Financial Frictions and the Great Productivity Slowdown

Romain Duval
International Monetary Fund

Gee Hee Hong
International Monetary Fund

Yannick Timmer
International Monetary Fund

We study the role of financial frictions for productivity. Using a rich cross-country firm-level data, we exploit variation in preexisting exposure to the 2008 global financial crisis to study the post-crisis productivity slowdown. Firms with weaker precrisis balance sheets experienced a highly persistent decline in post-crisis total factor productivity growth relative to their less vulnerable counterparts, accounting for about one-third of the within-firm productivity slowdown. This decline was larger for firms that faced a more severe tightening of credit conditions. Financially fragile firms cut back on innovation activities, one channel through which financial frictions weakened post-crisis productivity growth. (*JEL* E32, E44, G32, O30, O40)

Received April 16, 2018; editorial decision April 4, 2019 by Editor Philip Strahan.

Productivity growth has declined in advanced economies since the global financial crisis (GFC) and has remained weak ever since (Adler et al. 2017; OECD 2015). Much attention in academic research has focused on whether the productivity slowdown reflects slowing innovation and technological diffusion (Andrews et al. 2015; Cette et al. 2016; Fernald 2015; Gordon 2016), amid declining business dynamism (Decker et al. 2016a, 2016b). Yet the abruptness, magnitude and persistence of the fall in total factor productivity (TFP) growth after the GFC makes it difficult to blame the productivity slowdown solely

We are thankful to Philip Strahan (the editor), Philippe Aghion, Mark Aguiar, John Bluedorn, Jan De Loecker, Giovanni Dell'Ariccia, Sebastian Doerr, Xavier Freixas, Fadi Hassan, Oleg Itskhoki, Atif Mian, Jesper Linde, Sebnem Kalemli-zcan, Nobuhiro Kiyotaki, Maria Soledad Martinez Peria, Benjamin Moll, Maurice Obstfeld, and Esteban Rossi-Hansberg; two anonymous referees; and participants at IMF, Princeton University, University of Bonn, University College Dublin, Bank for International Settlements, Bank of Korea, Korea University, ECB, Compnet 13th Annual Conference, and Brookings seminars and conferences for helpful comments and discussions. The views expressed in the paper are solely those of the authors and do not necessarily represent the views of the institutions to which the authors are affiliated. Send correspondence to Romain Duval, International Monetary Fund, 700 19th Street NW, Washington, DC 20431; telephone: 202-623-9907. E-mail: rduval@imf.org.

doi:10.1093/rfs/hhz063 Advance Access publication June 7, 2019

on such slow-moving structural forces. A defining feature of the GFC was the sharp unanticipated tightening of credit supply conditions that took place in the aftermath of the collapse of Lehman Brothers on September 15, 2008. This paper argues that the interplay between tighter credit conditions and weak corporate balance sheets generated "TFP hysteresis," playing an important role in the puzzling post-crisis productivity slowdown in advanced economies.

Our empirical strategy exploits the sharp and unforeseen tightening of credit conditions that took place in the immediate aftermath of the collapse of Lehman Brothers on September 15, 2008. Using an extensive cross-country firm-level data set put together by merging different waves of ORBIS, we start by showing that the decline in average within-firm TFP growth between the pre- and post-crisis periods was significantly larger for firms with greater preexisting balance sheet vulnerabilities. This holds within narrowly defined country-industry cells, that is, controlling for any country-industry (supply or demand) shocks and then comparing firms with strong versus weak balance sheet vulnerabilities within each cell. We then show that precrisis balance sheet weakness was associated with a larger TFP slowdown for firms that faced a more severe tightening of credit conditions around Lehman, an exogenous event we measure either at the country level by the increase in the average credit default swap (CDS) spread of domestic banks around September 15, 2008, or at the firm level by the increase in the average CDS spread of their main creditor banks. This further indicates that productivity was adversely affected by an interaction between a credit supply shock and preexisting corporate financial vulnerabilities. These estimated effects are highly persistent: the TFP level gap between more and less vulnerable firms opens in 2009 and further widens in subsequent years, ruling out that we are capturing a cyclical phenomenon. These effects are also large; a simple back-of-the-envelope calculation suggests they may account for up to a third of the within-firm TFP growth slowdown across our cross-country firm-level data set between the 6 years before and 6 years after the crisis.[1]

Our main measure of financial vulnerability captures ex ante rollover risk and is the amount of debt prior to the crisis that was scheduled to mature during the crisis, measured as the burden of current liabilities (maturing within a year) at the end of 2007. This "maturing debt" empirical strategy is motivated by those in several recent papers (Almeida et al. 2011; Benmelech et al. 2011). Because the GFC was unforeseen, firms' debt structure prior to the crisis is unlikely to be correlated with other unobserved firm characteristics that might correlate with the magnitude of the decline in their TFP growth post-crisis. For

[1] Credit conditions tightened much more in peripheral euro area countries (GIIPS), so the effects of rollover risk on the productivity slowdown are larger in these countries. For countries that have been more isolated from the Lehman bankruptcy, financial frictions played a much smaller role.

this reason, debt maturing during the crisis is our preferred firm-level measure of financial vulnerability.[2]

The causal interpretation of our estimates rests on two further grounds. First, the results are not driven by more vulnerable firms being less productive or having enjoyed slower productivity gains before the crisis; more and less vulnerable firms do not significantly differ along these or other relevant dimensions. Second, in a placebo test, we confirm that the change in within-firm TFP growth between the pre- and post-2000 recession periods was unrelated to pre-2000 balance sheet vulnerabilities. This underlines the peculiar nature of the GFC, which was associated with a massive credit supply shock, unlike the 2000 recession that followed the burst of the dot-com bubble.

Having established that financial frictions mattered for the post-GFC TFP slowdown, we then turn to the question of why they did so. While we do not provide a comprehensive answer to this question, we explore the role of weaker intangible investment as one among several possible channels. When credit markets froze after September 15, 2008, maturing debt could not be rolled over, or only at a much higher cost. The larger was the amount of maturing debt that could not be rolled over, the greater was the pressure on firms to reduce expenditure. Unlike intangible investment, such as research and development (R&D) or workforce training, most forms of physical capital can be pledged as collateral to obtain a loan, and they can more quickly translate into sales. Firms that had to roll over larger amounts of maturing debt had therefore a greater incentive to cut back on intangible investment, which, in turn, could have affected TFP. We find supportive evidence for this conjecture. Using the same empirical strategy as for our productivity analysis, we show that firms with preexisting balance sheet vulnerabilities cut back on intangible investment more than their less vulnerable counterparts after the crisis, and that this divergence was larger in countries where credit conditions tightened more during Lehman. Other unexplored but related factors may also have played a role, such as the sudden inability of high-rollover-risk firms to finance their working capital and thereby to use their inputs efficiently. However, the persistence of the firm-level TFP losses even as credit conditions gradually improved after Lehman suggests to us that temporarily weaker intangible asset investment, which led to a highly persistent reduction in the intangible capital stock, played a significant role.

In addition to studying the innovation input in terms of investment in intangible assets, we also study the effect of financial vulnerabilities on innovation outcomes. Using a newly available cross-country firm-level database for patents, we find that more vulnerable firms had a stronger reduction in the number of patent applications compared to less vulnerable firms.

Our paper relates to the recent literature on the effects of financial frictions on productivity. The dominant strand of this literature focuses on

[2] Our measure of debt maturing in 2008 also includes short-term debt that matures in 2008. Table 9 runs several robustness tests to ensure our results are not driven by the inclusion short-term debt maturing in 2008.

resource misallocation across firms (Hsieh and Klenow 2009; Restuccia and Rogerson 2008).[3] Some studies highlight that financial frictions can increase misallocation, and thereby weaken TFP, by preventing an optimal allocation of resources toward, and the entry of, more credit-constrained firms (Midrigan and Xu 2014; Moll 2014). Other papers highlight instead that credit booms due to large capital inflows, and lax credit conditions more broadly, can lead to misallocation of resources and productivity losses (Benigno et al. 2015; Borio et al. 2016; Gopinath et al. 2017). Our paper does not directly relate to this literature, because we focus on the much-less researched impact of financial frictions on within-firm productivity growth, not on the misallocation of resources between firms.[4]

More closely related to our work are papers by Aghion et al. (2010, 2012). Aghion et al. (2010) theoretically show that credit constraints can lead firms to cut R&D spending—and long-term illiquid investments more broadly—during recessions. Aghion et al. (2012) find supportive empirical evidence using French firm-level data. Compared with these papers, our work is novel in that we focus on productivity rather than only on R&D investment, highlight the role of specific firm-level vulnerabilities, and study their role for a broad cross-country firm-level data set by exploiting the September 2008 collapse of Lehman Brothers as an exogenous credit supply shock. Theoretical models by Garcia-Macia (2015) and Anzoategui et al. (2016) further highlight that reduced investments in intangible assets can slow within-firm productivity growth. Our empirical evidence is consistent with this prediction.

Finally, our paper also relates to a recent literature on how the GFC affected firms. Giroud and Mueller (2017) find that U.S. firms that had weaker balance sheets reduced employment more than their healthier counterparts. Chodorow-Reich (2013) show that banking frictions—having a relationship with a weak bank—also mattered, and Siemer (2014) finds that small young firms were most affected. Also focusing on the United States, Benmelech et al. (2011) carry out several empirical exercises that highlight the broader role of financial frictions, including refinancing risk, for firms' labor force adjustment. Benmelech et al. (2017) estimate that such financial frictions contributed to sizeable job losses in large U.S. firms during the Great Depression. All these studies focus on employment. Ridder (2016) also exploits variation in firm exposure to the GFC to study the real impact of credit constraints on U.S. firms, but he does not focus on TFP. Closer to our paper, Huber (2018) exploits variation in

[3] See Restuccia and Rogerson (2013) for a literature review of misallocation and productivity.

[4] Although we do not explicitly study this issue, our results still highlight one potential source of the misallocation of resources between firms, namely, the heterogeneous impact of credit conditions on within-firm TFP growth. This effect leads to greater dispersion in TFP between firms, which, in the presence of frictions in capital and/or labor markets, should also increase dispersion in their marginal products of capital and/or labor. In that regard, our paper also bears some connection to the literature on the cleansing effect of recessions. As emphasized in Caballero and Hammour (1998), that literature highlights that credit frictions could undo at least some of the positive cleansing effect of recessions by forcing the exit of productive but constrained firms (see, e.g., Osotimehin and Pappadà 2017).

