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Migration and sovereign default risk☆

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ABSTRACT

During sovereign debt crises, countries experience persistent economic declines, spiking spreads, and outflows of capital and workers. To account for these salient features, we develop a sovereign default model with migration and capital accumulation. The model has a two-way feedback. Default risk lowers workers' welfare and induces emigration, which in turn intensifies default risk by lowering tax base and investment. Compared with a no-migration model, our model produces higher default risk, lower investment, and a more profound and prolonged recession. We find that migration accounts for almost all of the lack of recovery in GDP during the recent Spanish debt crisis.

1. Introduction

Sovereign debt crises typically feature a persistent decline in economic activity, a dramatic increase in sovereign spreads, and significant outflows of capital and workers. For example, before 2007, Spain experienced an economic boom with substantial capital and labor inflows that expanded the labor force almost two percent per year. During the recent 2008 debt crisis, Spain's economic activity fell far below its pre-crisis trend and its trade balance reversed from deficit to surplus. Moreover, with a soaring spread, Spain's immigration declined dramatically, and the net migration rate became negative after 2011. In this paper, we reconsider these salient features in a unified framework with the focus on the interaction of default risk, capital flows, and migration. We show that changes in migration can account for a substantial fraction of the persistent decline in economic activity.

Default risk, capital flows, and migration reinforce each other. Facing a high borrowing cost from default risk, a government borrows less, and capital inflows fall. To repay its debt, the government has to increase taxes and reduces transfers,

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which in turn lowers resident welfare and increases their incentive to migrate out of the country. On the other hand, emigration decreases future capital returns, reduces investment, and erodes 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 larger capital outflows and an even deeper and longer recession. Our quantitative analysis shows that capital outflows and emigration help to explain the higher persistence of Spain's crisis on GDP rather than GDP per capita.

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 both in certain countries and within Europe with EU enlargement (Caliendo et al., 2017; Klein and Ventura, 2009).

We incorporate a migration decision and capital accumulation into a standard sovereign default model. The economy consists of a production technology using both capital and labor, a continuum of workers, and a central government. We consider a consolidated problem where the government makes choices of capital accumulation, labor, and international borrowing and default.[1] Workers make migration choices in the presence of an idiosyncratic stochastic migration cost. A worker leaves the country when either the staying value or the migration cost is low. The government can also default on its bond under the cost of productivity losses 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. 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 more elastic, which reduces the incentive to invest during the recovery period. Emigration provides further magnification by increasing the default risk. After a one standard deviation negative productivity shock, the per-capita GDP falls 5.6% in the benchmark model, 4.8% in the no-migration model, and 4.2% in the no-default-no-migration model. The fall in the aggregate GDP is even more significant in our model. Even 20 periods after the shock, the fall in aggregate GDP in the benchmark model is still 2.7 times the decline in the no-migration model and 3.5 times the decline in the no-default-no-migration model.

Despite the larger swings in national economic activity when migration is possible, we find agents prefer living in an environment with an option to migrate. This option is particularly valuable since it essentially puts a lower bound in the worst states of the world. Even for a worker who faces a high migration cost and always stays in the country, she may gain from migration because of the capital migrants leave behind. Thus, migration provides some insurance to both migrants and non-migrants alike.

We apply our framework to the recent debt crisis in Spain, which featured an increase in sovereign spreads together with a large outflow of workers. We focus on the peak-to-trough dynamics of GDP, sovereign spreads, and migration from 2008 to 2013 as well as the recovery through 2016. In the data, GDP per capita declines by 14%, spreads increase from 38 basis point to 435 basis point, and net migration rate drops from 0.95% to *negative* 0.54%. We choose an initial state on productivity, capital, and bond and a path of productivity shocks to minimize the distance between the model and the data in terms of GDP per capita, investment per capita, spreads, net migration rate, and the trade-balance-to-GDP between 2008 and 2016. Our model successfully replicates the crisis as well as the recovery. By 2016, we see that the aggregate GDP is only six percent below its initial level in the no-migration model, while it is down by 18% in our benchmark model and 21% in the data. Hence, migration accounts for almost all of the lack of recovery in the detrended GDP between 2013 and 2016.

Our model builds on the sovereign default model pioneered by Eaton and Gersovitz (1981), Arellano (2008), Aguiar and Gopinath (2006), and Yue (2010). Most work in the literature studies an endowment economy and abstracts from capital accumulation, except for Bai and Zhang (2012), Gordon and Guerron-Quintana (2018) and Arellano et al. (2018). Our contribution lies in providing a framework that embeds both capital accumulation and migration choice into a sovereign default model. The endogenous capital choice affects resident welfare, default risk, and borrowing cost; it, therefore, has a signifi-

[1] Alternatively, private agents can invest, borrow, and default internationally. In this case, due to pecuniary externality, the government has the incentive to impose taxes or subsidies to domestic investment and 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.

cant 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.

Most existing work that studies the connections between sovereign default and private sectors focuses on the link between sovereign spreads and firm behavior. Mendoza and Yue (2012) construct a 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 et al. (2017) measures the aggregate implications of sovereign risk with both 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 studies an emphasis on the interaction between the sovereign and private sectors during the debt crisis. We, however, emphasize the interplay between the sovereign and labor migration. In our paper, migration generates another source of endogenous default cost during a debt crisis. Our paper also relates to the literature on the interaction of sovereign default risk and labor market frictions, for example Balke (2016).

The amplification effect of financial frictions has been extensively studied in the literature, which goes back to Bernanke et al. (1999) and Kiyotaki and Moore (1997). Our work shares a mechanism similar to Mendoza (2010) and Arellano et al. (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 (2019) and Deng (2019) study debt and migration at the regional level of the U.S. in the presence of a public good. Similar to our approach, migration changes debt per person in each region. At the regional- or sub-regional level migration flows can be larger than at the national level while external indebtedness is much larger at the national than regional level. One sign of the importance of considering national migration in the European debt crisis is that there is a 10 percentage point difference in the change in detrended GDP and GDP per capita by 2018.

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. Bandeira et al. (2019) study migration in fiscal consolidations absent default considerations and apply these ideas to the Greek economy. Our paper differs in that we focus on sovereign default risk.

2. Spreads and migration during European debt crises

We now discuss the relationship between economic activity, migration, and default risk in Europe from the Great Recession to the European Debt Crisis and beyond. We emphasize that the countries at the core of the crises, Spain, Ireland, Portugal, and Greece, experienced a substantial reduction in net migration and all shifted from expanding to contracting populations. These reversals in labor flows appear to be above and beyond what can be explained by measures of current economic activity and are explained in part by the worsening outlook as captured by the rise in sovereign borrowing rates. Given the reporting of migration flows is annual, we focus on annual data.

With the start of the Great Recession in 2008, Greece, Ireland, Portugal, and Spain experienced a dramatic decline in aggregate activity, which eventually led to an increase in sovereign spreads. Meanwhile, capital and workers began to flow out of these countries. To construct spreads, we take the government ten-year bond yields from the OECD database. Spreads are the difference between government bond yields and that in Germany. We take the migration data from International Migration statistics from Eurostat because it has the most consistent definition of migrants among all the available data sets.[2] We define the net migration rate as the ratio of net migration (inflows minus outflows) during the year to the average population in that year. A positive net migration rate means inflows outweigh outflows.

There is a strong negative relationship between net migration and sovereign spreads. Fig. 1 plots government bond spreads on long-term debt and net migration rates for Greece, Ireland, Portugal, and Spain from 2008 to 2015. The Greek spreads, for instance, increased by more than 20% in 2009–2012. During this period, the net migration rate fell by almost one percentage point. 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 considering the previous large immigration inflows. The average annual net migration rate was 1.2% in 2000–2009 and dropped to −0.13% in 2010–2016.[3]

To further confirm the correlation between sovereign default risk and net migration, we conduct a panel regression of net migration rates on government spreads and other control variables using 23 European countries from 2008 to 2016.[4]

[2] Other datasets include (a) International Migration Flows to and from Selected Countries by the United Nations (b) International Migration Database by OECD, (c) Database on Immigrants in OECD and non-OECD Countries (DIOC-E), and (d) Global Bilateral Migration Database by World Bank. DIOC-E supplies more detailed characteristics of migrations, for example, age and education. See Appendix A for details.

[3] A similar negative relationship holds for government bond yields and net migration rates. See Appendix B for Germany, Greece, Ireland, Portugal, and Spain.

[4] List of countries: Austria, Belgium, Czech Republic, Denmark, Finland, France, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Netherlands, Norway, Poland, Portugal, Slovenia, Spain, Sweden, Switzerland, and United Kingdom. Germany is not in the list due to the construction of government spreads.

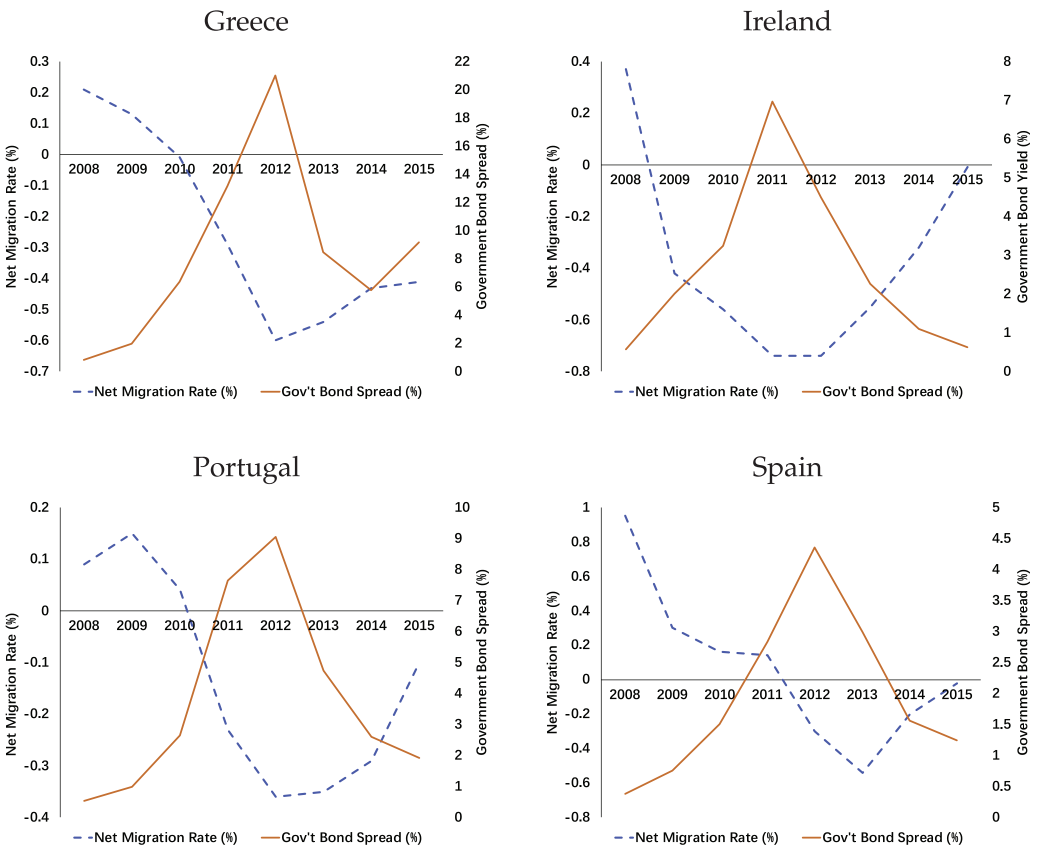

Fig. 1. Government bond spreads and net migration rate.
Notes: Net migration rate is defined as the ratio of net migration during the year to the average population in that year (dashed line, left axis). Spreads are defined as the difference between the government ten-year bond yield and that in Germany. (solid line, right axis).

