and impulse responses to productivity shocks. We also contrast our model with two reference models, one without a migration choice and one without migration or default risk. In our model, default risk and migration interact and generate a large and persistent contraction in output during recessions.

4.1 Parameterization

We set the length of a period to one year. The productivity loss after default takes 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 productivity shock z follows an AR(1) process:

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

where ρ_z captures the persistence of the shock, and innovation ϵ follows a normal distribution with zero mean and standard deviation of η_z.

There are two groups of parameters. The parameters in the first group are taken directly from the literature, and those in the second group are jointly chosen to match empirical moments (see Table 2). The first set of parameters includes $\{\alpha, \delta, \sigma, \lambda, r\}$. We set the capital share α to 0.34, and the depreciation rate takes a standard value 8% annually. 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 chosen 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 introduces 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 E 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 2 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.

In Figure 3, 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 3 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.

4.3 Impulse Responses

In this section, we present the impulse responses (IRF) to a negative productivity shock. To emphasize the amplification effect arising from the migration and default risk, we compare the IRFs in our benchmark model to those in the two reference models. The first reference model abstracts from migration and is denoted *no-migration*. The second reference model further shuts down the default risk and is called *no-default-no-migration*. The *no-migration* model extends the classical model in standard sovereign default literature by allowing for capital accumulation. The model is similar as Gordon and Guerron-Quintana [2018b] and Bai and Zhang [2012]. By comparing the *no-migration* model and the *benchmark* model, we can figure out how much migration channel contributes to the recession.

To construct the impulse response functions 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 4 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 3.5% on impact following the decline in productivity. Spread increases because under a persistent shock, low productivity implies a higher default risk in the future. Lenders, therefore, charge a higher spread to compensate for their default risk. High spread implies high borrowing costs for the government, which therefore reduces borrowing and increase domestic taxes to repay the debt. Low productivity, together with the high lump-sum tax, lowers the value of staying in the country; workers migrate out of the country, population growth rate becomes negative, -0.15%, and then comes back to zero gradually, as shown in Panel (f). Both low productivity and the ensued small population reduce investment returns, capital becomes lower than the steady state. Panel (c) plots per-capita capital. It first increases slightly due to migration. Capital per capita falls about 2.2% in the second period and continues to be depressed for more than 20 periods. With lower labor and capital, GDP is lowered by 2.5% on impact and takes more than 20 periods to go back to the steady state. In Panel (d), we plot the response for per-capita GDP and aggregate GDP. Aggregate GDP decrease for 3.0% and recovers very slowly. After 20 periods, aggregate GDP is still more than 2% below the mean. Consumption per capita in Panel (e) is reduced by 4.9% to repay the debt.

To show that our benchmark model generates a large amplification over shocks, we compare the benchmark model with the two reference models. Both the reference models share the same parameters as in the benchmark model except for the default penalty parameter χ_2. Table 3 shows the value of χ_2 in each model and the moments. For the *no-default-no-migration* model, we increase χ_2 to 0.99 such that there are no defaults in equilibrium. The mean and standard deviation of spreads are both zero, as shown in the last column of Table 3. The *no-migration* model still has default risk, we re-calibrate χ_2 so that this model generates the same average spread as in the benchmark model. The implied χ_2 is lower than the benchmark model parameters governing the default costs so that the average spreads in the *no-migration* model are the same as those in the benchmark model. Without migration, the default incentive is lower. Hence the default cost χ_2 has to be lower from 0.85 to 0.836 to generate the benchmark spread. In all three models, consumption volatility is close to that of output. Investment is the most volatile in our model since both default risk and migration amplifies the response of investment.

In Figure 5, 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-no-migration* 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.

Following a one standard deviation decline of productivity, the spread goes up except in the no-default model. The IRFs of per-capita capital in panel (b) illustrates the amplification effect from default and migration. When there is no default risk and no migration, capital only declines about 0.6% on impact. With default risk, capital falls by approximately 1.5%, more than doubled that without default. The reason is that bad productivity shock raises the default risk and the government's borrowing cost. The government has to raise the lump-sum tax to repay its debt. Higher tax crowds out consumption and investment. Capital drops by more. When there are default risk and migration, the capital falls by an extra 0.8%. This is because the lower population reduces the return for investment.

Given that capital per capita increases on impact due to emigration, per-capita GDP does not fall the most in benchmark model. However, per-capita GDP and aggregate GDP decline a lot in the next period. The decline of per-capita GDP in the benchmark model is 0.23% larger than that in the no-migration model and 0.48% larger in the no-default-no-migration model (benchmark: 2.73%, no-migration: 2.5%, no-default-no-migration: 2.25%). The decline of aggregate GDP is even more pronounced in benchmark 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. Recall that per-capita GDP does not fall more than the reference models in the first period. This is because the per-capita capital increases on impact with fewer workers.

These IRFs shows that our model generates a sizeable endogenous persistence due to two reasons. First, under a negative productivity shock, financial frictions tighten, and the economy reduces investment in response to lower external financing. Furthermore, endogenous default risk slows down the capital accumulation. Second, with endogenous migration choice, workers emigrate more when the productivity is low and spread is high. Emigration increases the debt burden of the sovereign, leading to further reduction of investment.