German counties' and firms' exposure to a large bank's lending cut during the GFC, and finds that more exposed German counties and firms experienced larger and persistent declines in output, capital, employment and innovative activity (patenting). Our paper provides cross-country firm-level evidence of TFP hysteresis effects from financial frictions, and highlights their contribution to the highly persistent productivity and output losses from the GFC in advanced economies. We also identify one channel—lower intangible asset investment—through which such adverse "TFP hysteresis" effects may have arisen.

1. Empirical Strategy

1.1 Identification approach

Our empirical setup is a differences-in-differences strategy that compares the difference in TFP growth between firms with high versus small preexisting balance sheet vulnerabilities, after versus before the sharp unforeseen credit conditions tightening in 2008 after the collapse of Lehman Brothers. It bears similarities with Giroud and Mueller (2017), who study the impact of this credit supply shock on employment in U.S. firms by regressing the change in firm-level employment around the GFC on the precrisis leverage ratio, their measure of firm-level credit constraint.[5] Here, our focus is on the change in TFP growth and, subsequently, on the change in investment in intangibles as a potential explanation rather than the change in employment. Our baseline regression is as follows:

$$\Delta TFP_{i,s,c}^{growth} = \beta_1 Vulnerabilities_i^{pre} + \alpha_{s,c} + \gamma' X_i + \epsilon_{i,s,c}, \qquad (1)$$

where $\Delta TFP_{i,s,c}^{growth}$ is the difference in average TFP growth of firm i, in sector s, and country c between the post-crisis (6 years after the crisis 2008) and the precrisis (6 years until 2008) periods. $Vulnerabilities_i^{pre}$ denote precrisis balance sheet vulnerabilities at the firm level discussed below, and X_i is a vector of firm-level controls including the age of the firm, log of its total assets and log of earnings (EBITDA) before the financial crisis. Our focus on the difference in firm-level TFP growth between two periods also means that all time-invariant firm characteristics that may affect TFP growth are implicitly controlled for. Standard errors are clustered at the country-sector level. The main variable we use to capture firm-level balance sheet vulnerabilities is the ex ante rollover risk, that is, the share of debt prior to the crisis that was scheduled to mature during the crisis, measured as the share of current liabilities (maturing within a year) at the end of 2007. This is in similar spirit to Almeida et al. (2011)

[5] One advantage of comparing the 6 years after versus the 6 years before the crisis is that this comparison allows for a dynamic TFP response instead of restricting it to be contemporaneous. Papers by Mian and Sufi (2014) and Khwaja and Mian (2008) are other recent examples of approaches that collapse the data around events. See Bertrand et al. (2004) for a discussion of differences-in-differences strategies.

and Carvalho (2015), who exploit heterogeneity in precrisis long-term debt maturity structure. Given that we aim to identify the effects of financial frictions on productivity growth, a threat to our identification strategy could be that our measure of vulnerability not only reflects financial frictions but also correlates with other unobserved factors associated with the post-GFC slowdown, for example, the quality of the firm's managers or the sensitivity of demand for its products to overall cyclical conditions. For instance, if, within a given industry, product demand was more sensitive to a decline in aggregate demand for a more vulnerable firm than for its less vulnerable counterpart, we could overestimate the negative effect of vulnerabilities on productivity growth. However, because the September 2008 shock to credit conditions was unforeseen, it is plausible to assume that firms did not systematically schedule their debt to mature just before the crisis to avoid rollover risk.[6] Therefore, firms' debt structure prior to this event is unlikely to be correlated with other unobserved firm characteristics that might correlate with the magnitude of the decline in TFP growth post-crisis. In addition, and crucially, our specification includes country-sector fixed effects. This implies that we compare the change in average TFP growth between more and less vulnerable firms within narrowly defined country-sector cells. This control is crucial because it is well established, for instance, that some sectors more heavily rely on external finance than others, and therefore exhibit higher leverage ratios (Rajan and Zingales 1998). Firms' productivity in trade-intensive sectors in export-oriented countries also may have suffered more than others from the trade slowdown after the crisis (Alcalá and Ciccone 2004). Likewise, in certain countries the crisis-related decline in demand and its cyclical impact on measured productivity may have been greater in certain sectors, such as construction, than in others. Finally, policy changes, such as tax, product, or labor market reforms, in some countries in the aftermath of the crisis might have affected productivity growth in certain sectors more than in others. By including country-sector fixed effects, we rule out that our results may be affected by such factors. To further identify the impact of tighter credit conditions on the post-crisis decline in TFP growth in firms with preexisting balance sheet vulnerabilities, we then exploit the fact that the magnitude of the credit supply shock that followed the collapse of Lehman Brothers on September 15, 2008, varied across countries. If balance sheet vulnerabilities indeed contributed to weaken within-firm TFP growth when credit conditions tightened, we should expect this effect to have been larger in countries where credit conditions tightened more. We test for this conjecture by augmenting our baseline regression (1) with an interaction term as follows:

$$\Delta TFP_{i,s,c}^{growth} = \beta_1 Vulnerabilities_i^{pre} + \beta_2 Vulnerabilities_i^{pre} * \Delta CDS_c + \alpha_{s,c} + \gamma' X_i + \epsilon_{i,s,c}, \quad (2)$$

[6] Cheng et al. (2014) show that even managers in the securitized finance industry failed to identify the housing bubble.

where ΔCDS_c is the change in the average CDS spread of domestic banks in country c between the 7 days before and after the Lehman bankruptcy. In the week after Lehman's bankruptcy, CDS spreads rose as banks tried to protect themselves against defaults of other banks (Brunnermeier 2009). All else equal, banks whose CDS spreads rose more around the collapse of Lehman Brothers experienced a larger increase in perceived vulnerabilities. These banks typically suffered a sudden erosion of bank capital and difficulties in obtaining funding on the interbank market (Afonso et al. 2011; Brunnermeier 2009). These balance sheet constraints may have, in turn, induced them to restrict credit supply, with adverse effects on real outcomes (Chodorow-Reich 2013; Ivashina and Scharfstein 2010). By exploiting the change in CDS spreads over a narrow window around the Lehman bankruptcy, we can plausibly consider it as a shock to credit supply and rule out that it was driven by other factors. For instance, the increase in the CDS spread is unlikely to be the consequence of a real shock that affected firms and, through them, banks' riskiness, because in the week just after the bankruptcy, the consequences for the economy had not yet materialized. Therefore, we argue that a greater exposure to the Lehman bankruptcy, as reflected in a larger increase in domestic bank CDS spreads around September 15, 2008, captures an exogenous tightening of aggregate credit conditions for domestic firms in the country considered. Note that using the change in domestic bank CDS spreads as a measure of the tightening of credit conditions for domestic firms implicitly assumes that the latter heavily rely on banks in their home country for their funding needs, and cannot fully tap other sources of credit as a substitute; we see this as a reasonable assumption given that our sample is dominated by small European firms that typically do not have access to corporate bond markets, syndicated lending or cross-border bank lending. In a final extension, we further sharpen our identification strategy by making use of matched firm-bank credit relationship data. These allow us to exploit variation in the degree of tightening in credit conditions across firms within countries. An important source of firm-level variation in the tightening of credit conditions is that domestic firms relied on different creditor banks, which, in turn, were differentially hit by the Lehman shock. We exploit this heterogeneity by estimating

$$\Delta TFP_{i,s,c}^{growth} = \beta_1 Vulnerabilities_i^{pre} + \beta_2 Vulnerabilities_i^{pre} * \Delta CDS_i + \beta_3 \Delta CDS_i + \alpha_{s,c} + \gamma' X_i + \epsilon_{i,s,c}, \quad (3)$$

where ΔCDS_i is now the change in the average CDS spread across firm's main creditor banks.

1.2 Data and stylized facts

Our firm-level variables are drawn from ORBIS, a unique cross-country longitudinal data set of both listed and unlisted firms provided by Bureau van Dijk. The data set features harmonized and rich information on firm' productive

activities (for instance, value-added output, capital stock, employment) and financial situation based on balance sheets and income statements (for instance, debt, assets, tangible and intangible fixed assets, long-term debt) from 1998 until 2013.[7] We focus on eleven advanced economies for which we also have information on aggregate financial and credit conditions over this period, namely Belgium, Germany, Spain, France, Italy, Japan, Korea, the Netherlands, Portugal, Sweden, and the United Kingdom.[8] We study firms in the nonfarm, nonfinancial business sector, which corresponds to the two-digit industry codes Ñ-82 in NACE Rev.2, covering both manufacturing and service sectors including, for example, real estate and profession/scientific/technical activities.[9] To ensure consistency and comparability of monetary variables across countries and over time, we adopt the methodology followed, in particular, by Gal and Hijzen (2016). First, the original data recorded in USD are converted into local currency. Subsequently, nominal variables are turned into real variables by applying local currency deflators obtained from OECD STAN (ISIC4 version), which are rebased to 2005 U.S. dollars using country-industry level PPPs obtained from Inklaar et al. (2005). In addition, we exclude very small firms (less than three employees), a common practice in studies using firm-level data, because of concerns about the reliability of the data and the consistency of variables over time. The main dependent variable used in the analysis is firm-level TFP growth. To obtain firm-level productivity measures, we estimate a production function for each 2-digit sector, and, upon estimating the input-output elasticities, we can recover the TFP estimates as residuals.[10] The usual estimation challenge consists of the potential simultaneity bias stemming from the input choices and the firms' productivity (unobserved to the econometrician but known to the firm). The production function literature traditionally addresses this concern through the control function approach where the demand for one input (like investment or intermediate inputs) is used to proxy for unobserved productivity (Ackerberg et al. 2015; Levinsohn and Petrin 2003; Olley and Pakes 1996). In this paper, we follow the approach proposed by Wooldridge (2009), which estimates all coefficients in a one-step (efficient) generalized method of moments (GMM) procedure and addresses the Ackerberg et al. (2015) critique of the identification of the labor

[7] See Gal (2013), Kalemli-Özcan et al. (2015b), and Gal and Hijzen (2016) for a more detailed description of the data set and merging the different ORBIS vintages.

[8] Our empirical specification only contains firms that continuously exist during the 6 years before and after the GFC. This requirement significantly reduces the estimation sample relative to the raw ORBIS data set. Furthermore, the coverage of firms substantially varies across countries. This variation is a well-known feature of ORBIS (see, e.g., Gopinath et al. 2017; Kalemli-Özcan et al. 2015b). In the sample we use for the specifications that interact firm-level vulnerability with country-level CDS spreads, some countries have less than 500 firms (Germany, Portugal, and the Netherlands, for instance), whereas others have more than 10,000 firms (France, Spain, Sweden, and Italy, for instance).