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 j denotes country, t time, m_{jt} net migration rates, α_j the country fixed effect, sp_{jt} government spreads, y_{jt} per-capita real GDP, and Z_{jt} 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 dynamics of the world economy. The data of GDP, exchange rate, and price level are from the Penn World Table 9.1 and the data for unemployment rate is from IMF. We logged and HP-filtered all variables except net migration rates and spreads.

Table 1 presents the regression results. Among our European countries, net migration is positively related to economic activity and negatively related to spreads and unemployment. Depending on our specification, we find a regression coefficient of −0.02 to −0.10 on spreads. Thus, going from no spread to a 4% spread, as in the case of Spain, would lower net migration by −0.08% to −0.40%. In Appendix C, we show these effects are larger if we lag all variables to take into account the fact that it takes time to migrate. Likewise, if we exclude Greece from our analysis, the effect of spreads on migration will be 50% larger. This finding may seem counter-intuitive since Greece had a relatively large net migration reversal. The reason is that it also experienced the largest rise in spreads, which lowers the elasticity of migration to spreads. In Appendix A, we show that Greece's migration reversal is larger when measured by the persistence of the reversal and adjusting for the skill level of migrants.

In summary, the European debt crises has been characterized by both high government spreads and a reduction in net migration. In the next section, we present a theory of migration and sovereign default risk.

3. Model

We now describe our model of sovereign default, capital accumulation, and migration. We consider a small open economy with a production technology, a continuum of workers, and a benevolent government. The aggregate output Y is produced with capital K and labor L using a Cobb-Douglas production function $Y = zK^{\alpha}L^{1-\alpha}$ where z is the stochastic productivity. The government borrows state-uncontingent bonds internationally and can default on them with the punishment

Table 1
Regression of net migration on government bond spread.

	(1)	(2)	(3)	(4)	(5)
Spreads	-0.10^{***}	-0.02^{*}	-0.10^{***}	-0.10^{***}	-0.02^{*}
	(0.02)	(0.01)	(0.02)	(0.02)	(0.01)
GDP	2.19^{*}	3.93^{***}	0.10	0.28	1.53
	(1.31)	(0.75)	(2.28)	(2.32)	(1.23)
Unemployment			−0.52	−0.61	-0.74^{***}
			(0.43)	(0.46)	(0.25)
Exchange rate			−2.21	−2.34	−2.05
			(2.40)	(2.42)	(1.28)
Price levels			−1.45	−1.59	−1.41
			(2.33)	(2.35)	(1.24)
US GDP				−2.20	−2.44
				(4.43)	(2.33)
Constant	0.42^{***}	0.27^{***}	0.42^{***}	0.41^{***}	0.26^{***}
	(0.05)	(0.03)	(0.05)	(0.05)	(0.03)
N	205	205	205	205	205
R^2	0.226	0.204	0.240	0.241	0.266
Country FE		yes			yes
Country controls			yes	yes	yes

Source: Eurostat, OECD, IMF, Period: 2008–2016. All variables except for spreads are HP-filtered. Standard errors in parentheses. * $p < .1$, ** $p < 0.05$, *** $p < 0.01$.

of lower productivity and exclusion from international markets for some periods. Our main departure from the canonical sovereign default model is the introduction of an endogenous stock of working residents. This stock evolves as a result of migration decisions.

3.1. Workers and the government

Workers have a discount factor β and a constant relative risk aversion utility function over consumption c,

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

where σ is the risk aversion parameter. Each period, a worker makes a discrete choice to stay or emigrate abroad. If she emigrates, the worker receives an exogenous and constant value W^m but must also pay the stochastic and idiosyncratic migration cost, δ_m, and does not work in the country in the current period. If she stays in the country, the worker remains as a home resident, provides one unit of labor inelastically, and receives lump-sum transfers from or pays lump-sum taxes to the government. The migration cost δ_m follows an exponential distribution with the cumulative distribution function $F(x) = 1 - e^{-\zeta_m x}$ where ζ_m is a constant parameter.

There is also an exogenous inflow of workers every period. The immigration rate at period t $m(z_t)$ depends on period t's productivity, $m(z_t) = \bar{m}\exp(z_t/\bar{z} - 1)$ where $\bar{m}$ is a constant and $\bar{z}$ is the mean productivity.[5] This is a reduced-form way to capture the cyclical movements in immigration and is similar to the approach of Neumeyer and Perri (2005) in modelling a country risk premium on international borrowing. All staying workers are identical in terms of their consumption, work, and transfers received.

The government is benevolent and cares about the social welfare as in Hall and Jones (2007)[6],

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t L_t u(c_t)$$

where L_t is the mass of remaining workers and c_t the consumption per capita at period t. The government can only issue state-uncontingent bonds internationally and can default on these obligations. Default involves a cut in productivity $z_d(z) \le z$. Following a default, the country receives a bad credit standing, $h = 1$, and is excluded from capital markets for a random period of time. With probability λ, the country in default regains a good credit standing $h = 0$ and access to international borrowing and lending. It is also no longer subject to the productivity losses. Following the sovereign default literature, we assume that only the government can borrow and lend internationally and that the government rebates all the proceeds back to the workers in a lump-sum fashion. While this implies that the government makes all consumption and investment

[5] Implicitly, we are assuming that emigration permanently affects the level of population and that emigrants are no more likely to return than foreign citizens.

[6] Unlike Hall and Jones (2007), we do not include a positive constant term in the per-period utility. Even without this positive constant term, the government still has an incentive to keep workers in the country to reduce the debt burden per capita. We also run a robustness check with a utility $\bar{u} + u(c)$ with $\bar{u} = 4$, a value consistent with the empirical estimates of the value of statistical life in Viscusi and Aldy (2003). The results of the estimated model under $\bar{u} + u(c)$ are similar to our benchmark. Results are available upon request.

decisions, we assume that individuals make self-interested migration decisions. Furthermore, the government does not affect the costs or external benefits of migration.

3.2. Recursive formulation

Each period the economy starts with a level of exogenous productivity, z, capital, K, public debt, B, a mass of workers L, and the credit standing h. Hence the aggregate state of the economy is summarized by (S, h) where $S = (z, K, B, L)$. 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, workers decide on whether to emigrate. Let a worker'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. If it repays then it chooses new borrowing and its state becomes (S_g, h) with $S_g = (z, K, B', L')$.

3.2.1. Migration choice

A worker chooses whether to migrate to maximize the value,

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

where W^s denotes the value if she stays in the home country and W^m is the value after she pays the migration cost and emigrates. The staying value is given by

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

where $H_c(S, h)$ is the per-capita consumption depending on the government's choice on default, borrowing, and investment. It is easy to see that there is a threshold migrate cost for emigration. A worker stays if and only if her migration cost is high enough, i.e. $\delta_m \geq W^m - W^s(S, h)$. Under the exponential distribution, the probability of staying in the home country is given by

$$Pr(\delta_m \geq W^m - W^s(S, h)) = e^{-\zeta_m (W^m - W^s(S,h))}. \tag{3}$$

Together with immigration function $m(z)$, the share of emigration (3) determines the next period's measure of workers,

$$L' = H_L(S, h) = e^{-\zeta_m (W^m - W^s(S,h))}(1 + m(z))L.$$

3.2.2. Default, borrowing, and investment

The government recognizes that its decisions to borrow, invest, and default affect the migration decisions of agents and the future stock of active citizens in the economy.[7] The government in the normal phase chooses whether or not to default to maximize the stayers' welfare:

$$V(z, K, B, L') = \max\left\{V^c(z, K, B, L'), V^d(z, K, L')\right\} \tag{4}$$

where V^c denotes the non-defaulting value and V^d the default value. Let $D(z, K, B, L') = 1$ 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:[8]

$$V^c(z, K, B, L') = \max_{C, B', K'} \quad L' u\left(\frac{C}{L'}\right) + \beta \mathbb{E}[V(z', K', B', H_L(S', h' = 0))] \tag{5}$$

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 GDP is produced with current capital stock, K, and post-migration workers, L', θ is the capital adjustment cost, $Q(z, K', L', B')$ is the bond price, which depends on the population after migration, the government's new borrowing and investment. It compensates lenders for the government's future default risks.

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. 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:

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

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[7] We abstract from many dimensions of resident heterogeneity. A particularly stark implication is that the government cares equally about non-citizen residents and citizen residents. For migration by European citizens with the E.U. this might be a reasonable approximation given that there are many non-discrimination provisions in E.U. law.

[8] Here the government cares about the total utility, i.e. the product of measure of workers and per-capita utility. In Appendix, we consider some alternative preferences in which either the government cares about per-capita utility only or the government also cares about the welfare of emigrants. Both preferences yield similar results.

subject to the budget constraint

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

During default, the country cannot borrow or save internationally. It, however, can still self-insure through capital accumulation.

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

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

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 the endogenous population L'.