5 Event Analysis for Spain

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. We first present the aggregate dynamics of Spain's economy during the 2012 debt crisis . We then show the migration flows during this episode. Lastly, we compare our model implications to Spanish data. Our model matches well the peak-to-trough changes in both government spreads and net migration.

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 6 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.

5.1 Migration in Spain

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. In general, immigration to Spain increased significantly at the beginning of the 21st century.

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 7 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.

5.2 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.[2] Then we get 7.89% as the peak in 2008 and -4.57% as the 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.[3]

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 4 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

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

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

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 accounts for 47% (= 0.59/1.25) of the decline in net migration during 2008-2012.

The event dynamics is driven by productivity shocks, endogenous financial frictions that arise due to default risk, 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 the migration channel contributing to aggregate dynamics. In this reference model, the mechanisms driving the dynamics are productivity and default risk without migration. Without migration, the government spread only increases by 0.71%, at most 18% the increase of spread in the benchmark.

6 Conclusion

We study the role of migration in propagating a sovereign debt crises. We provide empirical evidence that debt crises, and the capital outflows they generate, are accompanied by large outflows of labor. We build a model of sovereign default, capital accumulation, and emigration to capture these interactions. With migration, spreads increase more in recessions and recessions are much more persistent.

The changing policies on intra- and extra-EU migration likely contributed to the diverse outcomes within Europe since the Great Recession and the start of the European Debt Crisis. These new policies likely contributed to differences in the persistence of the recent recessions compared to previous recessions. Considering policies to address the pecuniary externalities from labor flows should be considered in future work.

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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

Table 2: Calibration

Parameter	Value	Target	Model
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%	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%

Table 3: Parameters and Moments: Benchmark and Reference Models

	Parameters			
		Benchmark	No-migration	No-default-no-migration
Penalty parameter χ_1		-0.78	-0.78	-0.78
Penalty parameter χ_2		0.85	0.836	0.99
	Targeted Moments			
	Data	Benchmark	No-migration	No-default-no-migration
Std. GDP	6.7%	6.5%	5.3%	4.5%
Mean(spread)	3%	3%	3%	0
Std. spread	2.8%	2.2%	2.5%	0
Std. C/std. GDP	0.96	0.96	0.97	0.99
Std. Inv/std. GDP	3.5	4.9	4.1	2.7
Std. migration rate	0.60%	0.25%	-	-
Mean(migration rate)	0.38%	0.36%	-	-

Table 4: Spain from 2008 to 2012

	GDP	gov spread	net migration
2008-2012 Difference (%)			
Data	-12.46	3.97	-1.25
Benchmark	-13.78	4.02	-0.59
No-migration	-11.39	0.71	0
2008 Levels (%)			
Data	7.89	0.38	0.95
Benchmark	8.36	0.51	1.60
No-migration	12.75	0.05	0
2012 Levels (%)			
Data	-4.57	4.35	-0.3
Benchmark	-5.42	4.53	1.01
No-migration	1.36	0.76	0