[9] See http://ec.europa.eu/eurostat/documents/3859598/5902521/KS-RA-07-015-EN.PDF.

[10] We observe the value added generated by the firm, but not the quantities produced, so our productivity is a value-added TFP measure.

coefficient. Specifically, we obtain TFP from the following expression:

$$TFP_{i,c,s,t} = va_{i,c,s,t} - \hat{\beta}_{k,s} * k_{i,c,s,t} - \hat{\beta}_{l,s} * l_{i,c,s,t-1}, \quad (4)$$

where va is value added, k is the physical capital stock, m are materials, l is the number of employees, and β_k and β_l are estimated using Wooldridge's GMM procedure. All variables are in real terms and in logs. Like many others (see, e.g., Gopinath et al. 2017), the price deflators on which we rely are observed only at the country-sector, rather than firm, level. As a result, firm-specific price variations within each sector affect our TFP estimates. While these can, all else equal, reflect quality changes, they can also reflect market power of the firm. If more resilient firms increased prices since the crisis, this would mechanically result in relatively higher measured productivity growth for these firms. However, because Gilchrist et al. (2017) show that financially constrained firms raised prices during the financial crisis, our results would be if anything, downward biased.[11] Finally, we collect available daily CDS spread data for all individual banks and, for each of them, measure exposure to the September 15, 2008, Lehman collapse as the change in the average CDS spread between the week after and the week before September 15. We derive from these bank-level data two indicators of tightening in credit conditions for firms, which enter Equations (2) and (3), respectively. The first is a country-level indicator, which we compute as the simple average of changes in bank CDS spreads around the Lehman collapse across all domestic banks within a given country.[12] The second is a firm-level indicator, which is the simple average of changes in the CDS spreads of the firms bank creditors. We compute it using the variable featured in AMADEUS, which lists for each firm up to five banks that are its most important credit providers. This variable has been used to identify firm-level financial shocks (originating from the matched banks) in several previous studies, including Giannetti and Ongena (2012), Kalemli-Özcan et al. (2015a) and Barbiero et al. (2016).[13] We use the matched firm-bank data from the 2015 vintage, relying on the assumption put forward by Kalemli-Özcan et al. (2015a) and Barbiero et al. (2016) that bank-firm relationships are sticky and do not vary much over time. This analysis entails a severe reduction in sample size, because of the unavailability of the BANKER variable for non-European countries and the inexistence of CDS spreads for many of the matched banks. For these reasons, we treat specification (3) as an extension rather than as the core of our analysis, which instead consists of specifications (1) and (2). Table 1 provides summary statistics for the data set. The table shows that the average firm experienced a large drop in TFP growth after the GFC, from 2.14%

[11] See also Syverson (2011) for a discussion of these pros and cons of using revenue-based productivity.

[12] Results are robust to considering the principal component of these spreads instead.

[13] The original source of this variable is Kompass. Kompass provides information on banks and firms over 70 countries to, in particular, establish bank-firm relationships. See Giannetti and Ongena (2012) for further details.

Table 1
Summary statistics

	Mean	Median	P25	P75	SD
ΔTFP^{growth}	−10.72	−8.78	−30.54	9.00	33.83
$\overline{TFP}_{pre}^{growth}$	2.14	2.82	−8.84	14.10	18.53
$\overline{TFP}_{post}^{growth}$	−6.73	−5.22	−17.89	4.02	17.13
Debt maturing 2008	30.81	24.98	15.80	39.70	21.51
Observations	134,838				
Debt maturing 2008 (Non-GIIPS)	26.05	21.56	14.23	32.58	17.86
Debt maturing 2008 (GIIPS)	37.45	31.89	19.50	49.99	24.26
ΔCDS_c (Non-GIIPS)	90.59	86.48	71.05	92.25	40.00
ΔCDS_c (GIIPS)	94.11	88.68	87.41	105.70	10.05

ΔTFP^{growth} is the difference in the TFP growth rate pre- versus post-crisis. $\overline{TFP}_{pre}^{growth}$ is the average TFP growth rate precrisis. $\overline{TFP}_{post}^{growth}$ is the average TFP growth rate post-crisis. *Debt maturing 2008* is the amount of debt maturing in 2008 divided by average total sales precrisis. The precrisis period ranges from 2002 to 2007. The post-crisis period ranges from 2008 to 2013. The table also reports the amount of debt maturing in 2008 divided by average total sales precrisis for GIIPS and Non-GIIPS countries separately. ΔCD_c is the change in the country-level CDS between the weeks before and after the Lehman bankruptcy, where the change in the country-level CDS is calculated as an average of the changes in domestic banks' CDS spread over the same window for GIIPS and non-GIIPS countries.

to -6.73%.[14] Our financial vulnerability variable shows substantial variation across firms. The amount of debt maturing in 2008 as a ratio of 2007 sales is 24.98% for the median firm, with a standard deviation of 21.52%. Figure 1 shows the TFP level path for firms with different degrees of rollover risk at the onset of the crisis. Before the crisis, the figure shows that *weak* firms (solid lines) experienced just as strong productivity growth as *strong* firms (dotted lines). However, after 2008, trajectories diverged, as *weak* firms experienced a much sharper drop in productivity growth. It is worth noting that the large gap between weak and resilient firms that opens in 2009 is not closed by 2013 (the last available year in our sample), and indeed appears to keep on widening.

2. Empirical Results

This section first presents our productivity growth regression results, and then investigates the impact of financial frictions on intangible investment as one possible channel through which tighter credit conditions may have affected post-crisis TFP growth in more vulnerable firms. We start with estimates of our baseline regression (1) in Section 3.1. Section 3.2 turns to our extended specifications (2) and (3), which exploit the cross-country and cross-firm heterogeneity in the degree of tightening of credit conditions around the collapse of Lehman Brothers. In Section 3.3, we rerun our specifications replacing TFP growth by intangible investment and patent applications, to test whether these were also affected by financial frictions. This enables us to establish a connection between the productivity slowdown and innovation activities.

[14] We focus on within-firm TFP growth and smaller firms experienced a larger post-crisis drop in TFP growth than larger firms, so these unweighted numbers are much larger than their weighted counterparts.

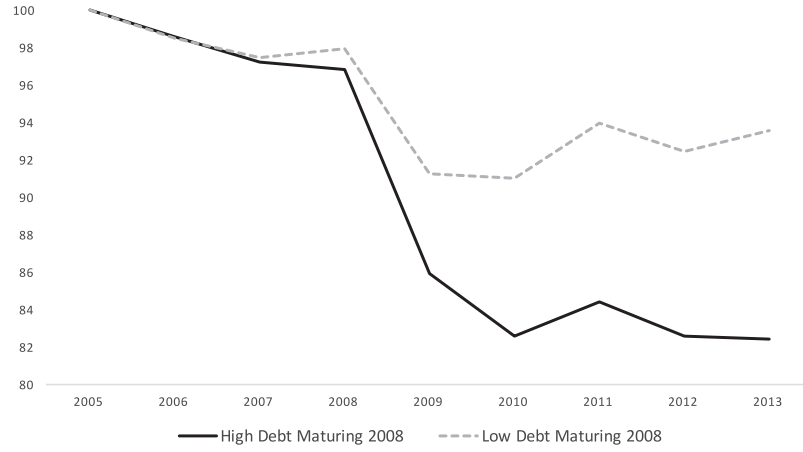

Figure 1
TFP level path for firms with different rollover risks (index 100 = 2005)
The TFP level path is shown as an index taking value of 100 in 2005. *High debt maturing 2008* corresponds to the 75th percentile of the distribution of *Debt maturing 2008*. *Low debt maturing 2008* corresponds to the 25th percentile of the distribution of *Debt maturing 2008*. *Debt maturing 2008* is the amount of debt maturing in 2008 divided by average total sales precrisis.

Table 2
Baseline regression results

Dependent variable	(1)	(2)	(3)	(4)
		ΔTFP^{growth}		
Debt maturing 2008	−0.0693***	−0.0704***	−0.0674***	−0.0935***
	(0.007)	(0.006)	(0.006)	(0.008)
R-squared	.127	.131	.142	.151
N	134,838	134,838	134,838	134,838
Country*Sector FEs	No	No	Yes	Yes
Sector FEs	No	Yes	—	—
Country FEs	Yes	Yes	—	—
Controls	No	No	No	Yes

The dependent variable ΔTFP^{growth} is the difference in the average TFP growth rate between pre- and post-crisis periods. *Debt maturing 2008* is the amount of debt maturing in 2008 divided by average total sales precrisis. The post-crisis period starts in 2008. Firm-specific controls include firm age, size of assets, and earnings (EBITDA). Standard errors are in parentheses. Standard errors are clustered at the country-sector level. $^{*}p < .1$; $^{**}p < .05$; $^{***}p < .01$.

Section 3.4 runs a placebo test that checks whether the effects of financial frictions vanish when focusing instead on the recession of the early 2000s, a recession not accompanied by a banking crisis.