3.2.3. Recursive equilibrium

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

1. Taking as given the consumption function $H_C(z, K, B, L, h)$, a worker's migration choice $\iota(S, h, \delta_m)$ and value functions $W(S, h, \delta_m)$ and $W^s(S, h)$ solve the worker's problem (2).
2. Taking as given the migration function $H_L(z, K, B, L, h)$, the government's choice of $D(z, K, B, L')$, $B'(z, K, B, L')$, $K'(z, K, B, L')$, $C(z, K, B, L')$, $C^d(z, K, B, L')$ and $K^{d\prime}(z, K, B, L')$ and its value functions V, V^c, V^d solve the government's problem (4).
3. Consistency. The per-capita consumption function is consistent with the government's optimal choice, $H_C(S, h = 0) = C(z, K, B, H_L(z, K, B, L, h = 0))/H_L(S, h = 0)$ 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.

One might be concerned that the model could have self-fulfilling equilibria where expectations of future default owing to expectations of a large outflow of workers leads to a larger outflow and default. While we cannot rule out such equilibria, we generally are not too concerned about them given the idiosyncratic costs of migration and the tendency of default to actually raise the return to staying. Moreover, traditional solution techniques work well suggesting those equilibria, if they exist, are unstable.

3.3. Transformed problem

Our model can be viewed as a neoclassical growth model of a small open economy with default frictions and persistent productivity shocks that permanently change the population. With permanent changes in population the government's problem is not stationary, but detrending by population yields a stationary model in per capita terms. We normalize the aggregate variables in per-capita terms denoted by lower case letters. Let the worker's per-period utility given by $u(c) = \frac{c^{1-\sigma}}{1-\sigma}$ where c is consumption per capita. Let the state be (s, h) with $s = (z, k, b)$ with $k = K/L$ and $b = B/L$ the per-capita capital and debt before migration, respectively.

The value of a worker is given by $w(s, h, \delta_m) = \max\{w^s(s, h), \quad w^m - \delta_m\}$. If the worker stays in the home country, his value 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 $h_g(s, h) = e^{-\zeta_m(w^m - w^s(s,h))}(1 + m(z))$.

Taking as given the current population growth g after migration, the government first chooses whether or not to default depending on the 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

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

subject to the budget constraint

$$c + b/g = z(k/g)^{\alpha} - \left[k' - (1-\delta)(k/g) + \frac{\theta}{2}\left(\frac{k'}{(k/g)} - 1 + \delta\right)^2 (k/g)\right] + q(z, k', b')\, b', \tag{6}$$

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. Notice that the capital stock and debt are deflated by population growth, g. We interpret this as the migrant gives up its claims to a share of capital income and defaults on its obligations to repay government. One can consider this as an exit tax.

The defaulting value is given by

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

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 $g_1'=h_g(z',k',0,h'=1)$ if the country remains in financial 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 $h_c(s,1)=c_d(z,k,h_g(z,k,b,1))$.

3.3.1. Migration and default risk

To clarify the role of migration on the government's default choices, we revisit the budget constraint (6) in the normal phase with no 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 the next periods capital stock, k', debt, b', and consumption per capita c to maximize its value (5). Migration has two effects here. On the one hand, higher net 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 with 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 role of the capital stock in the debt burden effect is unique to our model of sovereign default.[9]

4. Quantitative analysis

We evaluate the quantitative properties of the model in this section. We first parameterize the model to the Spanish economy. Next, to illustrate the key interaction between borrowing and migration, we plot the bond spread schedules. We also discuss how welfare is influenced by the option to migrate. We then study the impulse responses to a productivity shock for our benchmark model and two alternative variations, one without migration choice and one without migration and default risk. In our model, default risk and migration interact and generate a significant and persistent contraction in output during recessions. We also explore the impulse responses to a migration shock. We then conduct an event analysis to see how much the model can generate the stylized facts of the Spanish recession, in particular, the joint outflows of capital and labor and the rise of sovereign default risk.

4.1. Parameterization and moments

We assume that the productivity shock z follows a first-order autoregressive process:

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

where ρ_z captures the persistence of the shock, and the innovation ε_t follows a normal distribution of mean zero and standard deviation of η_z. After default, productivity takes a form in the fashion of Chatterjee and Eyigungor (2012), $z_d(z)=z-\max\left\{\chi_1 z+\chi_2 z^2,0\right\}$ with $\chi_1<0<\chi_2$. Under this form, the productivity loss, $\max\left\{\chi_1 z+\chi_2 z^2,0\right\}$, is higher for countries that default under a higher level of productivity. We solve the model with global methods. Appendix E reports details of the computational algorithm employed to solve for the model's equilibrium.

We consider an annual model and parameterize it to match the key properties of the Spanish economy from 1980 to 2017. Given our aim is to understand some of the persistent movements in economic activity, we consider the properties relative to a long-run trend (HP smoothing parameter of 10^5) in annual data. 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 chosen to match relevant empirical moments jointly (see Table 2). The first group includes $\{\sigma,\ r,\ \delta,\ \lambda,\ \rho_z,\ \alpha\}$. We set the risk aversion σ at 2 and the risk-free rate r at 4%. The depreciation rate takes a standard value of 10% for annual data. The return parameter λ is

[9] Gordon and Guerron-Quintana (2019) discuss a related debt burden effect in the presence of a fixed stock of housing.

Table 2
Parameters.

Assigned parameters	
Risk aversion σ	2
Risk-free rate r	4%
Capital depreciation rate δ	0.1
Return probability λ	0.25
Productivity persistence ρ_z	0.9
Capital share α	0.5
Moment-matching parameters	
Productivity volatility η_z	0.018
Discount factor β	0.83
Penalty parameter χ_1	−0.40
Penalty parameter χ_2	0.48
Capital adjustment cost θ	4
Migration cost distribution ζ_m	0.0105
Exogenous inflow $\bar{m}$	0.086

chosen to be 0.25 so that defaulting countries are excluded from international financial markets for four years on average, consistent with the finding in Gelos et al. (2011). The persistence of the productivity process ρ_z is set to be 0.9, comparable with many international real business cycle studies.

We choose the capital share α as 0.5, higher than the standard value. Here is the reason. As in the standard sovereign default model, the calibrated discount factor is lower than the risk-free rate to allow the model to generate reasonable default rates. A low $\beta(1+r)$ reduces investment incentives, which in turn leads to a low investment rate on average. To make the model generate a reasonable default rate and investment rate, we increase the capital share α. Alternatively, we can increase the depreciation rate as in Gordon and Guerron-Quintana (2018). The model with high depreciation rate behaves like the no-capital model in Section 5.2.

The second group includes seven parameters: standard deviation η_z in the productivity process, the discount factor β, the default cost parameters χ_1 and χ_2, capital adjustment cost θ, and the migration parameters ζ_m and $\bar{m}$. We choose these parameters to jointly target the following moments of Spanish data: the volatility of GDP per capita 6.3%, the average and volatility of spreads of 1% and 1.2%, the volatility of trade-balance-to-GDP of 3.4%, the ratio of investment volatility to GDP volatility of 3, the mean and volatility of net migration rate: 0.68% and 0.78%. Even though we chose all these parameters jointly, we can give a heuristic description of how the sample moments included in the estimation inform specific parameters. As is standard, the capital adjustment cost θ matters mostly for the investment volatility. The default cost parameters and the discount factor affect most of the average and volatility of spreads and the debt adjustment. Default costs also affect the investment incentives, and hence shape investment dynamics. The volatility of productivity shocks affects the volatility of GDP, investment, and spreads. The mean and volatility of migration are informative about the migration parameters ζ_m and $\bar{m}$.

The first two columns in Table 3 report the targeted and non-targeted moments of the data and the benchmark model. Our model closely matches the target moments and contains additional business cycle co-movements that are consistent with the data. During debt crises, spreads spike, and capital and labor flow out of the country. These happen both in the data and in the model. The correlations of spread with GDP per capita, trade balance-to-GDP, and migration are −83, 72, −77% in the data, and −17, 12, −24% in the model, respectively. The co-movements are smaller in our model due to the quick debt adjustment after shocks under a one-period debt model.[10] Our model produces countercyclical trade-balance-to-GDP, though lower than the data. Migration is also positively correlated with GDP with a correlation of 77% in the data and 96% in the model.

4.2. Reference models

To emphasize the amplification effect arising from migration, capital flows, and default risk, we compare our benchmark model with 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 canonical model in the sovereign default literature by allowing for capital accumulation. The model is similar to Bai and Zhang (2012) and Gordon and Guerron-Quintana (2018) but with a one-period bond and a small open economy. By comparing the no-migration and benchmark model, we can figure out how much the migration channel contributes to the business cycle dynamics. The no-default-no-migration model has little financial frictions and is close to Mendoza (1991). Both reference models share the same parameter values as the benchmark except that the no-

[10] There are two alternatives to fix these co-movements: fixed cost of issuing debt or long-term debt. Adding long-term debt exacerbates the convergence problem since our model has both migration choice and sovereign default. Future decisions shape current migration and default decisions, which in turn dictates future decisions. We therefore stick to the one-period debt and no fixed issuing cost as the early sovereign default literature, for example Arellano (2008), Aguiar and Gopinath (2006), and Yue (2010).

Table 3
Data, benchmark, and alternative models.