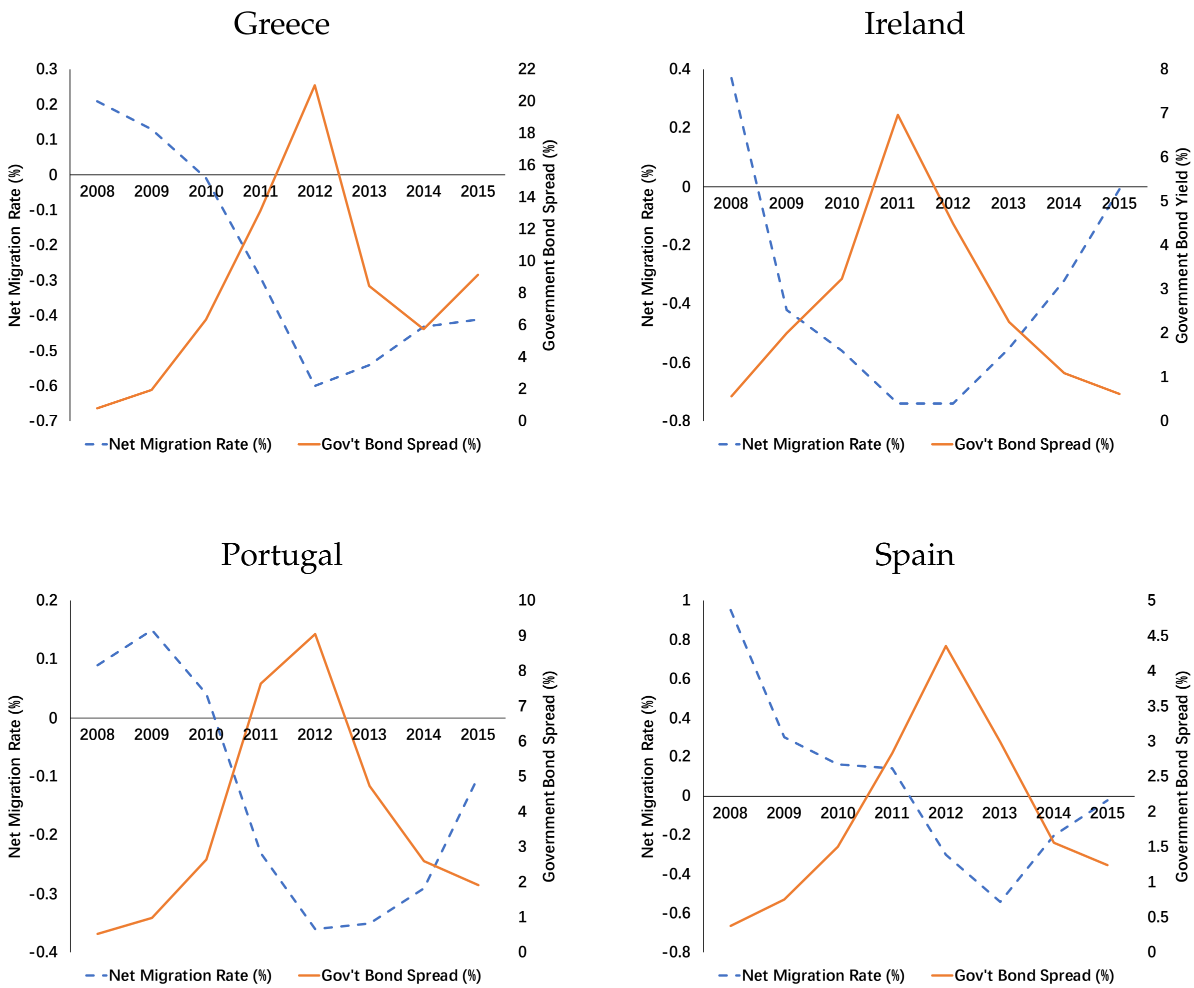


Figure 1: Government Bond Spreads and Net Migration Rate

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). Spreads are defined as the difference between the government ten-year bond yield and that in Germany. (solid orange line, right axis).

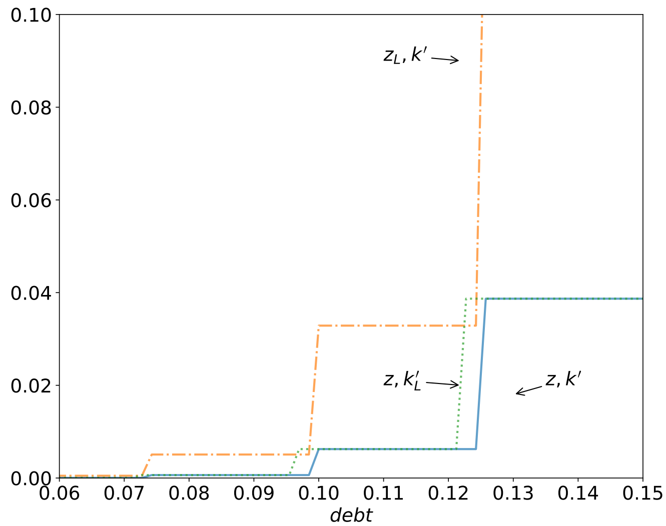
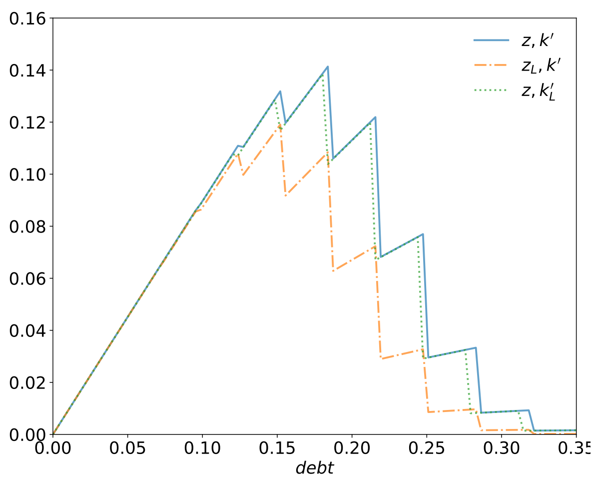
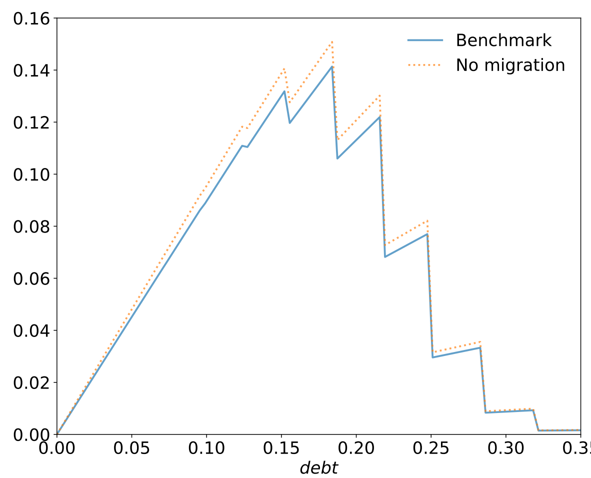


Figure 2: Bond Spread Schedule

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.