2.1 Baseline regression results

Table 2 shows our baseline regression (Equation (1)) results for different sets of (country-, sector- and country-sector) fixed effects and with and without firm-level controls. Firms with more vulnerable balance sheets, as measured by a higher share of debt maturing in 2008, experienced a stronger decline in TFP

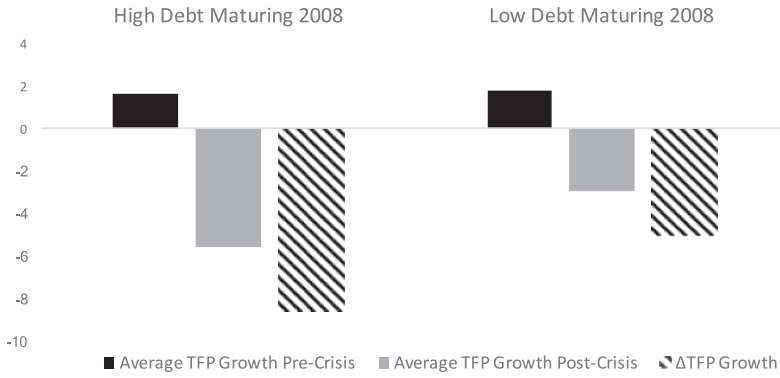

Figure 2
Estimated TFP growth decline for firms with different rollover risks
ΔTFP^{growth} is the difference in the average TFP growth rate between the pre- and post-crisis periods. *Average TFP growth pre- (post) crisis* is the average TFP growth rate precrisis (post-crisis). *Debt maturing 2008* is the amount of debt maturing in 2008 divided by average total sales precrisis. *High (low) debt maturing 2008* corresponds to the 75th percentile (25th percentile) of the cross-firm distribution of *Debt maturing 2008*. The post-crisis sample starts in 2008. Column 4 of Table 2 provides the underlying regression estimates.

growth. The estimated impact using our preferred specification including both country-sector fixed effects and firm-level controls (Column 4) is quantitatively large: a 10-percentage-point higher share of debt maturing in 2008 was associated with a 0.94-percentage-point drop in annual TFP growth in the post-crisis period.[15] Figure 2 graphically illustrates these results. The figure shows the implied difference in average TFP growth between pre- and post-crisis periods for firms at the 75th and 25th percentiles of the cross-firm distribution of the indicator of financial vulnerability (more and less vulnerable firms, respectively). While both types of firms experienced comparable TFP growth until 2008 (black bars), the post-crisis drop in TFP growth was much less in the former (gray bars) than in the latter (shaded bars).[16] One concern with our identification strategy could be that firms with more debt maturing in 2008 also tend to have more short-term debt in general. The amount of short-term debt could, in turn, be correlated with unobserved firm characteristics, such as their expected future TFP growth or how well managed they are. If firms with more short-term debt and therefore more debt maturing in 2008 are more sensitive to business-cycle fluctuations, the stronger drop in TFP for these firms

[15] These results are quantitatively and statistically robust to additionally controlling for each firms' average rollover risk for the years 200Ñ-2007. This robustness test further shows that our results are not driven by the fact that firms that had balance sheet vulnerabilities on the eve of the financial crisis were intrinsically weak firms that were structurally forced to raise short-term debt. Also noteworthy is that rerunning our baseline regression using as the dependent variable the change in the leverage ratio (rather than the change in TFP growth) yields a strong negative and statistically significant coefficient (results available on request); this suggests that firms that entered the crisis with higher shares of maturing debt indeed faced rollover problems that led them to deleverage more than their less distressed counterparts.

[16] Note that the average precrisis TFP growth is positive on average for both types of firms from 2002 to 2007, whereas the TFP level declined from 2005 to 2007 as shown in Figure 1.

could be mechanically linked to demand rather than to financial frictions. To address this issue, we add average current liabilities before 2007 as a further control variable. Average current liabilities prior to 2007 control for how much short-term debt the firm had before the crisis, because current liabilities reflect the debt scheduled to mature within a year. Table 2 shows that controlling for average precrisis current liabilities does not significantly affect our main coefficient of interest but yields a small and statistically insignificant coefficient for the average precrisis current liabilities variable itself. These results highlight that the amount of debt maturing in 2008 carries different information from that captured by the amount of debt maturing in other years. The interaction between maturing debt in 2008, that is, rollover risk that year, and tighter financial conditions in 2008 drives the slower TFP growth in the post-crisis period. How much of the total (firm-level) TFP growth slowdown do these findings account for? A rough back-of the-envelope calculation can provide an illustrative estimate. Let us assume conservatively that firms that did not have any debt maturing in 2008 did not face financial frictions, and therefore did not experience any related slowdown in TFP growth. Using the coefficient of debt maturity 2008 in Column 4 of Table 2 (-0.094) and multiplying it by each fir's share of debt maturing in 2008 yields each fir's estimated TFP growth loss due to preexisting financial vulnerabilities. We then aggregate each individual fir's TFP growth loss, using their value-added levels as weights, to derive the overall effect. This illustrative calculation yields an aggregate TFP growth loss of about 2.39 percentage points compared to a state in which there would have been no financial frictions. By comparison, the aggregate TFP growth drop observed in our sample, which can be calculated as the weighted sum of each firm's change in TFP growth between the pre- and post-crisis periods, is about of 6.37 percentage points.[17] This tentatively suggests that the interplay between tighter credit conditions and firm' preexisting financial vulnerabilities may account for some 37% ($\sim$ 2.39/6.37) of the total within-firm TFP growth loss after the GFC.

2.2 Extended specifications

Our baseline specification highlights the interplay between balance sheet vulnerabilities and the 2008 shock to credit conditions in driving down TFP growth post-crisis, but it does not recognize that the shock to credit conditions was in fact heterogenous across countries and firms. To remedy this and sharpen our identification strategy, this section provides estimates of our extended specifications (2) and (3). Our main extended specification is (2), which tests for interactions between our measure of precrisis firm-level vulnerability and the change in the average CDS spread of domestic banks between the weeks before and after September 15, 2008. We standardize the CDS spread by first

[17] The aggregate change in TFP growth between the pre- and post-GFC periods in ORBIS is comparable in magnitude to that obtained when using EUKLEMS. In EUKLEMS, euro-area TFP growth was a cumulative 2.8% from 2001 to 2007, followed by a cumulative 3.4% decline in the subsequent 6 years.

subtracting the sample mean and then dividing by the standard deviation. Hence, this variable takes value one when the CDS spread increase after the Lehman bankruptcy is one-standard-deviation (about 20 basis points) larger than in the average country in our sample. Standardizing the change in CDS also allows us to interpret the direct effect of firm-level vulnerabilities as their effect on the change in TFP growth in the average firm in the average country.[18] The results, which are reported in Table 4, confirm the role played by tighter credit conditions in the post-crisis TFP slowdown. Firms with preexisting balance sheet vulnerabilities experienced a larger drop in TFP growth (vis-à-vis their less vulnerable counterparts) in countries where credit conditions tightened more; interaction terms between both firm-level vulnerability measure and the country-wide change in bank CDS spreads are statistically significant at the 1% confidence level, as are the direct effects. Based on the results in Column 4, in a country that experienced an average increase in bank CDS spreads, a 10-percentage-point increase in the share of debt maturing in 2008 was associated with a 0.95-percentage-point drop in annual TFP growth. In a country where the increase in CDS spreads was 1-standard-deviation larger than the average country, the corresponding decline in TFP growth was 1.13 percentage points larger (1.13 $\sim$10*0.113*1). Figure 3 graphically illustrates this cross-country heterogeneity also using the estimates from Column 4 in Table 4. The two bars compare the post-crisis decline in TFP growth for firms that lie on the 25th (low rollover risk) and 75th (high rollover risk) percentiles of the precrisis distribution of the share of debt maturing in 2008 for two hypothetical countries. These two hypothetical countries differ from one another by the degree of credit conditions tightening, namely, an average country is compared to a country with tighter credit conditions which experienced 1-standard-deviation larger CDS spread around the Lehman bankruptcy. The difference is sizeable: a higher share of debt maturing in 2008 is associated with a substantially larger decline in post-crisis TFP growth in the country where CDS spreads increased more (right bar).

To further sharpen our identification strategy, we now estimate an extended specification (3) that interacts our measure of precrisis firm-level vulnerability with the change in the average CDS spread of the main creditor bank(s) of the firm considered between the weeks before and after September 15, 2008. As noted above, this comes at the cost of a severe reduction in sample size as not all firms report their creditors (see Kalemli-Özcan et al. 2015b for further details on the limitations of creditor information in certain countries). Nonetheless, the results, which are shown in Table 5, strengthen our key finding: firms with greater debt maturing in 2008 suffers a larger drop in TFP growth post-Lehman, and that drop was greater for firms that faced a more severe

[18] The difference in coefficients on the direct effects of vulnerabilities between Tables 2 and 3 can be partly explained by the fact that the coefficient in Table 2 captures the impact in the average firm (not necessarily in the average country), whereas the coefficient in Table 4 captures the impact in the average firm in the average country.

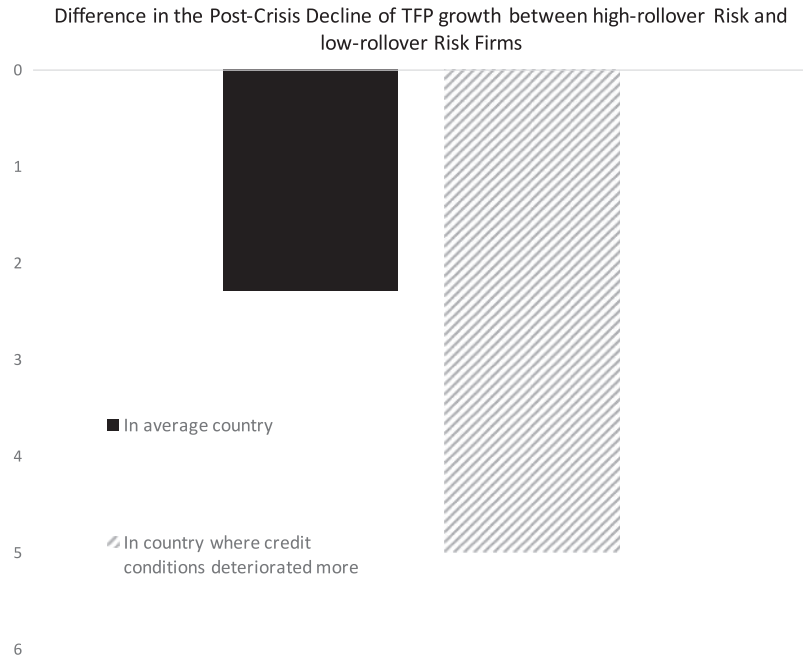

Figure 3
Estimated TFP growth decline for firms with different rollover risks: The role of country exposure in the collapse of Lehman Brothers
Rollover risk is the amount of debt maturing in 2008 divided by average total sales precrisis. *High (low) debt maturing 2008* corresponds to the 75th (25th) percentile of the cross-firm distribution of *Debt maturing 2008*. The *average country* corresponds to a no change in CDS spread after standardizing the variable. The *country where credit conditions deteriorated more* corresponds to 1-standard-deviation larger change in standardized CDS spread compared to the average country CDS spreads. The post-crisis sample starts in 2008. Column 4 of Table 4 provides the underlying regression estimates.

tightening of credit conditions (from their matched banks). The interaction of debt maturing in 2008 and the increase in the matched firm-bank CDS spread is negative and statistically significant at the 5% confidence level. It is also economically significant: a 10-percentage-point larger ratio of debt maturing in 2008 was associated with a 1.63-percentage-point steeper decline in average annual TFP growth post-crisis for a firm whose main creditor bank(s) had an average exposure to Lehman, but with a 1.86 percentage points (1.63 + 0.23 = 1.86) larger decline in TFP growth for a fir's whose main creditor bank(s) faced an increase in CDS spreads that was one-standard-deviation larger than the average. Although smaller than the implied impact from the specification with the country-wide CDS spread (Equation (2)), this still amounts to a large cumulative impact of precrisis vulnerabilities on the TFP level over the 6 years after the GFC, while keeping in mind that a 10-percentage-point larger ratio is equivalent to just half a standard deviation of the cross-firm distribution of debt maturing in 2008. Finally, an increase in the CDS spread of the fir's