	Data	Benchmark	No-migration	No-default No-migration	No capital	No exit tax
Targeted Moments						
Std. GDP (%)	6.30	6.29	6.20	5.64	3.63	7.95
Avg. spread (%)	1.02	1.02	0.62	0	0.91	0.94
Std. spread (%)	1.21	0.64	0.40	0	0.85	0.58
Std. trade balance/GDP (%)	3.44	3.48	2.67	2.03	2.94	3.45
Std. investment/Std. GDP	2.98	3.69	2.52	1.92	0	3.32
Avg. net migration rate (%)	0.68	0.68	0	0	0.67	0.68
Std. net migration rate (%)	0.78	0.55	0	0	0.37	0.58
Non-Targeted Moments						
Std. Aggregate GDP (%)	6.62	6.84	6.20	5.64	4.02	8.52
Std. consumption %)	6.74	5.55	5.82	5.84	5.16	6.68
Correlation with spread (%)						
GDP	-83	-17	-10	–	-11	-17
Trade balance/GDP	72	12	6	–	26	14
Net migration rate	-77	-24	–	–	-14	-22
Correlation with GDP (%)						
Trade balance/GDP	-67	-3	1	-6	-23	-17
Net migration rate	77	96	–	–	100	96
Parameters different from benchmark						
Risk-free rate r		0.04	0.04	0.2	0.04	0.04
Capital share α		0.5	0.5	0.5	0	0.5
Penalty parameter χ_2		0.48	0.48	0.7	0.48	0.48
Capital adjustment cost θ		4	4	4	0	4
Exogenous inflow $\bar{m}$		0.086	0	0	0.072	0.0775

Notes: This table reports the moments for data and models, as well as the alternative parameters that are adopted for alternative models. *GDP*, *consumption*, and *investment* in the table refers to per capita terms. Column "No-migration" corresponds to the reference model that shuts down migration compared with the benchmark model. Column "No-default No-migration" refers to the reference model that further shuts down default. We discuss "No-migration" and "No-default No-migration" models in details in Section 4.2. Column "No exit tax" refers to a case where migrants can take their share of the capital stock with them (Section 5.1). Column "No capital" corresponds to a model without capital accumulation (Section 5.2).

default-no-migration model has a high default cost α_2 and a risk free rate of 0.2. We pick the value of risk free rate to make $\beta(1+r)$ close to 1 and the range of debt close to the benchmark levels. This ensures that the capital-output ratio is similar across models and that the country is not at its borrowing constraint as would be the case if $\beta(1+r) << 1$. Parameters for the reference models are reported in the bottom panel of Table 3. The comparison between the no-default-no-migration and the no-migration model brings out the effect of default risk on capital flows during a recession.[11]

We now compare the moments of the benchmark model with those of the reference models, which are shown in Table 3. The no-migration model has similar volatility of GDP as in the benchmark, but it has more stable trade balance and investment, both about 70% variation of the benchmark model. The average spread is also smaller, 62 basis points, compared to 102 basis points in the benchmark. These numbers demonstrate the effect of migration on default risk and capital flows. Emigration during bad times worsens the country's ability to repay and hence increases default risk and the spread in the benchmark model. A tightened spread schedule further reduces the capital flows and lowers the volatility of trade balance and investment. Without migration, spread is also less correlated with GDP, changing from -17% in the benchmark to -10% in the no-migration model.

The no-default-no-migration model has a further reduction in volatilities. The volatility of GDP decreases from 6.3 to 5.6 from the benchmark, and the volatility of trade-balance-to-GDP ratio is less than 60% of the benchmark, so is the investment volatility. Note that the results are similar if we choose a higher β instead of a higher r.

4.3. Migration, spreads, and workers' welfare

In this section, we explore the impact of migration on default decisions, spread schedule, and workers' welfare. We start with how repaying and default values change with migration. We then present the bond spread schedules as a function of productivity, borrowing, capital, and migration. We then discuss the size of the welfare gain of workers from migration.

We first consider how an exogenous change in population growth from migration, g, affects the default decision of the government. Fig. 2 plots the value of repaying, v^c, and the defaulting value, v^d, as a function of exogenous population growth rate, g, at the median level of productivity, capital per worker, and debt per worker (z, k, b) in the limiting distribution. First, both values decrease with g showing that the congestion effect of capital dominates. Worker inflow reduces the both the repaying and defaulting value of current residents since each one has lower capital and output per capita. The decline

[11] We also considered an alternative paramaterization: fixing the risk-free rate at 4% and increasing the discount factor such that the bond is not bounded. The business cycle moments and impulse response functions are quite similar.

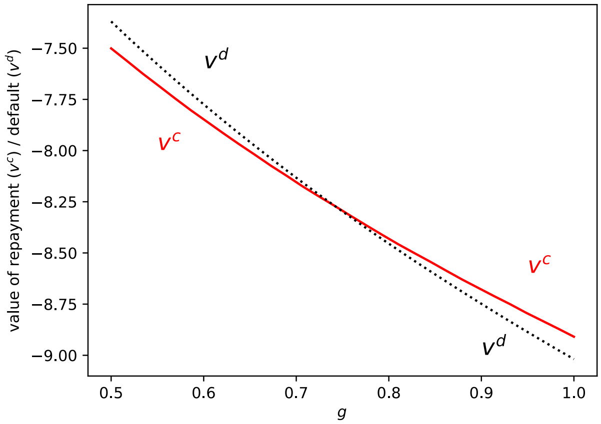


Fig. 2. Value of repayment/default as a function of exogenous g.
Notes: This figure plots the value of repayment (solid line) and the value of defaulting (dotted line) as a function of exogenous g, respectively.

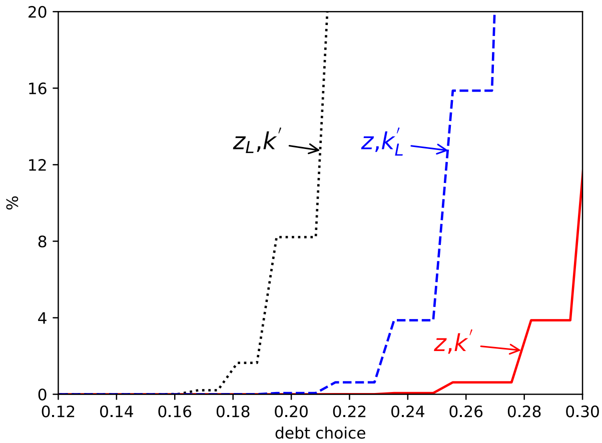


Fig. 3. Bond spread schedule.
Notes: This figure plots bond spread schedule as a function of debt choice. The solid line plots for median productivity and median capital. The dotted line plots for low productivity and median capital and the dashed line plots for median productivity and low capital.

of defaulting value, however, is faster than that of the repaying value. The reason is that high population growth, g, also reduces the debt burden per capita, which mitigates the reduction in v^c. Hence when population growth g is low, the country is more likely to default since v^d is higher than v^c. In our baseline model, the migration g is endogenous. It is high when productivity and capital are high or when the debt is low.

In our model, given the current realization of productivity, z, each combination of per-capita borrowing and next period capital is associated with a different bond price, summarized by the bond price function $q(z, k', b')$. The spread is defined as the inverse of the bond price minus the risk-free rate, $sp = 1/q(z, k', b') - (1 + r)$. Fig. 3 plots the bond spread as a function of debt choice under different levels of productivity and capital. The solid line plots the spread schedule under the median productivity and capital. At each level of (z, k'), higher borrowing increase future default probability, which generates a higher spread. The bond spread is higher when productivity is low or when the capital stock is low-lower productivity or capital stock associates with a lower debt repayment capacity, which increases default risk today.

To see the role of migration on default risk, we also compare the benchmark spread schedule with that in the no-migration model in Fig. 4. Both spread schedules plot as the function of debt choice b' under the median productivity level z and the median capital k' from each limiting distribution. The median k' is 0.72 in the benchmark and 1.63 in the no-migration model. Our benchmark model faces higher spread schedule for the same level of debt. The borrowing limits are also smaller in our benchmark model. The spread schedule is tighter in our model because high borrowing leads to less migration tomorrow, which increases the defaulting value, v^d, more than the repaying value, v^c, as shown in Fig. 2.

We now show that residents value the option to migrate even if it may lead to deeper and more persistent downturns for the nation as a whole. Fig. 5 plots three values as a function of capital for the median level of productivity and debt in the benchmark model. The first value, the solid line, is the worker's value $w^s(s, h)$ conditional on staying this period. This value includes the current utility of staying plus the future value with the option to leave. The second value, the solid line,

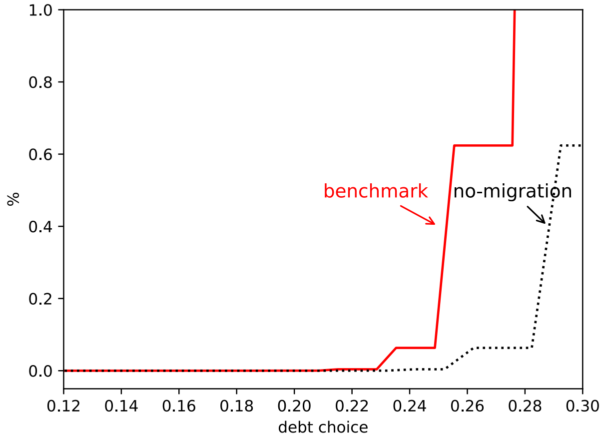


Fig. 4. Bond spread schedule: comparison.
Notes: This figure plots the spread schedule as a function of debt choice for the benchmark (solid line) and the default-no-migration model (dotted line).

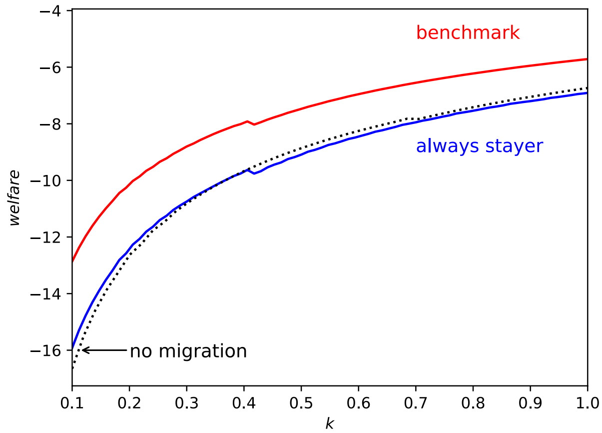


Fig. 5. Welfare comparison.
Notes: This figure plots welfare as a function of capital for stayers in the benchmark (solid red line), always stayers in the benchmark (solid blue line), and workers in the default-no-migration model (dotted black line). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

is a hypothetical value for a worker who always stays in the economy. We can view this is the realized value when the worker always draw a very high migration cost δ_m. Specifically, the welfare of the always stayer is constructed recursively as

$$w^{as}(s,h) = u(h_c(s,h)) + \beta \mathbb{E} w^{as}(s',h').$$

The difference between the value of an always stayer and the worker's value capture the option value of migration. The last value, the dotted line in the figure, is the value function in the no-migration model. The gap between this value and the value for an always stayer w^{as} captures the effect of migration other than the outside value, for example the congestion effect through k/g and the debt burden effect through b/g.

We make several observations. First, the worker's welfare is always higher in our benchmark than in the model with no-migration. By comparing welfare of a representative stayer with that of an always stayer we establish that a majority of the welfare gain is due to the option value of migration. Second, when the capital stock is large, the welfare of an always stayer w^{as} is lower than the welfare in the no-migration model. The reason is that high k deters emigration, which tends to increase population faster and thus lower the capital per capita and welfare. Lastly, migration also serves as a tool for risk sharing. The relative consumption volatility in our benchmark model is 0.88, while it is 0.94 in the no-migration model.