(a) Capital Inflows



(b) Benchmark and Reference Model

Figure 3: 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.

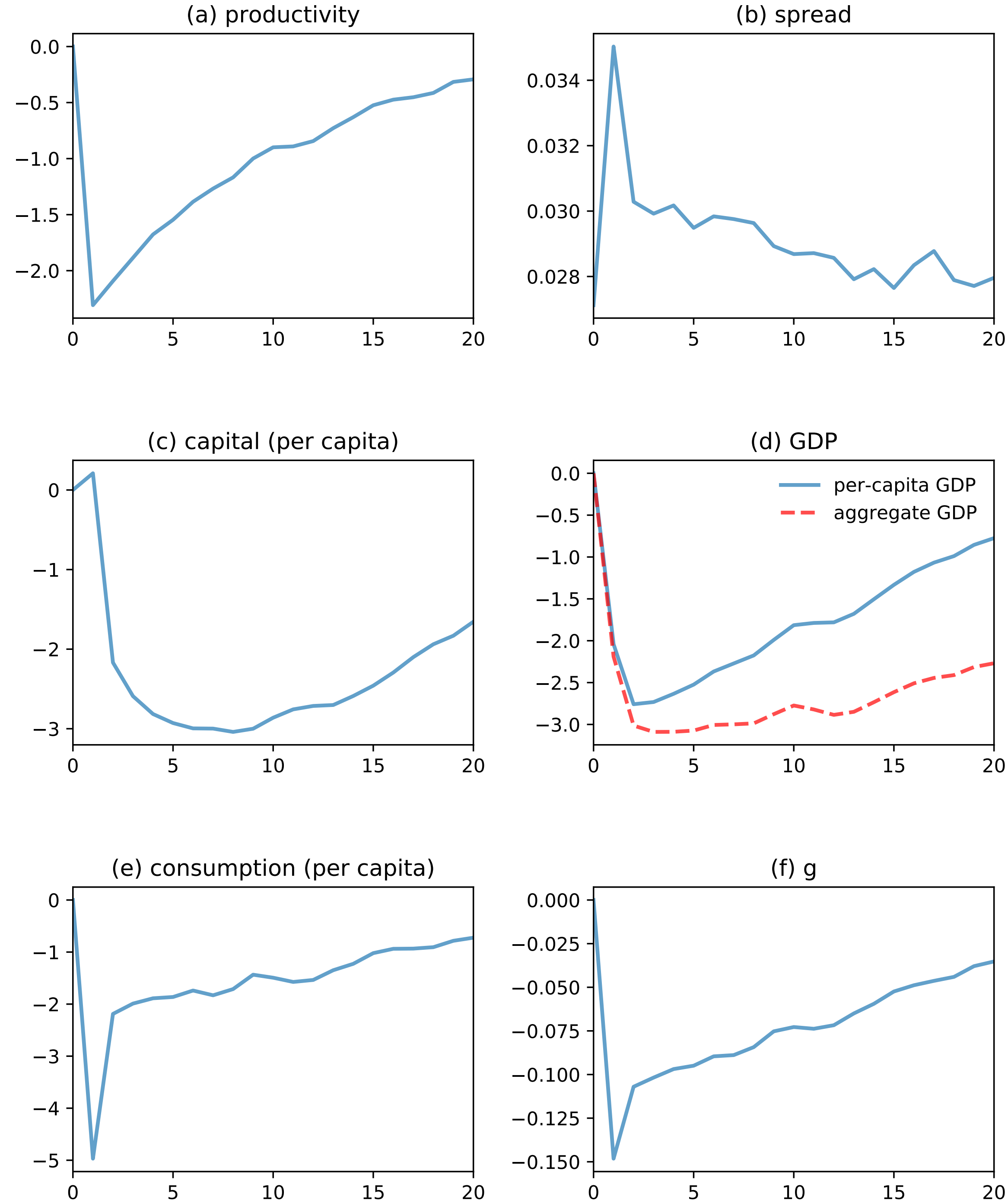


Figure 4: Impulse Response Functions to a Decline in Productivity

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