Table 3
Baseline regression: Controlling for short-term debt before the crisis

Dependent variable	(1)	(2)	(3)	(4)
	$\Delta\, TFP^{growth}$			
Debt maturing 2008	−0.0686***	−0.0729***	−0.0953***	−0.0883***
	(0.007)	(0.011)	(0.008)	(0.012)
Avg. current liabilities precrisis		0.00637		−0.0104
		(0.011)		(0.011)
R-squared	.142	.142	.151	.151
N	130,319	130,319	130,319	130,319
Country*Sector FEs	Yes	Yes	Yes	Yes
Sector FEs	—	—	—	—
Country FEs	—	—	—	—
Controls	No	No	Yes	Yes

The dependent variable ΔTFP^{growth} is the difference in the average TFP growth rate between pre- and post-crisis periods. *Debt maturing 2008* is the amount of debt maturing in 2008 divided by average total sales precrisis. The post-crisis period starts in 2008. *Avg. current liabilities precrisis* is the mean of current liabilities divided by sales before 2007. Firm-specific controls include firm age, size of assets, and earnings (EBITDA). Standard errors are in parentheses. Standard errors are clustered at the country-sector level. $*p < .1$; $**p < .05$; $***p < .01$.

Table 4
Extended specification: Accounting for cross-country heterogeneity in exposure to the collapse of Lehman Brothers

Dependent variable	(1)	(2)	(3)	(4)
	ΔTFP^{growth}			
Debt maturing 2008	−0.0706***	−0.0956***	−0.0682***	−0.0951***
	(0.007)	(0.007)	(0.006)	(0.007)
Debt maturing 2008 $*$ ΔCD_c	−0.0823***	−0.105***	−0.0824***	−0.113***
	(0.024)	(0.024)	(0.020)	(0.021)
R-squared	.143	.161	.156	.169
N	104,275	104,275	104,275	104,275
Country*Sector FEs	No	No	Yes	Yes
Sector FEs	No	Yes	—	—
Country FEs	Yes	Yes	—	—
Controls	No	No	No	Yes

The dependent variable ΔTFP^{growth} is the difference in the average TFP growth rate between the pre- and post-crisis periods. *Debt maturing 2008* is the amount of debt maturing in 2008 divided by average total sales precrisis. The post-crisis period starts in 2008. ΔCD_c is the standardized change in the country-level CDS between the weeks before and after the Lehman bankruptcy, where the change in the country-level CDS is calculated as an average of the changes in domestic banks' CDS spread over the same window. Firm-specific controls include firm age, size of assets, employment, and earnings (EBITDA). Each specification also includes interactions between each of these controls and ΔCD_c. Standard errors are in parentheses. Standard errors are clustered at the country-sector level. $*p < .1$; $**p < .05$; $***p < .01$.

main creditor bank(s), in and of itself, does not appear to affect TFP growth, as suggested by its statistically insignificant coefficient. This further confirms that it is the interplay between preexisting firm-level vulnerability and tighter credit conditions, rather than tighter credit conditions per se, that mattered for the post-GFC TFP slowdown.

2.3 Financial frictions and innovation

Having established that financial frictions mattered for the post-GFC TFP slowdown, we now turn to the question of why they did so. While we do not

Table 5
Extended specification: Accounting for firm-level heterogeneity in exposure to the collapse of Lehman Brothers

Dependent variable	(1)	(2) $\Delta\ TFP^{growth}$	(3)	(4)
Debt maturing 2008	−0.112***	−0.154***	−0.114***	−0.163***
	(0.014)	(0.014)	(0.015)	(0.015)
ΔCDS$_i$	−0.140	−0.251	−0.176	−0.301
	(0.214)	(0.214)	(0.217)	(0.214)
Debt maturing 2008 $*\Delta$CDS$_i$	−0.0232**	−0.0231**	−0.0243**	−0.0229**
	(0.010)	(0.010)	(0.010)	(0.011)
R-squared	.0640	.0922	.0793	.109
N	20,798	20,798	20,798	20,798
Country*Sector FEs	No	No	No	Yes
Sector FEs	No	No	Yes	—
Country FEs	Yes	Yes	Yes	—
Controls	Yes	Yes	Yes	Yes

The dependent variable ΔTFP^{growth} is the difference in the average TFP growth rate between pre- and post-crisis periods. *Debt maturing 2008* is the amount of debt maturing in 2008 divided by average total sales precrisis. The post-crisis period starts in 2008. ΔCDS$_i$ refers to the standardized change in the average CDS spread of the firm's main creditor bank(s) (up to five of them, drawn from the $BANKER$ variable in AMADEUS) between the weeks before and after the collapse of Lehman Brothers. Firm-specific controls include firm age, size of assets and earnings (EBITDA) and are interacted with ΔCDS$_i$. Standard errors are in parentheses. Standard errors are clustered at the country-sector level. $*p < .1$; $**p < .05$; $***p < .01$.

attempt to provide a comprehensive answer to this question, we explore the role of weaker innovation activities as one possible channel. A wide range of recent studies have linked investments in intangible assets with productivity since the influential work of Corrado et al. (2005, 2009). When hit by a financial shock, firms may adjust various types of investment differently depending on expected returns, risks and gestation periods (Garcia-Macia 2015; Holmstrom and Tirole 1997; Matsuyama 2007; Ridder 2016). Whereas most forms of physical capital can be pledged as collateral to obtain a loan, intangible assets, such as R&D or workforce training, cannot. Furthermore, investments in intangible assets tend to translate more slowly into sales and to be riskier. Therefore, our hypothesis is that credit-constrained firms cut their investment in intangible assets, resulting in lower innovation and contributing in part to a sharper productivity slowdown after the crisis. To test this hypothesis, we follow the same difference-in-differences strategy used earlier, only that now the change in the innovation activities replaces the change in TFP growth as our dependent variable. First, we use the investment rate in intangible assets as our dependent variable. We define the investment rate in intangibles as the change in the stock of intangible assets divided by value added available in ORBIS. This is comparable in spirit to the investment rate expressed as a share of gross domestic product (GDP) in national accounts. Our baseline regression is as follows:

$$\Delta Int\_Investment_{i,s,c} = \beta_1 Vulnerabilities_i^{pre} + \alpha_{s,c} + \gamma' X_i + \epsilon_{i,s,c}. \quad (5)$$

Furthermore, we assess if firms cut investment in intangibles more than investment in physical capital by estimating the following regression:

$$\Delta Share\_Intangible_{i,s,c} = \beta_1 Vulnerabilities_i^{pre} + \alpha_{s,c} + \gamma' X_i + \epsilon_{i,s,c}, \quad (6)$$

which is analogous to Equation (5) but now considering as dependent variable the change in the share of intangibles in total assets. Total assets are the sum of tangible (physical) and intangible fixed assets. Table 6 shows these results. First two columns use the investment in intangible assets as the dependent variable, whereas Columns 3 and 4 use the share of intangible investments as the dependent variable. Columns 1 and 2 show that firms with more vulnerable balance sheets indeed cut their investment in intangible assets significantly more than their less vulnerable counterparts. Considering that investment rates are typically much lower for intangible assets than for tangible ones, the estimates are also economically significant. Based on the estimates in Column 2, a 10-percentage-point increase in the share of debt maturing in 2008 was associated with a 0.18-percentage-point drop in the investment rate in intangibles. In addition, as the results in Columns 3 and 4 show, firms with more vulnerable balance sheets indeed reduced the share of intangibles in total assets more than their less vulnerable counterparts. Using the estimates in Column 4 of Table 6, a 10-percentage-point larger share of debt maturing in 2008 was associated with a 0.58-percentage-point decline in the share of intangible assets. As a further exploration of this channel, we study whether financial vulnerabilities affected not only innovation inputs like intangible investment but also innovation outcomes (see, e.g., Kogan et al. 2017). An important outcome of the innovation process is firm' patenting behavior, a simple measure of which is the number of patent applications filed by each firm every year. This is available from the European Patent Offic's Worldwide Patent Statistical database (Patstat), the most extensive cross-country firm-level database for patents.[19] Using a link to match patent applications with firms provided by Bureau van Dijk, we merge these data with our Orbis data set to obtain a matched patent-firm dataset. The merging procedure involves a substantial loss of observations (about three-fourths), because of missing observations in either of the data sets. Although most firms do not innovate or, at least, do not file for patent protection, the data enable us to rerun our econometric analysis using the change in the number of patents between the pre- and post-crisis periods as the dependent variable by estimating the following regression:

$$\Delta PatentApplications_{i,s,c} = \beta_1 Vulnerabilities_i^{pre} + \alpha_{s,c} + \gamma' X_i + \epsilon_{i,s,c}. \tag{7}$$

The results, which are presented in Columns 5 and 6 of Table 6, confirm that firms with greater precrisis financial vulnerabilities reduced their innovation activities in the post-crisis period. A 10-percentage-point higher share of debt maturing in 2008 was associated with a 0.1 decline in the annual number of patent applications. While this number might not seem large, one should bear in mind that patent filing is a rare activity whose cross-firm distribution is

[19] For an introduction to Patstat, see De Rassenfosse et al. (2014). For further details, see https://www.epo.org/searching-for-patents/business/patstat.

Table 6
Financial frictions and innovation

Dependent variable	(1) $\Delta Int\_Investment$	(2) $\Delta Int\_Investment$	(3) $\Delta Share\_Intangible$	(4) $\Delta Share\_Intangible$	(5) Δ PatentApplications	(6) Δ PatentApplications
Debt maturing 2008	−0.0188***	−0.0184***	−0.0633***	−0.0584***	−0.00137***	−0.00100***
	(0.002)	(0.002)	(0.010)	(0.010)	(0.00037)	(0.00035)
R-squared	.0406	.0407	.373	.379	.0353	.0419
N	97,487	97,487	101,150	101,150	37,136	37,136
Country*Sector FEs	Yes	Yes	Yes	Yes	Yes	Yes
Controls	No	Yes	No	Yes	No	Yes

The dependent variable $\Delta Int\_Investment$ for Columns 1 and 2 is the difference in the investment in intangible assets as a ratio of the value added pre- versus post-crisis. The dependent variable $\Delta Share\_Intangible$ for Columns 3 and 4 is the difference in the share of intangible assets in total capital pre- versus post-crisis. The dependent variable Δ *PatentApplications* for Columns 5 and 6 is the difference in the average number of patent applications each year pre- versus post-crisis. *Debt maturing 2008* is the amount of debt maturing in 2008 divided by average total sales precrisis. The post-crisis period starts in 2008. Firm-specific controls include firm age, size of assets, and earnings (EBITDA). Standard errors are in parentheses. Standard errors are clustered at the country-sector level. $*p < .1$; $**p < .05$; $***p < .01$.

also highly skewed; for all firms that have already at least one patent, the 75th percentile of the distribution of the annual number of patent applications is 0 and the 90th percentile is 1.