4.4. Impulse response functions

In this section, we first present the impulse response functions (IRF) to a negative productivity shock. To highlight the role of default risk and migration, we compare the IRFs in our benchmark model with those in no-default-no-migration and no-migration model. We then consider the IRFs to a one-time negative migration shock.

4.4.1. IRFs to productivity shock

To construct the IRFs, we simulate 30,000 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, capital, and credit standing converges to the limiting distribution. In period 401 (period 1 in the plots), we introduce a one-standard-deviation drop in the productivity shock. From period 401 on, the productivity shocks follow again its underlying Markov process. The impulse response functions plot the average, across the 30,000 paths, of the variables. Fig. 6 plots IRFs for investment per capita, GDP per capita, spreads, the ratio of trade balance to GDP, migration, default probability, average productivity, and the aggregate GDP. The solid lines are for our benchmark model, the blue dashed lines are for the no-default-no-migration model, and the dotted lines are for the no-migration model.

In all the models, after the adverse and persistent productivity shock, investment and GDP fall, capital flows out of the country as the trade balance increases. The standard mechanism applies here. An adverse productivity shock lowers the expected future investment return and generates a fall in investment. GDP per capita plummets due to both low productivity and falling capital stock from the reduction of investment. Under the low investment returns, capital flows out of the country. In the no-default-no-migration model, the country borrows more to smooth consumption, but the investment effect dominates, and overall trade balance increases.

Comparing to the no-default-no-migration model, the no-migration model has a much more significant drop in investment and a larger increase in the trade-balance-to-GDP ratio. The key is the presence of default risk in the no-migration model. The persistent low productivity induces higher default risk in the future. As a consequence, lenders tighten the bond spread schedule, as shown in Fig. 3. Spreads increase from about 0.6% to 0.8%, as shown in the no-migration line in Panel (d). With the higher spread schedules, the government has to reduce investment and consumption to repay the debt; the trade balance goes up by an extra 3% in the no-migration model than the no-default-no-migration model. By construction, there are no changes in the mass of workers in the models without migration. Hence the net migration rates in the no-migration model and no-default-no-migration model remain at zero in panel (e).

Our benchmark model features both default risk and migration. Facing a gloomy future, workers migrate out of the country; the population growth rate declines by 0.5%, as shown in panel (e). The smaller workforce, in turn, pushes down investment returns, leading investment per capita to drop even further, almost by 44%, as shown in the solid line in panel (a). GDP per capita also falls by more and spreads go up from 0.8% to 1.6%. On impact, default rates also increase in the no-migration and the benchmark model. During default, the country suffers further losses in productivity. Hence, the average productivity in the benchmark model declines by an extra 0.8% as shown in panel (f).

On impact, the increase in the trade-balance-to-GDP ratio in the benchmark is almost the same as in the no-migration model. This may be surprising given the stronger decline in investment, but there are two competing forces here. On the one hand, the extra decrease in investment and the increase in spread drives capital out of the country, generating a larger rise of trade balance in the benchmark model. On the other hand, a large increase in equilibrium default reduces trade balance. Here is the reason. The impatient country runs a positive trade balance on average since it holds debt and has to repay in the limiting distribution. After default, the trade balance reduces to zero. In the current parameterization, the two working forces happened to cancel each other; the increases in the trade-balance-to-GDP are the same in the two default models. Conditional on not defaulting, our benchmark model has a larger increase in trade balance, as shown in panel (c) of Figure 15 in Appendix.

The decline of per-capita GDP in the benchmark model is 0.76% larger than that in the no-migration model and 1.4% larger than that in the no-default-no-migration model. Among the 0.76% extra decline of GDP, about 80% is due to the additional TFP loss from default. Gordon et al. (2018) find that about a third of the drop in GDP following default can be attributed to default costs in Argentina. Here we show that in a model with migration, default cost could contribute to a larger fraction of output reduction. To further tease out the effect of default cost, we also plot the IRFs conditional on not defaulting in Figure 15 in Appendix. In this case, the average productivity in the benchmark is about 2% higher than the no-default-no-migration case as the surviving states must have higher productivity. As a result, there are smaller capital inflows, less emigration, and smaller GDP decline in the benchmark model. Nonetheless, GDP per capita still declines more and recovers slower than the no-default-no-migration and the no-migration model, as shown in panel (b) of Figure 15.

The decline of aggregate GDP is even more pronounced in the benchmark model, as shown in panel (f). Until 20 periods after the shock, the fall in aggregate GDP in the benchmark model is still 2.7 times the decline in the no-migration model and 3.5 times the decline in the no-default-no-migration model.

These IRFs shows that our model generates a sizeable endogenous persistence due to two reasons. First, under a negative productivity shock, the endogenous borrowing constraints from financial frictions tighten, and the economy reduces investment in response to lower external financing. Endogenous default risk slows down capital accumulation. In addition, default punishment could also contribute to the sizeable decline in output. 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.

Our model is well-suited to evaluate the role of changes in migration on economic activity. These changes may represent a change in foreign economic activity or policies that stimulate migration without changing the world interest. Fig. 7 plots the IRFs for a one-time negative migration shock. We start with the state with the median levels of (z, k, b) and keep the productivity at this level throughout. We then shock the economy with a migration shock, which leads to a 0.5% decline in the net migration rate. The smaller size of the workforce is associated with a higher capital per capita and GDP per

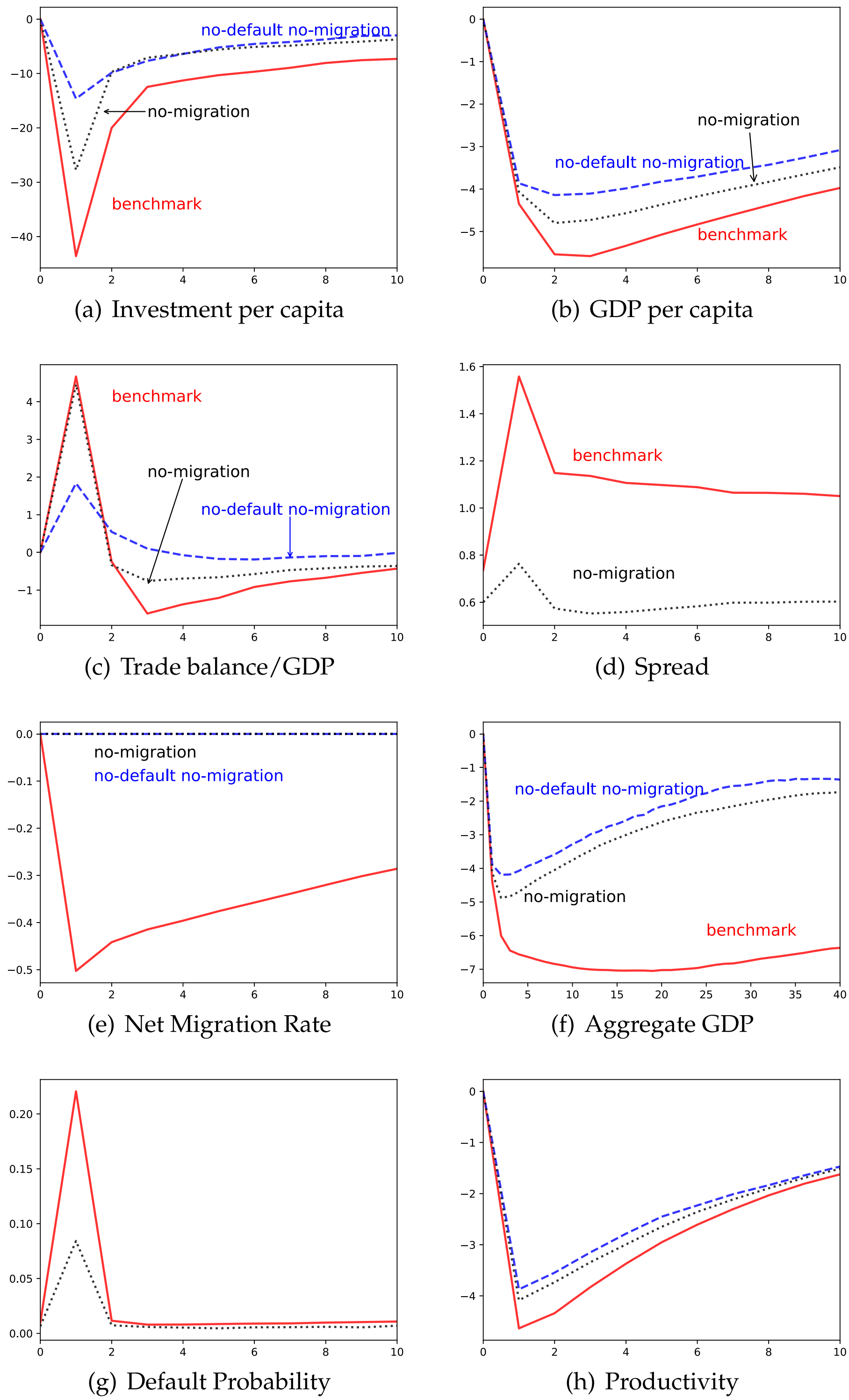


Fig. 6. Impulse response functions to a decline in productivity.

Notes: This figure plots impulse response functions to a decline in productivity for benchmark model (solid line), no-migration model (dotted line) and no-default-no-migration model (dashed line).