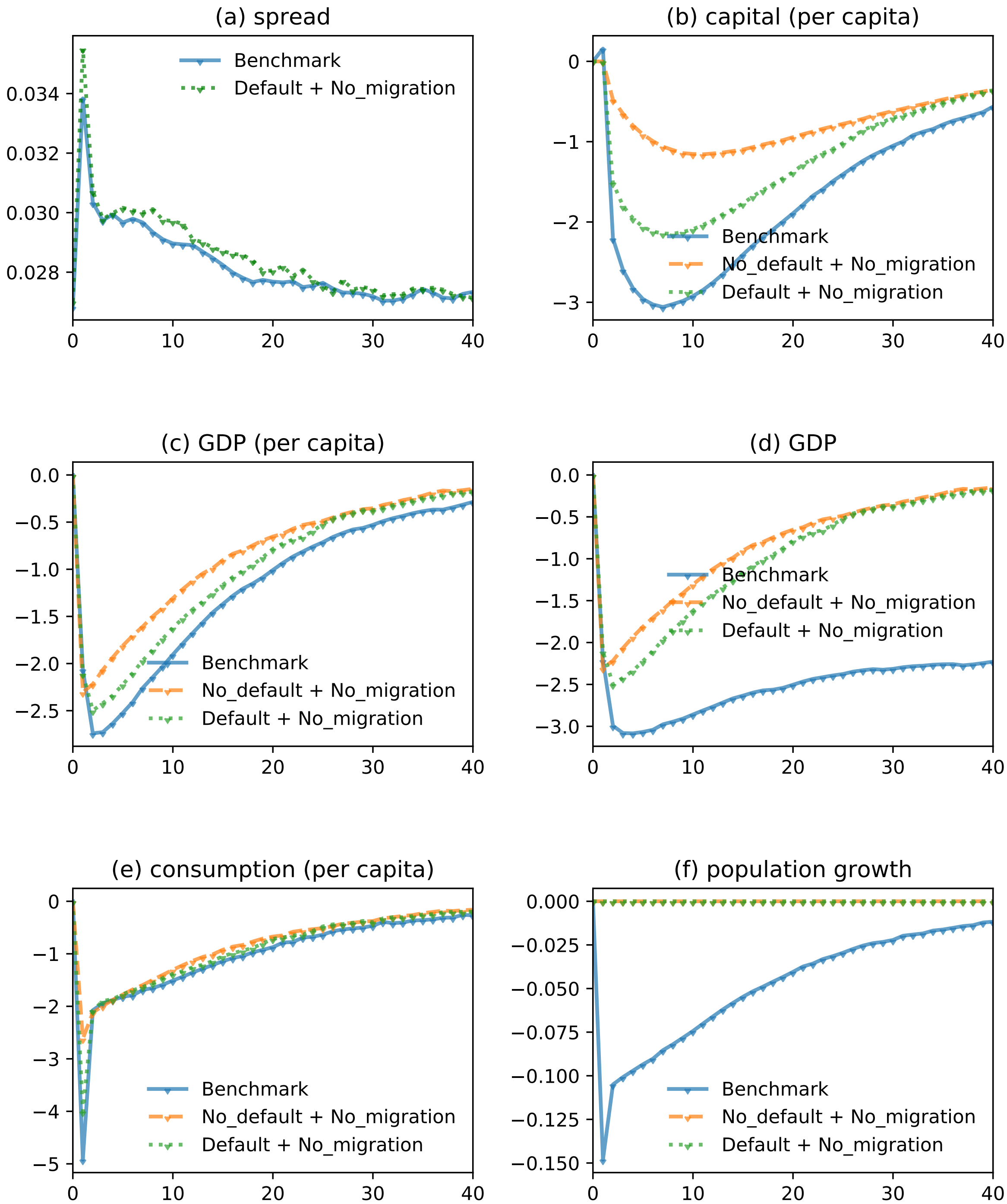


Figure 5: Impulse Response Functions to a Decline in Productivity: Benchmark and Reference Models

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.

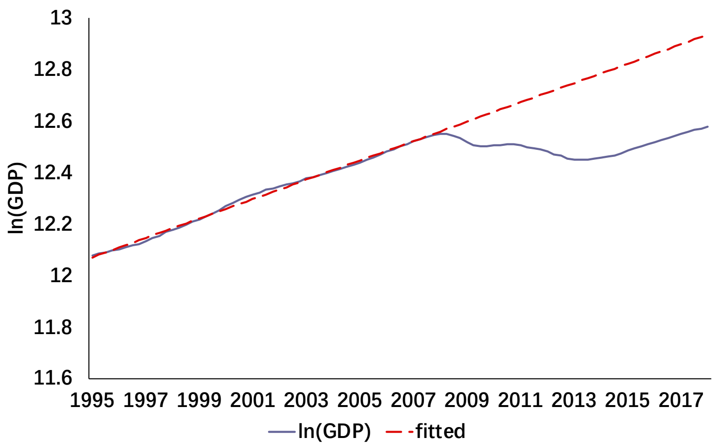
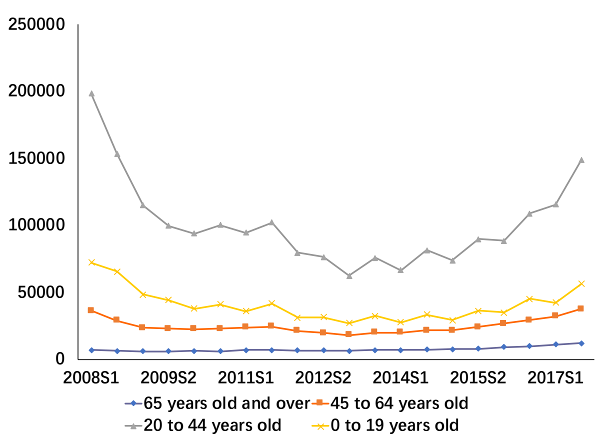
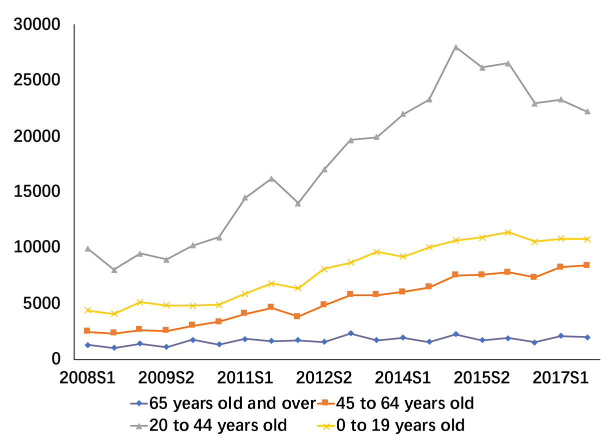