2.4 Placebo test

To confirm that our results reflect the peculiar nature of the GFC, which was associated with a massive credit supply shock, we run a placebo test under which we estimate the impact of firm-level financial vulnerabilities on the change in within-firm TFP growth after the 2000 recession that followed the burst of the dot-com bubble. Because this recession was not associated with a banking crisis, when rerunning regressions (1) and (2) with 2000 instead of 2008 as the assumed crisis year, we should not find any statistically significant impact of the share of debt maturing in 2000 on the change in firm-level TFP growth between the pre- and post-2000 recession periods. This is indeed what comes out of Table 7, where none of coefficients reported in Columns 1–4 show any statistical significance. Figure 3 graphically presents these results. Unlike Figure 1, which showed starkly different post-crisis TFP growth paths for firms with different levels of precrisis financial vulnerabilities, Figure 4 shows no such difference around the 2000 recession, which, although much milder than the post-GFC recession, was still associated with a large TFP decline after 2001 in our sample of firms. This is consistent with previous studies that show that recessions associated with banking crises tend to have a prolonged negative effect on investment and real GDP, whereas regular recessions do not (Cerra and Saxena 2008; Rioja et al. 2014). Our findings suggest that the role of financial frictions for TFP may be one channel through which financial crises have been found to have a puzzling, permanent adverse effect on real GDP.

Table 7
Placebo test: Early 2000s recession

Dependent variable	(1)	(2)	(3)	(4)
	ΔTFP^{growth} (post-2000 minus pre-2000)		$\Delta Int\_Investment$ (post-2000 minus pre-2000)	
Debt maturing 2000	−0.0719	−0.0152	0.00483	0.00496
	(0.046)	(0.031)	(0.033)	(0.028)
R-squared	.170	.204	.104	.105
N	53,139	53,139	3,295	3,295
Country*Sector FEs	Yes	Yes	Yes	Yes
Controls	No	Yes	No	Yes

The placebo post-crisis period runs from 2000 to 2005, with 2000 assumed to be the crisis year. The dependent variable ΔTFP^{growth} is the difference in the average TFP growth rate between the pre- and post-crisis periods. The dependent variable $\Delta Int\_Investment$ is the difference in the investment in intangible assets as a ratio of value added pre- versus post-crisis. *Debt maturing 2000* is the amount of debt maturing in 2000 divided by average total sales pre-2000. Firm-specific controls include firm age, size of assets, and earnings (EBITDA). Standard errors are in parentheses. Standard errors are clustered at the country-sector level. $^{*}p < .1$; $^{**}p < .05$; $^{***}p < .01$.

3. Robustness Checks

3.1 Alternative productivity measures

Given the methodological and data issues involved in measuring TFP, we confirm that our main result holds when using alternative TFP measures or even just labor productivity. To this end, we rerun our baseline regression replacing our TFP measure with three alternative variables: TFP derived from an estimation of the production function by simple OLS, rather than the Wooldridge approach; TFP calculated—rather than estimated—as the Solow residual from a simple Cobb-Douglas production with labor and capital and constant returns to scale, with the labor share of all firms in each industry being set equal to the average labor share observed across all countries and years in the OEC's STAN database; labor productivity, measured as the ratio of real value-added output to the number of employee, and therefore immune to the key issues involved in TFP measurement. Table 8 reports the results, which largely confirm those in Table 2: firms with greater financial vulnerabilities prior to the crisis experienced a sharper decline in TFP and labor productivity growth after the crisis. The magnitudes of the coefficients are also broadly in line with those in Table 2: a 10-percentage-point higher share of debt maturing in 2008 was associated with a 0.1-percentage-point further weaker average TFP productivity growth rate in the post-crisis period, and a 0.5-percentage-point weaker labor productivity growth.

3.2 Debt rollover risk

One potential issue with our debt-rollover-risk variable is that it may not be fully predetermined because it includes not only maturing long-term debt but also short-term debt. By definition, short-term debt maturing in 2008 was incurred in 2007. While the September 2008 collapse of Lehman Brothers and the associated shock to credit conditions were largely unforeseen in 2007, the

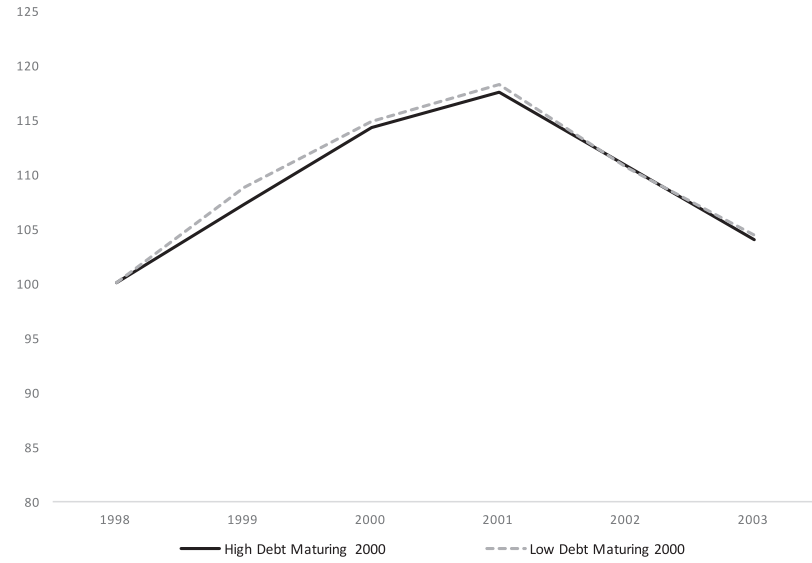

Figure 4
TFP level path for firms with different rollover risks: 2000 recession (index 100 = 1998)
The TFP level path is shown as an index taking value 100 in 1998. *High (low) debt maturing in 2000* corresponds to the 75th (25th) percentile of the cross-firm distribution of *High debt maturity 2000*. *Debt maturing 2000* is the amount of debt maturing in 2000 divided by average total sales pre-2000.

amount of short-term debt that firms decided to take on in 2007 might still have been driven in part by future expected economic and financial conditions. To address this potential endogeneity issue, several recent papers use only long-term maturing debt as a measure of firms' exposure to unforeseen financial shocks (see, e.g., Almeida et al. 2011; Carvalho 2015). The decomposition of maturing debt into its short- and long-term components required to follow such strategy is not available in Orbis. However, we perform three alternative exercises in the same spirit, all of which strengthen confidence in our results. First, we construct an alternative vulnerability measure that removes debt to suppliers and contractors (trade credit) from the total debt that matures in 2008. Trade credit is typically short-term debt and is sizeable, accounting for about 17% of debt maturing for the median firm. If the potential endogeneity of short-term debt to economic and financial conditions biases our results, then excluding trade credit should affect our results. However, as shown in Column 2 of Table 9, the coefficient of our modified "Debt maturing 2008[CG1]" variable that excludes trade credit turns out to be very close to, and does not significantly differ from, the baseline coefficient reported in Column 1.[20] This suggests that the effects of short-term debt and maturing long-term debt, which we would

[20] A formal test confirms that there is no statistical difference in the coefficients relative to our baseline. The results are available on request.

Table 8
Baseline regression: Alternative measures of productivity

Dependent variable	(1)	(2)	(3)	(4)	(5)	(6)
	Labor Productivity		Cobb-Douglas CRS		OLS	
Debt maturing 2008	−0.0438***	−0.0513***	−0.0703***	−0.106***	−0.0611***	−0.0950***
	(0.004)	(0.004)	(0.008)	(0.010)	(0.008)	(0.010)
R-squared	.0297	.0342	.0864	.0975	.0927	.102
N	143,472	143,472	145,400	145,400	142,734	142,734
Country*Sector FEs	Yes	Yes	Yes	Yes	Yes	Yes
Controls	No	Yes	No	Yes	No	Yes

The dependent variable *Labor productivity* is the difference in the labor productivity growth rate pre- versus post-crisis. *Cobb-Douglas CRS* is the difference in TFP (Solow residual) pre- versus post-crisis, assuming industry-specific labor shares from the OECD-STAN data and Cobb-Douglas production function with constant returns to scale (see Gal 2013 for further details). *OLS* is the difference in TFP derived from an OLS regression, based on a Cobb-Douglas production function without additional constraints on returns to scale. *Debt maturing 2008* is the amount of debt maturing in 2008 divided by average total sales precrisis. Post-crisis starts in 200. Firm-specific controls include firm age, size of assets and earnings (EBITDA). Standard errors are in parentheses. Standard errors are clustered at the country-sector level. *$p < .1$; **$p < .05$; ***$p < .01$.

