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growth - what explains it and will it
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THE SLOWDOWN IN US PRODUCTIVITY GROWTH - WHAT EXPLAINS IT AND WILL IT PERSIST?

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Abstract

The US recovery following the Great Recession has been marked by persistent low growth. At the same time, productivity growth has consistently disappointed in the aftermath of the last recession. This has raised doubts about the long-term growth prospects of the US economy and led to worries about secular stagnation. This paper contributes to the debate by empirically revising the main determinants of labour productivity growth over the period 1999-2013 for a panel of US states, focusing on capital deepening, R&D spending, the sectoral composition, financial factors and business dynamism. We find that more than half of the slowdown in productivity growth in the period 2011-13 relative to its sample average is due to a decline in the rate of capital deepening. The other major factor explaining the recent weakness in productivity growth - more closely related to TFP - is the slowdown in business dynamism experienced by the US economy. By contrast, financial factors appear to have become supportive of productivity growth in that period.

Keywords: Labour productivity; Total factor productivity; Potential output; Business dynamism.

JEL Classification: D24; E24; J24; O47

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1 Introduction and literature review

“By far the most important global economic issue is the persistent decline in productivity growth that threatens to undermine progress for all.”¹

Labour productivity growth in the US business sector has been surprisingly soft after the Great Recession, growing at an average of only 0.5% per year since 2011, compared with an annual long-run growth rate of 2.5%. This weakness in productivity growth is not confined to the United States, but is rather a global phenomenon (Conference Board 2016). It has spurred a bout of academic research with the aim of shedding light on the weakness of one of the most important drivers of future economic prosperity and growth.

A strand of the literature relates the slowdown in productivity growth to the fading effects of technological advances and, in particular, the information and communication technology (ICT) revolution. Many have argued that the resurgence in US productivity growth in the mid-1990s was the result of an exceptional ICT boom (Jorgenson 2001, Oliner and Sichel 2002, Jorgenson et al. 2005, Oliner et al. 2007) and that the recent subdued pace of productivity growth is merely the return to more “normal” rates (Fernald 2014). More broadly, however, Gordon (2012, 2014, 2016) argues that the productivity benefits of prior innovations, including the ICT, have been exhausted and that recent technological discoveries may simply be less revolutionary compared with earlier inventions such as railway or electricity. By contrast, a few others are more optimistic that technological progress will continue to enhance productivity and transform the economy (Brynjolfsson and McAfee 2011, 2014, Baily et al. 2013, Byrne et al. 2013). In relation to this debate, some have argued that the lower productivity returns from technological advances could be due to capital mismeasurement. Although measuring intangible investment and knowledge creation properly is challenging (Syverson 2011), recent work by Byrne et al. (2016) finds little evidence that the productivity slowdown is due to *growing* mismeasurement of the gains from IT innovation. Similarly, Syverson (2016) challenges the IT mismeasurement hypothesis and its ability to account for a substantial portion of the productivity slowdown.

Another explanation for the productivity slowdown relates to the diffusion of R&D and technology within the economy. Cardarelli and Lusinyan (2015) find that the TFP growth slowdown since the mid-2000s has been widespread across US states, with the average state moving away from the production frontier. They argue that the slowdown owes more to a declining efficiency in combining factors of production and slower catching up (influenced by educational attainment and investment in R&D) than to a diminishing pace of technological progress. This result is consistent with the findings by the OECD (2015), which suggest that TFP growth at the frontier has not declined noticeably, while it is the gap between frontier and laggard industries or firms that explain the fall in aggregate TFP growth. The decline in business dynamism, discussed later on, also suggests that the diffusion of innovation to the economy is slower. For example, Decker et al. (2015) find that firms’ responsiveness to productivity (TFP) shocks has declined substantially in the US high-tech manufacturing sector in the post-2000 period, suggesting slower technology diffusion.

The literature has also studied the relevance of compositional changes in explaining productivity developments. In general, Byrne et al. (2016) find that shifts in the sectoral composition

¹Financial Times, 30 May 2016.

of the economy from manufacturing to lower-productivity services sector are not a central part of the story. The TFP slowdown is similar if one holds industry weights fixed and does not reflect a rising share of slow-growth industries. Their results are consistent with some previous studies that have found that the shrinking size of well-measured sectors such as manufacturing was not a first-order explanation for previous swings in productivity growth (Baily and Gordon 1988, Sichel 1997). An aspect that seems more relevant for productivity changes, however, is the shift to or the emergence of sectors characterised by high innovation or business dynamism. As evidenced by Haltiwanger et al. (2016), in the post-2000 period, the high-tech and energy-related industries exhibited a significantly larger share of activity by high-growth young firms compared with other sectors. This suggests potentially increased gains in productivity growth from a rapid expansion of these two sectors during our sample period. At the same time, however, the finding by Haltiwanger et al. (2014) that start-ups in the high-tech sector have been sharply declining since 2000 could partly explain the more recent aggregate productivity slowdown.