Figure 6: Recession in Spain



(a) Immigration Flows (Foreigners)



(b) Emmigration Flows (Spanish)

Figure 7: 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.

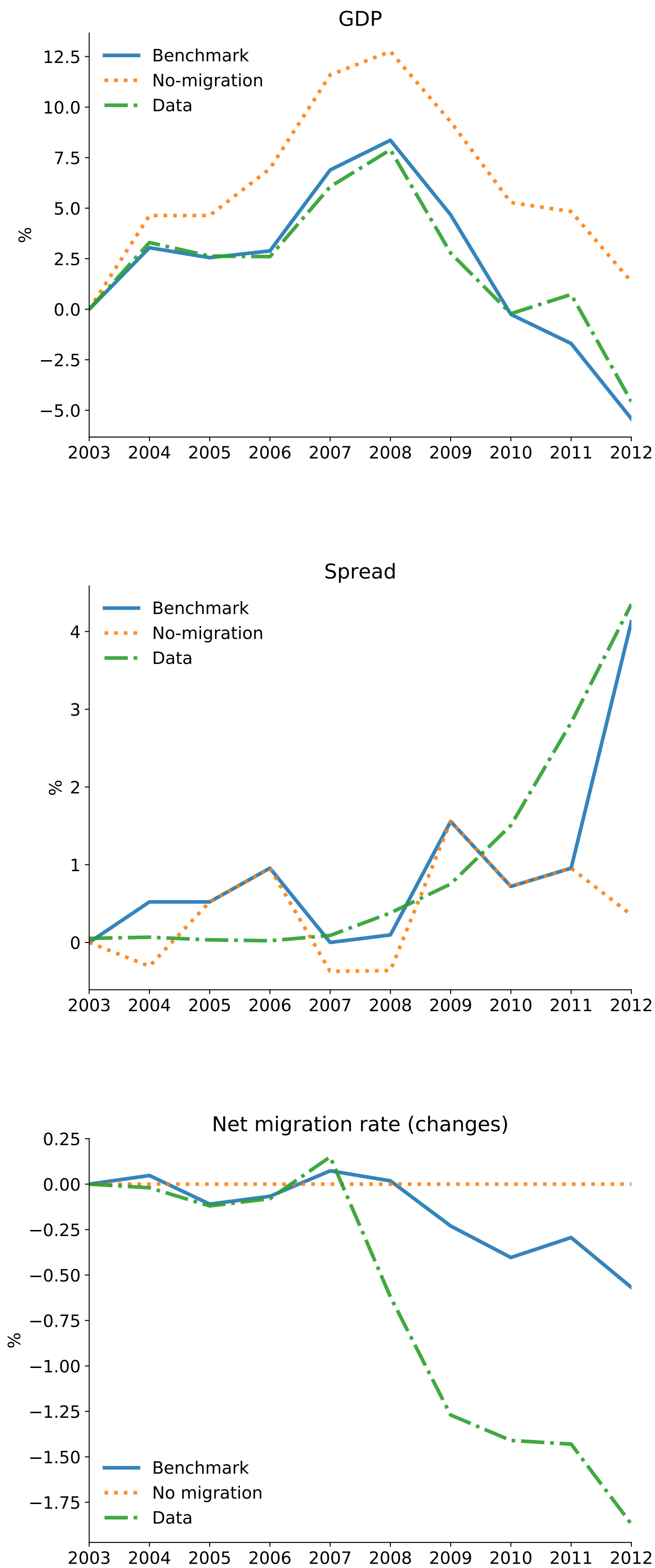


Figure 8: Event Analysis for Spain (Models and Data)

Online Appendix to "Migration and Sovereign Default Risk"

by George Alessandria, Yan Bai, and Minjie Deng

A 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 5 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.

Table 5: 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]

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 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 6 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%). Table 7 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 6: 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 9, 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

Table 7: 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.

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.

B More Stylized Facts

B.1 Government Bond Yield and Net Migration

Figure 10 and 11 plots the government bond yield and net migration rate for Greece, Ireland, Portugal, Spain and Germany during 1998-2015. Similar with the pattern in the main text, the net migration rate drops when government bond yield rises rapidly. For Germany, the government bond yield decreased from 1.4% to 0.5% from 2008 to 2015, 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.

C Robustness Check

Table 8, 9 and 10 provide robustness checks for empirical specification (1). Table 8 shows the result with lagged independent variables. Table 9 shows the result with both current and lagged independent variables. Table 10 presents the result when we substitute spread with lagged spread in Table 9.