Table 9
Baseline regression: Alternative measures of debt maturing 2008

Dependent variable	(1)	(2)	(3)	(4)
			$\Delta\, TFP^{growth}$	
Debt maturing 2008	−0.0935***		−0.0988***	−0.0906***
	(0.008)		(0.013)	(0.009)
Debt maturity 2008, excl. trade credit		−0.0822***		
		(0.007)		
R-squared	.151	.150	.135	.162
N	134,838	134,295	31,285	103,409
Country*Sector FEs	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes
Sample	All	All	Debt maturity >=2 years	Excl. firms with only ST debt

The dependent variable ΔTFP^{growth} is the difference in the average TFP growth rate between pre- and post-crisis periods. *Debt maturing 2008* is the amount of debt maturing in 2008 divided by average total sales precrisis. *Debt maturing 2008 excl. trade credit* removes debt to suppliers and contractors (trade credit) from the total debt that matures in 2008. Column 3 only includes firms that did not issue any financial debt in 2007. Column 4 excludes all firms that we know only have short-term debt. The post-crisis period starts in 2008. Firm-specific controls include firm age, size of assets and earnings (EBITDA). Standard errors are in parentheses. Standard errors are clustered at the country-sector level. *$p < .1$; **$p < .05$; ***$p < .01$.

like to identify but cannot estimate because of a lack of adequate data, are of comparable magnitude. As a second robustness check, we rerun our baseline regression only on the subset of firms that did not issue any financial debt in 2007. By implication, these are firms whose financial debt that was scheduled to mature in 2008 at the end of 2007 had an original maturity of at least 2 years and was therefore closer to capturing long-term maturing debt than our baseline variable. Note that sample size shrinks by over three-fourths when restricting the analysis only to this subset of firms. The coefficient of the "Debt maturing 2008" we obtain in Column 3 is very similar to, and does not significantly differ

from, the baseline coefficient reported in Column 1.[21] This again suggests that the effects of short-term maturing debt and long-term maturing debt are broadly similar. Third, and still in the same spirit, we rerun our baseline regression on a sample that excludes all firms that we know only have short-term debt. These are the firms that do not have any long-term financial debt in 2007, and whose financial debt maturing in 2008 is equal to the issuance of financial debt in 2007. Column 4 shows that our results hold, and the magnitude of the estimated coefficient is unaffected, when we remove those firms—about one-fourth of the total number of firms—from our estimation sample.

3.3 Other dimensions of financial vulnerability

We also check whether other dimensions of firm' financial vulnerability also affected post-crisis productivity growth, over and above the impact of our preferred rollover risk measure (debt maturing in 2008). To this end, we consider the following three additional variables: the ratio of cash and cash equivalents to total assets, a high value of which should reduce liquidity risk, all else equal; leverage, measured as the ratio of total liabilities to total assets; the interest coverage ratio (ICR), measured as the ratio of interest expenses to earnings, which captures the fir's ability to meet its interest payments. All three indicators are averaged over the precrisis period and included in our baseline regression, either separately or jointly. Table 10 shows the results. Most importantly, the coefficients of debt maturing in 2008 are highly stable across all specifications. The role of the random distribution of debt maturing in 2008 for post-crisis TFP growth is unaffected by the presence of different other measures of financial vulnerability. This is even though other dimensions of financial vulnerability also appear to have affected post-crisis TFP growth. All coefficients have the expected signs and are statistically significant, except for the cash ratio when all indicators are entered jointly in Column 4.

3.4 GIIPS versus non-GIIPS

Firms in GIIPS countries (Greece, Ireland, Italy, Portugal, and Spain) were on average more financially vulnerable than their counterparts in non-GIIPS countries coming into the financial crisis. Furthermore, banks in GIIPS countries experienced a somewhat larger spike in their CDS spreads than their non-GIIPS counterparts around the collapse of Lehman Brothers (Table 1), and a much larger one later in the crisis.[22] Therefore, one would expect a more severe decline in productivity growth due to financial vulnerabilities in GIIPS countries. To test for this, we rerun our baseline regression for GIIPS and non-GIIPS countries separately. Table 11 shows that our baseline result holds for

[21] Results from a formal test for Columns 3 and 4 are available on request.

[22] As noted earlier, to focus on a plausibly exogenous shock to credit supply, our empirical analysis exploits only the change in CDS spreads over a narrow window around the Lehman bankruptcy and ignores any changes that might have taken place later during the post-crisis period.

Table 10
Baseline regression: Incorporating other measures of financial vulnerability

Dependent variable	(1)	(2)	(3)	(4)
	ΔTFP^{growth}			
Debt maturing 2008	−0.0900***	−0.0907***	−0.0917***	−0.0907***
	(0.007)	(0.007)	(0.007)	(0.007)
Cash precrisis	0.0284***			0.000564
	(0.007)			(0.008)
Leverage precrisis		−0.0363***		−0.0229***
		(0.008)		(0.009)
ICR precrisis			−0.0236***	−0.0193***
			(0.005)	(0.005)
R-squared	.151	.151	.158	.158
N	133,272	134,838	117882	116,441
Country*Sector FEs	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes

The dependent variable ΔTFP^{growth} is the difference in the average TFP growth rate between the pre- and post-crisis periods. *Cash precrisis* is the ratio of average cash and cash equivalents to total assets before the crisis. *Leverage precrisis* is average leverage, measured as the debt-to-asset ratio, before the crisis. *ICR precrisis* is the average ratio of interest expenses to earnings (EBITDA), that is, the inverse of the interest coverage ratio, before the crisis. Firm-specific controls include firm age, size of assets and earnings (EBITDA). Standard errors are in parentheses. Standard errors are clustered at the country-sector level. $*p < .1$; $**p < .05$; $***p < .01$.

Table 11
Baseline regression: Country groups

	(1) GIIPS	(2) Non-GIIPS	(3) Euro	(4) Non-Euro
Debt maturing 2008	−0.132***	−0.0517***	−0.116***	−0.0492***
	(0.014)	(0.009)	(0.011)	(0.012)
R-squared	.0957	.0737	.103	.0709
N	83,714	61,686	112,003	33,397
Country*Sector FEs	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes

The dependent variable ΔTFP^{growth} is the difference in the average TFP growth rate between the pre- and post-crisis periods. *Debt maturing 2008* is the amount of debt maturing in 2008 divided by average total sales precrisis. Post-crisis starts in 2008. Firm-specific controls include firm age, size of assets and earnings (EBITDA). Column 1 considers firms in GIIPS countries only (Greece, Ireland, Italy, Portugal, and Spain), and Column 2 excludes firms in GIIPS countries. Column 3 considers European firms only, whereas Column 4 considers non-European firms only (Japan, Korea, the United Kingdom, and Sweden). Standard errors are in parentheses. Standard errors are clustered at the country-sector level. $*p < .1$; $**p < .05$; $***p < .01$.

both samples. Furthermore, we find stronger effects of financial vulnerabilities affecting the post-crisis TFP growth in GIIPS countries compared to non-GIIPS countries. Based on Column 2 in Table 11, a firm with a 10-percentage-point higher share of debt maturing in 2008 experienced a 1.32-percentage-point decline in TFP growth in GIIPS countries versus only 0.52 percentage point in non-GIIPS countries. To gain a sense of the overall impact of financial frictions on the post-crisis aggregate productivity losses, we repeat the back-of-the-envelope calculation in Section 3.1, but now separately for GIIPS and non-GIIPS countries using the coefficients shown in Table 11. We find that financial frictions may have accounted for about 46% of the total within-firm TFP growth loss for GIIPS countries, versus only 15% for non-GIIPS

countries.[23] A similar argument could be made that firms based in Europe, in general, have experienced a larger slowdown in productivity compared to firms based outside of Europe. Columns 3 and 4 show that European firms in our sample experienced about 0.7-percentage-point larger productivity decline than their counterparts outside of Europe, namely, in Japan, Korea, the United Kingdom, and Sweden, in response to the same severity of financial frictions.

3.5 Old firms versus young firms

Young and old firms may differ fundamentally in that the former may be forced to take up short-term debt for lack of alternative means of funding, while the latter may have more options and may therefore set their debt maturity more freely. In this robustness check, we check for any potential endogeneity issue due to firm age by splitting our sample in two bins—older firms and younger firms—and comparing the coefficients of each bin. Older (younger) firms are defined as those that are more (less) than 16 years old—the average firm age in our sample—in 2007. Table 12 reports the results. Our main finding appears to hold for both samples, whereas the coefficients of debt maturing in 2008 do not significantly differ between them when we group young and old firms together and interact a dummy for young with the share of debt maturing in 2008.

3.6 Controlling for the level of TFP prior to the crisis

In a final robustness check, we check for the robustness of our baseline results when controlling for the average level of TFP before the crisis. This is to address the potential concern that the post-crisis change in firm's TFP growth could be somehow related to its precrisis TFP level, which, in turn may correlate with the firm's reliance on short-term debt. For example, it could be that firms that had higher short-term debt prior to the crisis were low-TFP-level firms that were catching up fast and were thus bound to experience a gradual slowdown in their TFP growth regardless of the GFC. In practice, however, the data show no material link between the average TFP level and short-term debt prior to crisis. The correlation is -0.09, and the average precrisis TFP level of firms that were above the 75th percentile of the distribution of short-term debt was just 1.1% higher than that of firms that were below the 25th percentile. Reflecting this, controlling for the level of TFP does not affect our baseline results, as shown in Table 13.

4. Conclusion

In this paper, we have studied the impact of financial frictions on firm-level productivity. Using a rich cross-country, firm-level data set and exploiting variation in preexisting firm-level exposure to the 2008 global financial crisis,

[23] Note that the share of debt maturing in 2008 was also higher for GIIPS than for non-GIIPS countries (Table 1).

Table 12
Baseline regression: Old firms versus young firms

Dependent variable	(1)	(2)	(3)	(4)
	ΔTFP^{growth}			
	Old firms	Young firms	Old firms	Young firms
Debt maturing 2008	−0.0647***	−0.0725***	−0.0823***	−0.105***
	(0.009)	(0.008)	(0.01)	(0.009)
R-squared	.183	.127	.193	.138
N	48,827	85,859	48,827	85,859
Country*Sector FEs	Yes	Yes	Yes	Yes
Controls	No	No	Yes	Yes

The dependent variable ΔTFP^{growth} is the difference in the average TFP growth rate between the pre- and post-crisis periods. Old (young) firms are firms with the age older (less) than 16 years in 2007. Firm-specific controls include firm age, size of assets and earnings (EBITDA). Standard errors are in parentheses. Standard errors are clustered at the country-sector level. $*p < .1$; $**p < .05$; $***p < .01$.

Table 13
Controlling for the precrisis TFP level

Dependent variable	(1)	(2)	(3)	(4)
	ΔTFP^{growth}			
Debt maturing 2008	−0.0698***	−0.0670***	−0.0629***	−0.0899***
	(0.006)	(0.005)	(0.005)	(0.006)
Average TFP level precrisis	−0.0641	0.637	0.860	0.595
	(0.419)	(0.655)	(0.673)	(0.609)
R-squared	.127	.131	.142	.151
N	134,838	134,838	134,838	134,838
Country*Sector FEs	No	No	Yes	Yes
Sector FEs	No	Yes	—	—
Country FEs	Yes	Yes	—	—
Controls	No	No	No	Yes

The dependent variable ΔTFP^{growth} is the difference in the average TFP growth rate between the pre- and post-crisis periods. *Average TFP level precrisis* is the average firm-level TFP level (measured by the Wooldridge method) before the crisis. Firm-specific controls include firm age, size of assets, employment, and earnings (EBITDA). $*p < .1$; $**p < .05$; $***p < .01$.

we have shown that the interplay between preexisting financial fragilities and tightening credit conditions weakened within-firm productivity growth after the crisis, and disproportionately so for firms that faced a more severe tightening of credit conditions. The resultant effect on TFP levels has been large and highly persistent; financial frictions may have accounted for about a third of the post-crisis within-firm productivity slowdown in advanced economies, and even more so in those (mostly southern European) that were hit hardest during the crisis and its aftermath. We have also provided evidence that more restrictive access to credit led more vulnerable firms to cut back on intangible capital investment, which was one channel through which financial frictions weakened productivity growth. Future research should delve deeper into this and other channels through which credit conditions could affect productivity within firms.