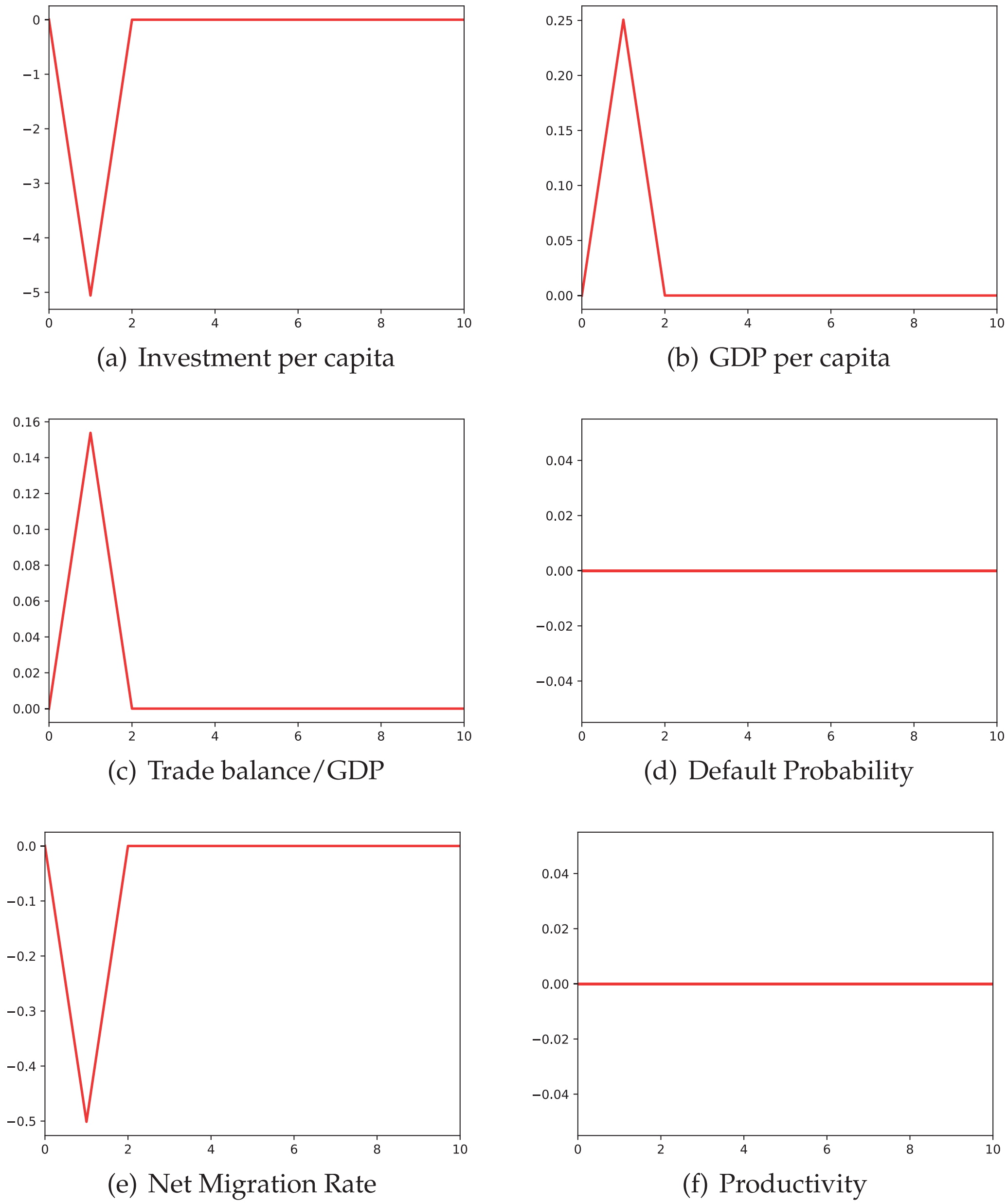


Fig. 7. Impulse response functions to a one-time decline in migration rate.
Notes: This figure plots the impulse response functions to a 0.5% one-time decline in migration rate. Note that the productivity is fixed at the median level.

capita. With $\alpha = 0.5$, GDP per capita increases by 0.25% on impact. The adverse migration shock also lowers the incentive to invest and investment per capita drops, which is, in turn, associated with higher capital outflows, i.e., an increase in the trade-balance-to-GDP ratio.

4.5. *Event analysis for spain*

In this section, we apply our model to understand and explain the persistent depression in Spain. We first present the aggregate dynamics of Spain's economy during the debt crisis. We then show the migration flows during this episode. Lastly, we compare our model's implications to Spanish data. Our model matches well the peak-to-trough changes in economic activity, government spreads, and net migration from a series of unanticipated persistent productivity shocks.

4.5.1. Salient features of Spanish debt crisis

To show a broad picture of the Spanish economy, we present the data series of GDP, investment, trade balance, and spreads in Fig. 9. The series of GDP, the investment rate, and trade balance are annual from 1980 to 2018. Spreads data is from 1998 to 2018.[12] Spain experienced an economic boom from 1998 to 2007 with GDP growing faster than its long-run trend (Panel a). Beginning in 2008, during the financial crisis of 2007-08, the Spanish economy started to contract. Spanish GDP fell each year from 2008 to 2014, before starting to recover at a modest pace. There is a more than 20% drop from peak-to-trough relative to trend (panel b). The boom and bust in this episode is much larger than previous cycles. A key feature is that the Spanish economy has not recovered to its long-run trend even 10 years after the onset of the crisis. Although the GDP per capita has a faster recovery when we account for the change in the active population, it is still below the long-term trend.

In 2012, Spain became a late participant in the European sovereign debt crisis with a soaring spread of 4.35% 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. Panel (c) plots the detrended investment and trade balance, both as a share of GDP. First, these two series are highly negatively correlated; high investment usually accompanies with low trade balance or capital inflows. Second, during the crisis period from 2007 on, investment declines by about 9 percentage points and recovers to its trend level slowly. The collapse in investment coincides with an increase in capital outflows as the trade balance increases almost 10 percentage points.

4.5.2. Migration in Spain

Spain received a large inflow of workers from 2000 on. Some of this inflow reflects a change in migration policy in Spain and some reflects a change in European Union policies. 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 a persistent immigration boom. Those leaving include both immigrants returning home or moving to a third country, and Spanish-born emigrants. Before the crisis, there is large scale net inflows. Between 2000 and 2008, the foreign-born population quadrupled from 1.5 million to 6 million. The primary driver of the immigration boom was the sustained economic growth between 1995 and 2007. Some of this was related to weak economic growth in South America, particularly in Argentina, Ecuador, and Bolivia, at the turn of the century and easy migration opportunities to Spain. 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.

Fig. 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.

In summary, the debt crisis in Spain demonstrates the striking pattern of the sovereign debt crises: a significant decline in aggregate activity, an increase in sovereign spreads, and dramatic capital and labor outflows of the country.

4.5.3. 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 and also extend the event to include part of the recovery. We deflate the nominal output series with the GDP deflator and detrend the annual time series for GDP per capita by logging the series and filtering with the Hodrick-Prescott filter, using a smoothing parameter of 10^6. We get 1.03% as the peak in 2008 and -13.28% as the trough in 2013 during debt crisis, hence a total decline of 14.31%. Spreads are the gap between government bond yields 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 -0.54% in 2013, a total 1.49% of declining. The ratio of trade balance to GDP increases from -5.59% in 2008 to 3.77% in 2013 and remains at the level through the end of our window.

[12] We start from 1998 since this is the first full year after the European Stability and Growth Pact that lead to the creation of the Euro at the end of the year.

We choose the initial state of the economy (z, k, b) and a path of productivity shocks z to minimize the distance between the model and the data in terms of GDP per capita, investment per capita, spread, net migration rate, and trade-balance-to-GDP between 2008 and 2016. Each shock is unanticipated but is persistent. All variables have equal weights. To generate a persistent recession, the model calls for a sequence of bad productivity shocks. Note that since there are no equilibrium defaults throughout the periods in all the models, the event calls for initial conditions that are more favorable than in the limiting distribution in that productivity and capital are relatively high, and external debt is relatively low.

Fig. 11 plots the dynamics of the model and data series. We normalize each series by its value in 2008. The solid red lines are for the benchmark model, and the solid gray lines are for the data. To highlight the interaction of migration and default risk in generating a persistent recession, we also feed in the same sequence of productivity shocks and the same initial state of debt and capital stock to the two reference models. The dashed lines are for the no-default-no-migration model, while the dotted lines are for the no-migration model.

Panel (a) plots the GDP per capita. Our benchmark model matches well the observed decline in aggregate GDP, about 14%. In contrast, for the same sequence of bad productivity shocks, the no-default-no-migration model only generates about 7.7% of declining in 2013, only half of what we observed in the data. The decline in the no-migration model is larger than the no-default-no-migration model but still lower than the benchmark, about 12%. Hence default risk contributes about 31% ($= (12 - 7.7)/14$), and migration choice contributes about 14% of decline in GDP per capita. Our benchmark model also matches the recovery of GDP nicely after 2013.

Panel (b) plots the series of investment per capita for the data and all three models. Our benchmark model successfully generates the sizeable decline in investment per capita of about 52%, as in the data. The model, however, has a faster recovery than the data. Investment goes back to the steady-state in 2016 in the benchmark model, but it is still 40% below the trend in the data. The no-default-no-migration model has a smaller decline before 2012, but its decline in 2013 is similar to the data. For the no-migration model, investment falls less than in the benchmark model.

In the data, spreads increase from 0.4% in 2008 to about 4.3% in 2012 and then decreases to 1.3% in 2016. Our benchmark model successfully produces this hump shape. The peak of spread is, however, 2% lower. Spreads in the data could be driven by non-fundamental shocks like investors' beliefs as modeled in Cole and Kehoe (2000) and Bocola and Dovis (2019). The latter estimates that rollover risk accounts for about 13% of Italian spread during 2008–2012 crisis using a sovereign default model with endowment economy and endogenous maturity choice. Without migration choice, the increase in spreads is 0.8% smaller than the benchmark.

The net migration rate in our benchmark also follows the observed series closely during and after the debt crisis, as shown in panel (d). The net migration rates in both the model and data drop by around 1.5% in 2013; it then increases back to -0.75% after the recovery of the economy. The two reference models abstract from migration and mute for the change of net migration rates.

Panel (e) plots the trade balance over GDP relative to its 2008 level. In the data, capital gradually flows out of the country and reaches its peak in 2013. During recovery, trade-balance-to-GDP starts to fall. Our model generated a quick capital outflow in 2009, but the trade-balance-to-GDP falls afterward. The no-default-no-migration has a much better match on the observed patterns of trade-balance-to-GDP, while the no-migration model follows a similar pattern as in the benchmark. In the presence of default risk, the bond price schedule tightens during bad times. As a result, the country reduces its borrowing drastically in 2009, which leads to an increase in the trade balance. With a lower debt liability, the country can reduce its borrowing slowly. The trade balances after 2009 are therefore lower than the 2008 level in both the benchmark and no-migration model.

Panel (f) plots the dynamics of real GDP and shows that the benchmark model provides a very close fit to the data in contrast to the alternative models. This is perhaps not surprising in that the alternative models miss out on the decline in aggregate GDP from a shrinking workforce. In total, from 2008 to 2013, our benchmark model generates a 19.5% drop in real GDP compared to the 21% in the data and 12.3% in the canonical sovereign default model without migration. As we saw in the impulse responses, the sovereign default model without migration predicts a strong recovery while the benchmark model does not. By 2016, we see that the sovereign default model with no migration GDP is only 6% below its initial level, while it is down 18% in our benchmark model and 21% in the data. Thus, migration accounts for almost all of the lack of recovery in detrended real GDP between 2013 and 2016.