D 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:

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

$$\frac{1}{L} V(z, K, L'(S), B) = v(s)$$

$$\frac{1}{L} V^c(z, K, L'(S), B) = v^c(s)$$

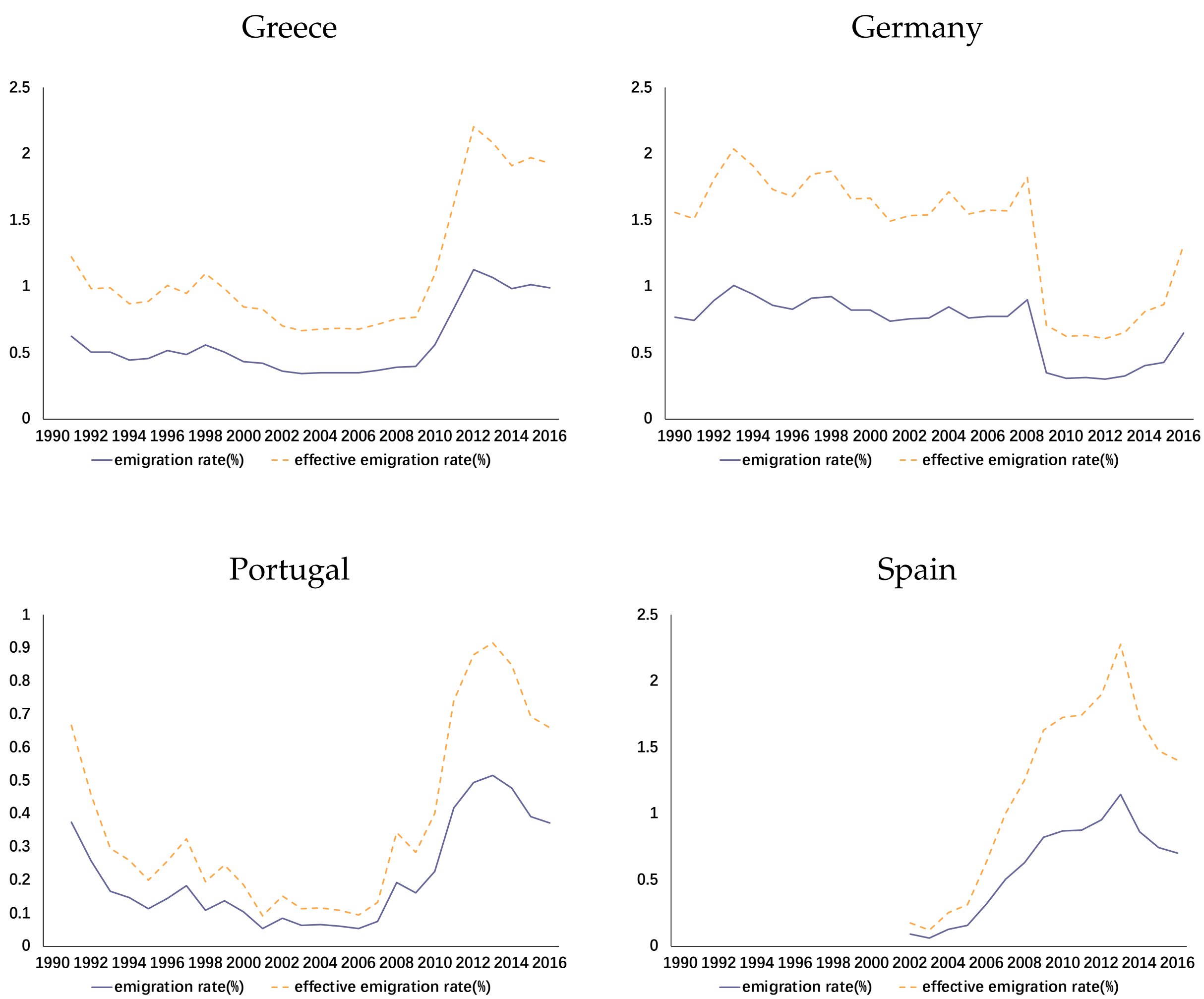


Figure 9: Effective Emigration Rate

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.