References

Ackerberg, D. A., K. Caves, and G. Frazer. 2015. Identification properties of recent production function estimators. *Econometrica* 83:2411–51.

Adler, G., R. Duval, D. Furceri, K. Koloskova, and M. Poplawski-Ribeiro. 2017. Gone with the headwinds: The global productivity slowdown. IMF Staff Discussion Note.

Afonso, G., A. Kovner, and A. Schoar. 2011. Stressed, not frozen: The federal funds market in the financial crisis. *Journal of Finance* 66:1109–39.

Aghion, P., G.-M. Angeletos, A. Banerjee, and K. Manova. 2010. Volatility and growth: Credit constraints and the composition of investment. *Journal of Monetary Economics* 57:246–65.

Aghion, P., P. Askenazy, N. Berman, G. Cette, and L. Eymard. 2012. Credit constraints and the cyclicality of R&D investment: Evidence from France. *Journal of the European Economic Association* 10:1001–1024.

Alcalá, F., and A. Ciccone. 2004. Trade and productivity. *Quarterly Journal of Economics* 119:613–46.

Almeida, H., M. Campello, B. Laranjeira, and S. Weisbenner. 2011. Corporate debt maturity and the real effects of the 2007 credit crisis. *Critical Finance Review* 1:3–58.

Andrews, D., C. Criscuolo, and P. Gal. 2015. Frontier firms, technology diffusion and public policy: Micro evidence from OECD countries. Working Paper, OECD.

Anzoategui, D., D. Comin, M. Gertler, and J. Martinez. 2016. Endogenous technology adoption and R&D as sources of business cycle persistence. Working Paper, Rutgers.

Barbiero, F., Brutscher, P., Kolev, A., and Wolski, M. (2016). Misallocation of investment in Europe: Debt overhang, credit market distress, or weak demand? Mimeo.

Benigno, G., N. Converse, and L. Fornaro. 2015. Large capital inflows, sectoral allocation, and economic performance. *Journal of International Money and Finance* 55:60–87.

Benmelech, E., N. K. Bergman, and A. Seru. 2011. Financing labor. NBER Working Paper, Northwestern University.

Benmelech, E., C. Frydman, and D. Papanikolaou. 2017. Financial frictions and employment during the great depression. *Journal of Financial Economics* Advance Access published February 28, 2019, 10.1016/j.jfineco.2019.02.005.

Bertrand, M., E. Duflo, and S. Mullainathan. 2004. How much should we trust differences-in-differences estimates? *Quarterly Journal of Economics* 119:249–75.

Borio, C. E., E. Kharroubi, C. Upper, and F. Zampolli. 2016. Labour reallocation and productivity dynamics: Financial causes, real consequences. Working Paper, BIS.

Brunnermeier, M. K. (2009). Deciphering the Liquidity and Credit Crunch 2007–2008. *The Journal of Economic Perspectives* 23:77–100.

Caballero, R. J., and M. L. Hammour. 1998. The macroeconomics of specificity. *Journal of Political Economy* 106:724–67.

Carvalho, D. 2015. Financing constraints and the amplification of aggregate downturns. *Review of Financial Studies* 28:2463–501.

Cerra, V., and S. C. Saxena. 2008. Growth dynamics: The myth of economic recovery. *American Economic Review* 98:439–57.

Cette, G., J. Fernald, and B. Mojon. 2016. The pre-great recession slowdown in productivity. *European Economic Review* 88:3–20.

Cheng, I.-H., S. Raina, and W. Xiong. 2014. Wall street and the housing bubble. *American Economic Review* 104:2797–829.

Chodorow-Reich, G. 2013. The employment effects of credit market disruptions: Firm-level evidence from the 2008–9 financial crisis. *Quarterly Journal of Economics* 129:1–59.

Corrado, C., C. Hulten, and D. Sichel. 2005. Measuring capital and technology: An expanded framework. In *Measuring capital in the new economy*, ed. C. Corrado, J. Haltiwanger, and D. Sichel, 11–46. Chicago: University of Chicago Press.

Corrado, C., C. Hulten, and D. Sichel. 2009. Intangible capital and US economic growth. *Review of Income and Wealth* 55:661–85.

De Rassenfosse, G., H. Dernis, and G. Boedt. 2014. An introduction to the patstat database with example queries. *Australian Economic Review* 47:395–408.

Decker, R. A., J. Haltiwanger, R. S. Jarmin, and J. Miranda. 2016a. Declining business dynamism: What we know and the way forward. *American Economic Review* 106:203–207.

Decker, R. A., J. Haltiwanger, R. S. Jarmin, and J. Miranda. 2016b. Where has all the skewness gone? the decline in high-growth (young) firms in the US. *European Economic Review* 86:4–23.

Fernald, J. G. 2015. Productivity and potential output before, during, and after the great recession. *NBER Macroeconomics Annual* 291:1–51.

Gal, P. 2013. Measuring total factor productivity at the firm level using OECD-ORBIS. Working Paper, OECD.

Gal, P. N., and A. Hijzen. 2016. The short-term impact of product market reforms: A cross-country firm-level analysis. Working Paper, IMF.

Garcia-Macia, D. (2015). The financing of ideas and the great deviation. Mimeo, Stanford University.

Giannetti, M., and S. Ongena. 2012. 'Lending by example': Direct and indirect effects of foreign banks in emerging markets. *Journal of International Economics* 86:167–80.

Gilchrist, S., R. Schoenle, J. Sim, and E. Zakrajšek. 2017. Inflation dynamics during the financial crisis. *American Economic Review* 107:785–823.

Giroud, X., and H. M. Mueller. 2017. Firm leverage, consumer demand, and employment losses during the great recession. *Quarterly Journal of Economics* 132:271–316.

Gopinath, G., Ş. Kalemli-Özcan, L. Karabarbounis, and C. Villegas-Sanchez. 2017. Capital allocation and productivity in south Europe. *The Quarterly Journal of Economics* 132:1915–67.

Gordon, R. J. 2016. *The rise and fall of American growth: The US standard of living since the Civil War*. Princeton: Princeton University Press.

Holmstrom, B., and J. Tirole. 1997. Financial intermediation, loanable funds, and the real sector. *The Quarterly Journal of Economics* 112:663–91.

Hsieh, C.-T., and P. J. Klenow. 2009. Misallocation and manufacturing TFP in China and India. *Quarterly Journal of Economics* 124:1403–48.

Huber, K. 2018. Disentangling the effects of a banking crisis: Evidence from german firms and counties. *American Economic Review* 108:868–98.

Inklaar, R., M. O'Mahony, and M. Timmer. 2005. Ict and Europe's productivity performance: Industry-level growth account comparisons with the united states. *Review of Income and Wealth* 51:505–36.

Ivashina, V., and D. Scharfstein. 2010. Bank lending during the financial crisis of 2008. *Journal of Financial Economics* 97:319–38.

Kalemli-Özcan, Ş., L. Laeven, and D. Moreno. 2015. Debt overhang in Europe: Evidence from firm-bank-sovereign linkages. Working Paper, University of Maryland.

Kalemli-Özcan, Ş., B. Sorensen, C. Villegas-Sanchez, V. Volosovych, and S. Yesiltas. 2015. How to construct nationally representative firm level data from the ORBIS global database. Working Paper, University of Maryland.

Khwaja, A. I., and A. Mian. 2008. Tracing the impact of bank liquidity shocks: Evidence from an emerging market. *American Economic Review* 98:1413–42.

Kogan, L., D. Papanikolaou, A. Seru, and N. Stoffman. 2017. Technological innovation, resource allocation, and growth. *Quarterly Journal of Economics* 132:665–712.

Levinsohn, J., and A. Petrin. 2003. Estimating production functions using inputs to control for unobservables. *Review of Economic Studies* 70:317–41.

Matsuyama, K. 2007. Credit traps and credit cycles. *American Economic Review* 97:503–16.

Mian, A., and A. Sufi. 2014. What explains the 2007–2009 drop in employment? *Econometrica* 82:2197–223.

Midrigan, V., and D. Y. Xu. 2014. Finance and misallocation: Evidence from plant-level data. *American Economic Review* 104:422–58.

Moll, B. 2014. Productivity losses from financial frictions: Can self-financing undo capital misallocation? *American Economic Review* 104:3186–221.

OECD (2015). The future of productivity. *Joint Economics Department and the Directorate for Science, Technology and Innovation Policy Note, OECD Publishing, Paris, France.*

Olley, G. S., and A. Pakes. 1996. The dynamics of productivity in the telecommunications equipment industry. *Econometrica* 64:1263–97.

Osotimehin, S., and F. Pappadà. 2017. Credit frictions and the cleansing effect of recessions. *Economic Journal* 127:1153–87.

Rajan, R. G., and L. Zingales. 1998. Financial dependence and growth. *American Economic Review* 88:559–86.

Restuccia, D., and R. Rogerson. 2008. Policy distortions and aggregate productivity with heterogeneous establishments. *Review of Economic Dynamics* 11:707–20.

Restuccia, D., and R. Rogerson. 2013. Misallocation and productivity. *Review of Economic Dynamics* 16:1–10.

Ridder, M. D. 2016. Investment in productivity and the long-run effect of financial crisis on output. Mimeo, Cambridge University.

Rioja, F., F. Rios-Avila, and N. Valev. 2014. The persistent effect of banking crises on investment and the role of financial markets. *Journal of Financial Economic Policy* 6:64–77.

Siemer, M. 2014. Firm entry and employment dynamics in the great recession. Working Paper, FRB.

Syverson, C. (2011). What determines productivity? *Journal of Economic Literature* 49:326–65.

Wooldridge, J. M. 2009. On estimating firm-level production functions using proxy variables to control for unobservables. *Economics Letters* 104:112–14.