In summary, the event analysis further confirms our finding that the interaction of migration and default risk help to explain the salient features of the sovereign debt crisis, large persistent decline of aggregate output, soaring spreads, and outflows of both capital and labor.

5. Extensions

In this section, we consider two extensions that highlight how some of our key assumptions about capital taxation upon migration and capital accumulation influence the transmission of the shock. First, we consider a case in which migrants can take their share of the capital stock with them. We call this the no exit tax case since in our benchmark case, the claims to the capital stock remained with the government. This case clearly increases the returns to migrating and leads to more serious crises. Second, we highlight the role of capital accumulation in the transmission of shocks.

5.1. Alternative exit tax

The amount of migration, and its aggregate effects, depends on how the value of staying fluctuates with the aggregate economy. A key determinant of the value of staying is whether migrants keep or lose their claims on national capital and whether by migrating they can escape their current debt obligations, since this affects the future income of non-migrants. In our base case, we assumed that migrants gave up their claims on the capital stock. In effect, migrants were paying an exit tax of $(K-B)/L$. Now we explore the polar extreme of allowing migrants to maintain their claims on the capital stock thereby lowering future income of non-migrants. To maintain symmetry, we require immigrants to bring capital with them. With this alternative structure, we find that recession is more persistent.

As our interest is to explore how the propagation of shocks through the borrowing capacity of a sovereign depends on the way agents are taxed upon migrating, we only alter the government's budget constraint.[13] Specifically, we model migrant's retained ownership of capital by assuming migrants take their capital with them. This effectively increases the debt of the country and leads us to rewrite the per-period budget constraint conditional on not defaulting as

$$c+b/g = zk^{\alpha} - \left[k' - (1-\delta)k + \frac{\theta}{2}\left(\frac{k'}{k} - 1 + \delta\right)^2 k\right] + q(z,k',b')\,b'. \tag{7}$$

The difference between this budget constraint and the one in the baseline model (6) is that the capital per capita is k when no exit tax, but it is k/g in the baseline model. Under this alternative exit tax, capital per capita does not change with the migrants, while in the baseline model, the government takes away the capital of the migrants and re-allocates it to the non-migrants, thereby increasing the incentive to stay.

Table 3 column "No exit tax" reports the properties of the model with this alternative government budget constraint. The parameter values are the same as in the benchmark except for the migration parameters, which we calibrate to match the average and volatility of the migration rate. The no-exit-tax model has a similar mean and volatility of spread as in the benchmark model. The GDP is, however, more volatile than the benchmark model, even if both models have similar mean and volatility of the migration rate.

To understand the force behind differential GDP volatility, let us revisit the difference between the benchmark and the no-exit-tax model. The GDP per capita is $z(k/g)^{\alpha}$ in the benchmark and is zk^{α} in the no-exit-tax model. For the same z process, the relative volatility of GDP per capita depends on the relative volatility of k/g and k in these two models, which in turn depends on the relative investment incentives. The expected marginal product of capital is $\alpha Ez'(k'/g')^{\alpha-1}$ in the benchmark, while it is $\alpha Ez'(k')^{\alpha-1}$ in the no-exit-tax model. Higher capital k' tend to attract migration and hence higher g', which dampens the investment incentive and leads to smaller volatility of capital in the benchmark. The volatility of capital is 7% in the benchmark and 10% in the no-exit-tax model. The capital per capita k/g is further lowered to 6.5% in the benchmark. In summary, the smoother GDP per capita in the benchmark is due to two reasons. First, capital is smoother in the benchmark. Second, the co-movement tendency of k and g also reduces the volatility of GDP per capita.

For the same reasons, this alternative fiscal implications of migration lead to more migration and more profound and prolonged recessions, as shown in IRFs in Fig. 8. This robustness check demonstrates again our crucial driver of the business cycle: the interaction of default risk and migration amplifies the adverse shocks. This mechanism is independent of our choice of migration policy, namely, whether or not to let migrants keep or lose their claims on the national capital. Either polar case, the benchmark or the no-exit-tax, shows the same amplification and persistent effect arising from default risk and migration choice.

5.2. Role of capital

We now discuss the role of capital accumulation in amplifying and increasing the persistence of economic activity following a persistent technology shock. Specifically, we consider an alternative model with no capital in the production function that faces the same process for Hicks neutral technology shocks. We call this model *no-capital*. We set the labor share as 1, $\alpha = 0$, and this model is equivalent to an endowment economy but with migration choice. We set the migration parameters to match the average migration rate. All other parameters are the same as the benchmark economy.

Table 3 reports the model's business cycle moments. The standard deviation of GDP per capita is about 3.6, compared to 6.3 in the benchmark. Without endogenous capital and $\alpha = 0$, GDP per capita is the same as the productivity shock z. The mean spread is slightly lower than the benchmark. The movement of the trade balance in this model is merely driven by the consumption smoothing motive and is about 20% less volatile. As in the standard sovereign default model, the trade balance is countercyclical due to the rising of spread schedule during bad times.

Fig. 8 plots the impulse responses to a negative productivity shock. From comparing the impulse responses of GDP and GDP per capita across the models, it is clear that capital magnifies their movements. Without capital, GDP per capita mean reverts with the shock. With capital, the trough in GDP per capita is two years later and about 30% larger. The gap between the two models increases slightly over time so that 10 years after the shock the drop in GDP per capita in the benchmark

[13] It would be straightforward to alter the migrant's problem to include an extra term related to the sale of capital. This would lead to a time-varying motive to migrate, although quantitatively this should be relatively small compared to the lifetime labor income from being abroad.

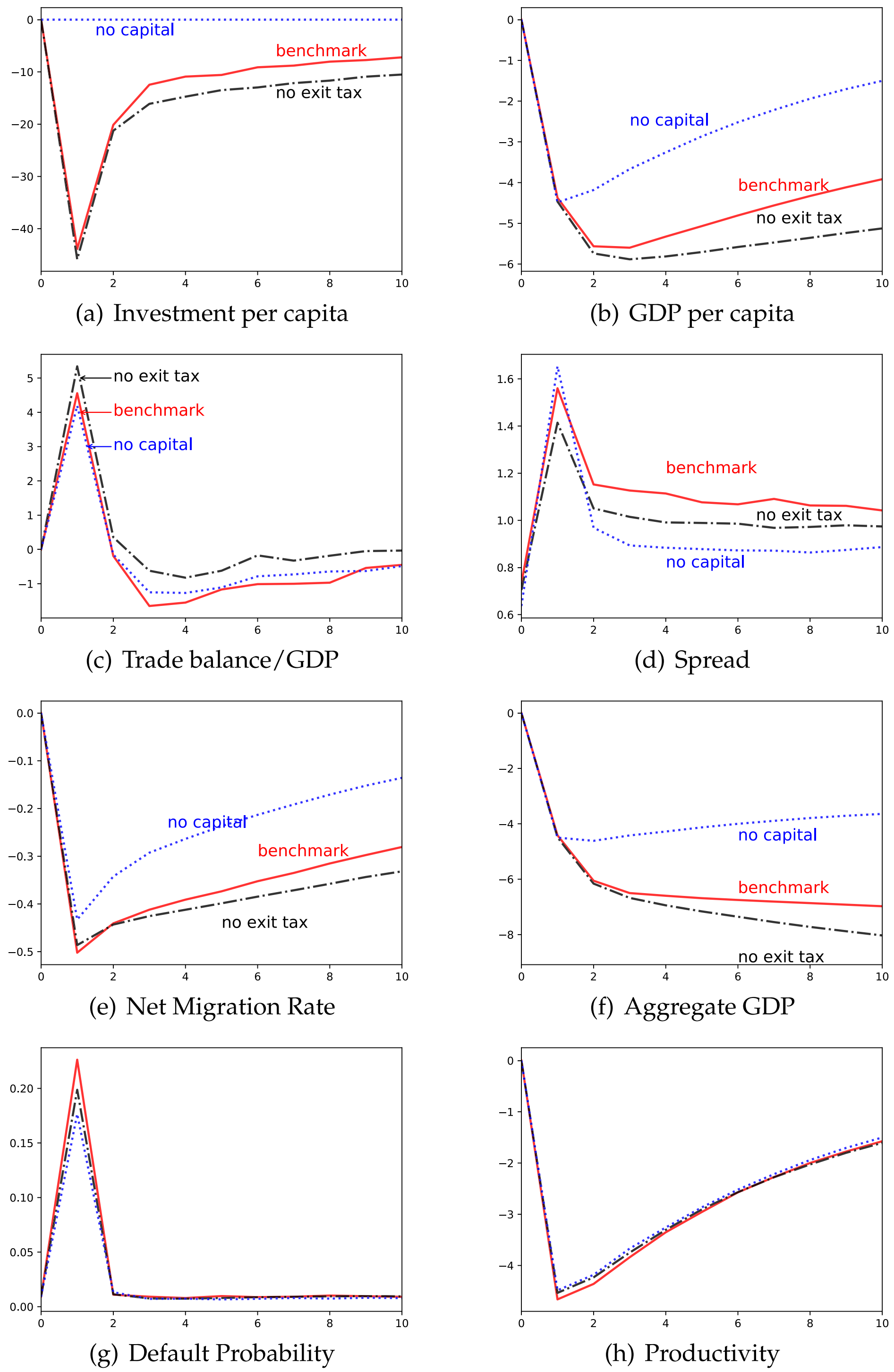
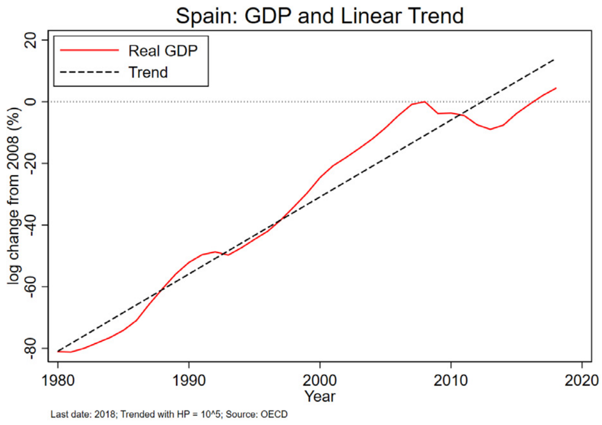
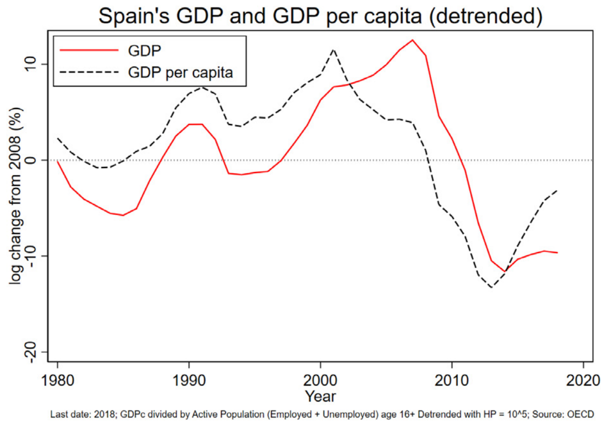