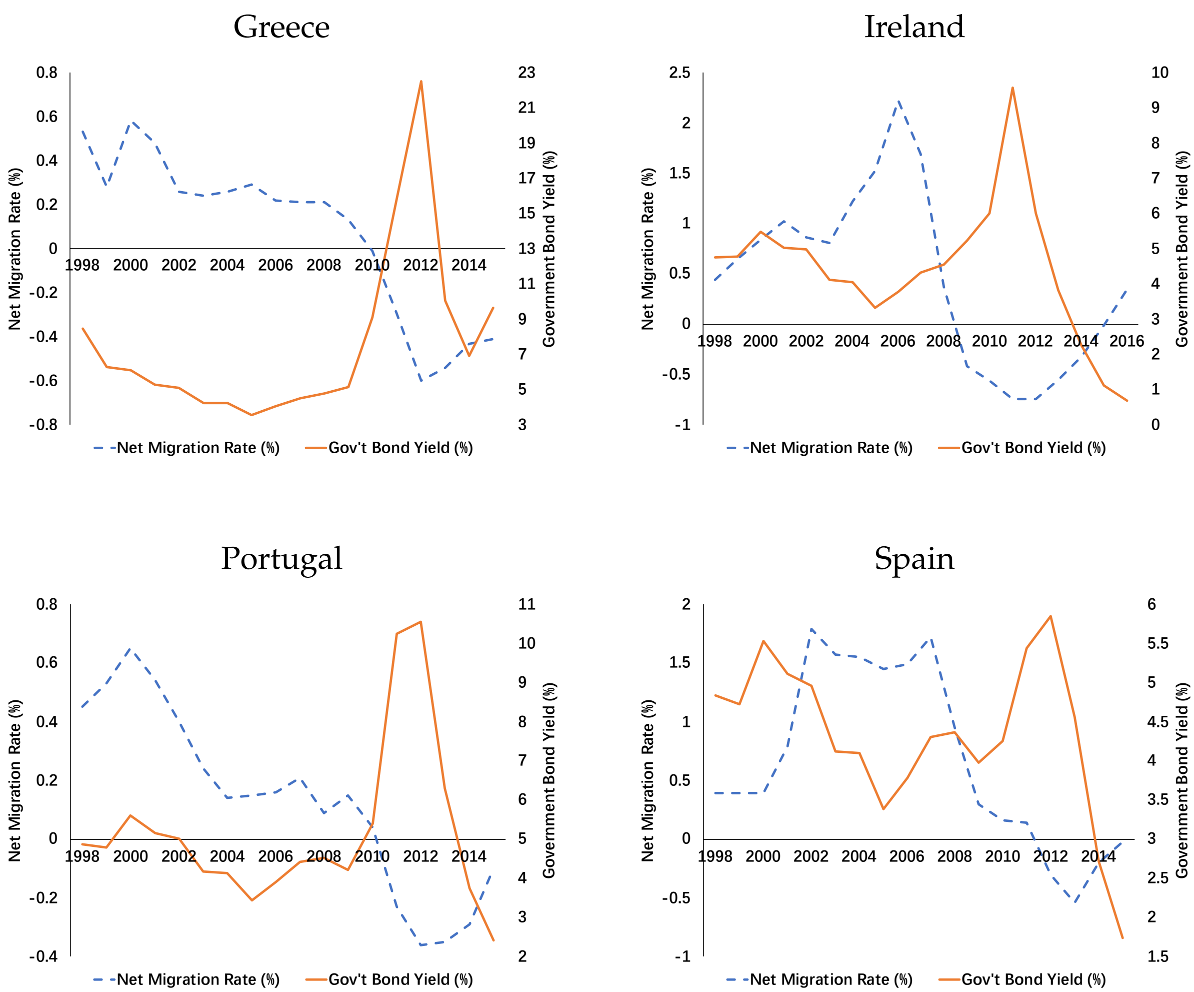


Figure 10: Government Bond Yield and Net Migration Rate

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).

Table 8: 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 9: 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 10: 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

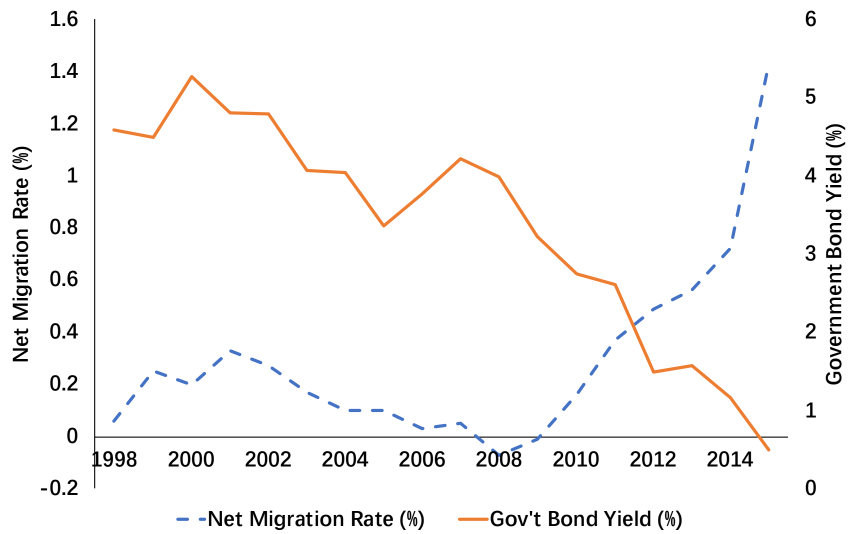


Figure 11: Government Bond Yield and Net Migration Rate in Germany

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).

$$\frac{1}{L}V^d(z,K,L'(S)) = v^d(z,k)$$

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

$$W^s(S,h) = w^s(s,h)$$

$$Q(z,K',L'(S),B') = q\left(z, \frac{K'}{L'(S')}, \frac{b'}{L'(S')}\right) = q(z,k',b')$$

$$c(s) = c(S)$$

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:

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

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

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

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

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:

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

which implies

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

Finally, for bond price schedule, we have:

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

E 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 20 equally spaced grid pints 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.