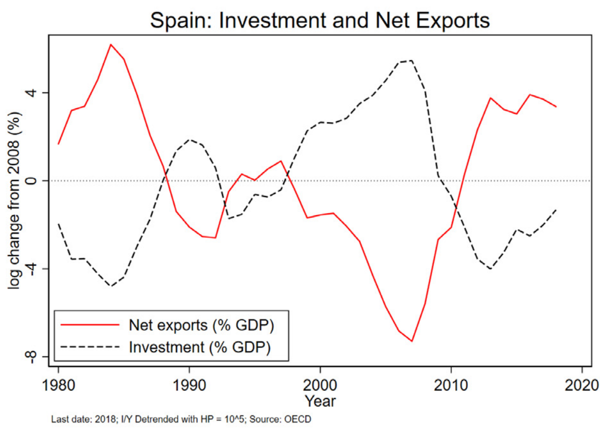
Fig. 8. Impulse response functions to a decline in productivity.
Notes: This figure plots the impulse response functions to a decline in productivity in benchmark model (solid line), no capital model (dotted line), and no exit tax model (dashed line).



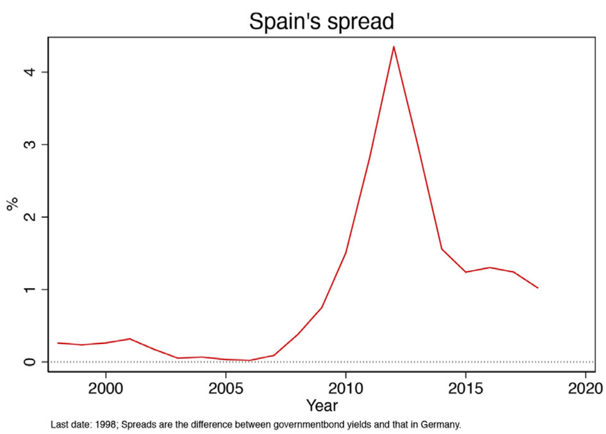
(a) GDP and Linear Trend



(b) Detrended GDP and GDP per Capita

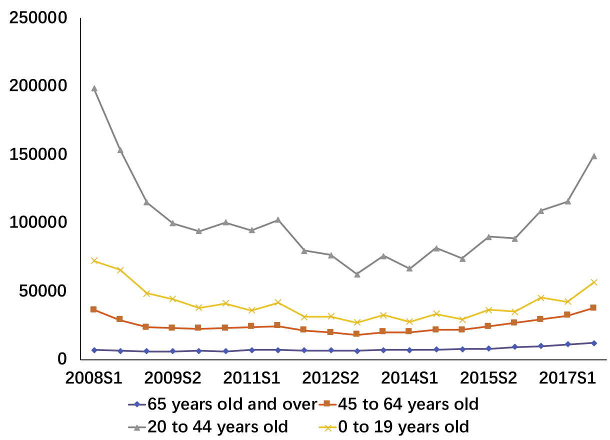


(c) Investment and Trade Balance

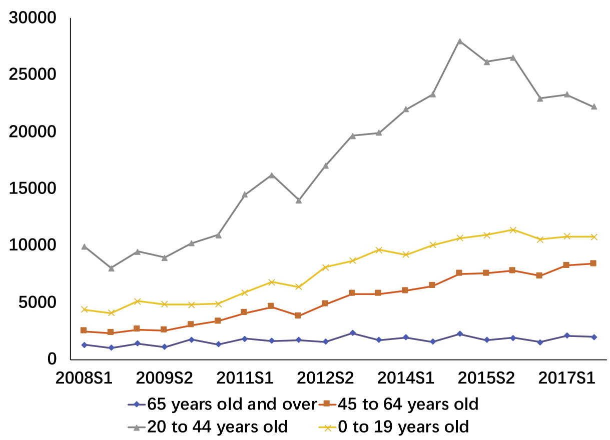


(d) Spreads

Fig. 9. Salient features of debt crisis: Spain.

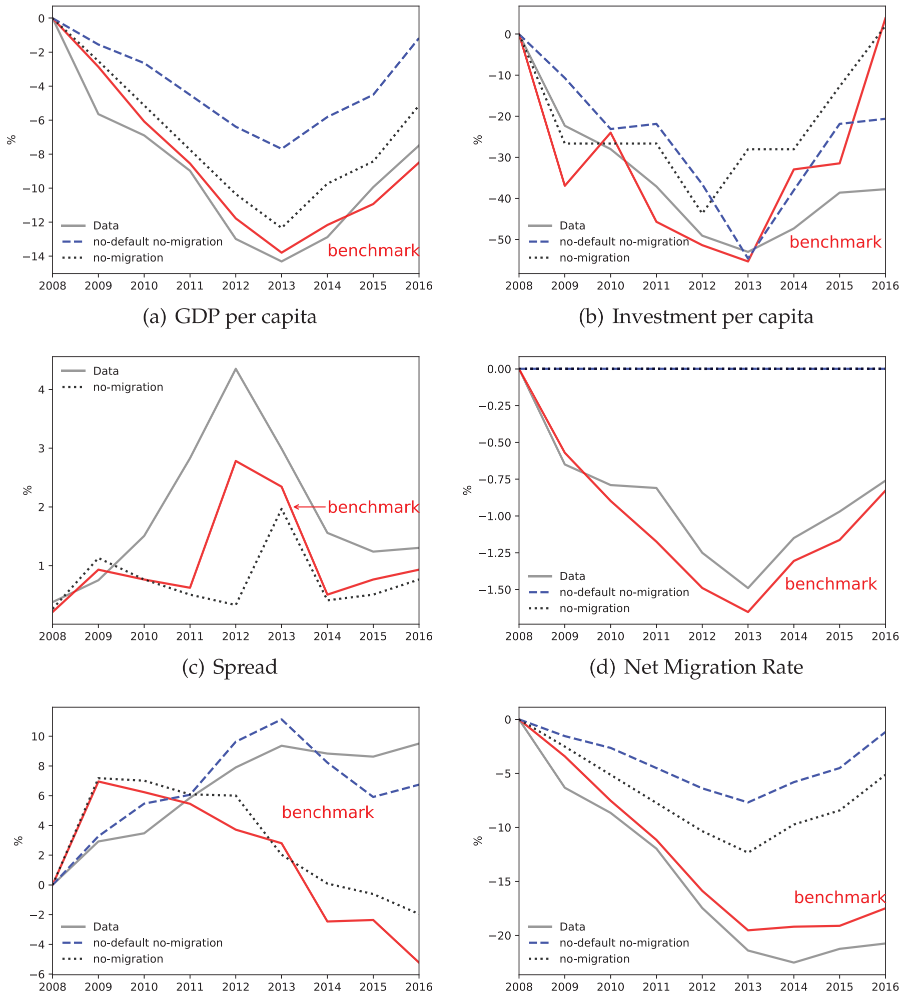


(a) Immigration Flows (Foreigners)



(b) Emmigration Flows (Spanish)

Fig. 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.



(a) GDP per capita

(b) Investment per capita

(c) Spread

(d) Net Migration Rate

(e) Trade Balance/GDP

(f) Aggregate GDP

Fig. 11. Event analysis for Spain.

model is nearly double that in the model with capital. The more delayed effect with capital arises from the steep and persistent decline in investment and a larger worker outflow. The larger worker outflows are related to the steeper and more prolonged recession with capital. As is well known, capital also magnifies the reversal in the trade balance, although this is mitigated somewhat by the higher default probability for the reasons discussed previously.

6. Conclusion

Migration amplifies sovereign debt crises. We provide empirical evidence that debt crises, and the associated capital outflows, are also accompanied by labor outflows. We build a model of sovereign default, capital accumulation, and emigration to capture these interactions. With migration, spreads increase more in recessions, capital flow reversals are larger, and recessions are much more persistent when measured in GDP but less persistent in per capita terms. Even though migration leads to lower economic activity in the country following a shock, residents are better off with the option to migrate even if they don't migrate. Of course, some caution is in order on these findings as we assume all agents are equally mobile.

While we find that introducing a migration decision into a sovereign default model has an important effect on economic activity, there are some important limitations to our analysis. First, we have abstracted from persistent differences in residents and migrants. In practice, there are large differences in the skills, wealth, and ages of emigrants and immigrants that will influence the evolution of an economy. Emigration of high-skilled young workers has a much more persistent effect on output, and the tax base, than emigration by older and less skilled workers (Deng, 2019). These sources of heterogeneity may also influence our welfare results as they will lead to persistent differences in international mobility and highly immobile residents will not value the option to migrate. Introducing worker heterogeneity in ability and citizenship also raises a host of questions about government preferences that we have purposely sidestepped. Second, the rising population of ex-patriots will influence future capital inflows via remittances as well as possible labor inflows. Finally, we have not separated public from private consumption. In practice, a key source of government expenditures in recessions, and rising internal debt, is rising public expenditures on social programs that are hard to adjust in the short-run. Bringing these features into future analyses should prove fruitful.

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. This change in migration policies, along with changes in trade and monetary policy, may also account for some of the differences in the persistence of the recent recessions compared to previous recessions. Considering policies to address the pecuniary externality from labor flows should be a focus of future work and be a key aspect of discussions of fiscal transfers in the presence of labor mobility.

We have focused on understanding the default decisions of a benevolent sovereign in the presence of endogenous migration holding migration policy constant in the presence of resident-based taxation. With migration, business cycles are more volatile and defaults are more frequent. These default decisions are optimal from the government's perspective given the insurance benefits of migration for emigrants and stayers alike. It would be interesting to study how these findings change when default, migration, and tax policy are chosen jointly.

Supplementary material

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.jmoneco.2020.04.007.

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