Another growing stream of research links productivity growth to (excessive) credit cycles and investigates the role of the credit cycle around the Great Recession for the slowdown in productivity growth. While the credit boom that preceded the financial crisis of 2008 resulted in a misallocation of resources towards the housing market prior to the crisis, a combination of financial factors has impeded the cleansing process in the aftermath of the crisis. The restricted access to credit for new and small firms has likely reduced entrepreneurial activity and spending on R&D, thus hurting innovation (Redmond and Van Zandwhege 2016). Meanwhile, the generally low funding costs, weak real wage growth and loan forbearance allowed a greater proportion of less productive firms to survive compared with previous recessions. Overall, the evidence suggests that financial factors have hindered the effective reallocation of labour and capital, delaying the recovery from the shock. Foster et al. (2014) find that in the Great Recession the intensity of reallocation fell rather than rose in the United States, while the reallocation that did occur was less productivity-enhancing than in prior recessions in the 1990s and 2000s. The authors contemplate that a clear candidate for this different pattern is the role of the financial collapse itself and the way it affected young businesses.

Cecchetti and Kharroubi (2012) also investigate how financial developments affect productivity growth in a sample of developed and emerging market economies. One of their key findings is that a fast-growing financial sector (measured by the squared five-year average private credit to GDP ratio) is detrimental to aggregate productivity growth. The mechanism of this is that booming industries draw in resources at a fast rate and it is only when they crash that one realises the extent of the over-investment that occurred and that many of these resources should have gone elsewhere. In the same spirit, Borio et al. (2015) investigate the link between credit booms, productivity growth and labour reallocations in a sample of more than twenty advanced economies over the period 1979-2009, and find that credit booms tend to weaken aggregate productivity growth by inducing a reallocation of labour towards lower productivity growth sectors such as construction. In addition, the authors find that after financial crises, the negative effect on productivity growth persists into post-recession years. The potential distortions to reallocation dynamics and the cleansing process in recessions due to credit constraints is also discussed by Barlevy (2003) and Osotimehin and Pappada (2016). The difference in their models is the

interaction of productivity and credit constraints, and whether the most productive firms are likely to be subject to credit constraints or not.

A further key explanation for the deterioration in productivity performance that features prominently in the literature is impediments in the optimal resource allocation between firms and sectors. Central to this discussion is the notion of business dynamism, which relates to business formation and labour market flexibility. Empirical evidence shows that strong entrepreneurship, high firm entry and exit rates and a high pace of job reallocation are productivity-enhancing (Foster et al. 2001, Bartelsman et al. 2013).² The vast empirical findings are consistent with theoretical models of firm dynamics that emphasise the importance of creative destruction for innovation and productivity growth (Acemoglu et al. 2013).

The key role of firm start-ups and young firms for business dynamism, and in particular for job creation and reallocation, has been highlighted by many authors (Decker et al. 2014*a*, Haltiwanger et al. 2013, Haltiwanger 2012, Dent et al. 2016). Along these lines, Foster et al. (2001, 2006) link young firms to productivity growth in the US manufacturing and selected services industries, including the retail sector. In more recent work using firm-level data for the entire US private sector, Haltiwanger et al. (2016) conclude that high growth young firms contribute disproportionately not only to job creation, but also to output and productivity growth. They find that the job reallocation triggered by young firms explains at least half of within industry labour productivity growth in the United States.

A main concern is that the pace of US business dynamism, both in the form of start-ups and job reallocation, has fallen over recent decades in all major sectors and that this downward trend has accelerated since 2000 (Haltiwanger et al. 2011, Davis et al. 2012, Reedy and Strom 2012, Hyatt and Spletzer 2013, Davis and Haltiwanger 2014, Pugsley and Sahin 2014, Gourio and Siemer 2014, Decker et al. 2014*b*, Haltiwanger 2015). For example, in a recent paper, Molloy et al. (2016) find that labour market fluidity (including hires and separations, interstate migration and job creation and destruction) has been on a clear downward trend since at least the early 1980s. Also, Molloy et al. (2013) show that cross-state migration was less than half as large in 2011 as its average over the period 1948-71.³

This slowdown in business dynamism can exhibit cyclical as well as secular patterns. A slowdown in the reallocation process, and thus productivity growth, can be temporary, driven for example by labour hoarding, increased spare capacity within firms and firms switching from more capital-intensive to more labour-intensive forms of production due to low real wages. It can, nevertheless, also be the result of more persistent or structural factors, such as changes in the sectoral composition of the economy and financial conditions, entrenched uncertainty about future economic prospects, or changes in the demographic composition of the workforce.

On the cyclical side, financial crises can impair business formation, while reducing labour-market fluidity. Bloom (2009) estimates that aggregate productivity growth often declines after an uncertainty shock, dropping to around 15% of its pre-shock value. The reason is that uncer-

²Under certain conditions, a slower pace of reallocation can be associated with higher productivity. See, for example, the transition from “mom-and-pop” single establishments to more productive large national chains in the US retail sector in the 1990s (Foster et al. 2006).

³Some explanations on the decline in labour market dynamics might be benign or even positive. For example, aging of population and more efficient matching process via the internet account for some of the decline in migration and job churning (Hyatt and Spletzer 2013).

tainty reduces the shrinkage of low productivity firms and the expansion of high productivity firms, reducing the reallocation of resources from less to more productive units. Increased uncertainty and credit restrictions can also reduce the willingness to take on entrepreneurial risk, potentially in a more persistent manner. Fort et al. (2013) find that young/small businesses are more sensitive to cyclical shocks and house price shocks (possibly due to their use of home equity as collateral for financing) than older/larger businesses. They argue that the disproportionately large decline of young/small businesses in the Great Recession and the resulting strong hit on net employment growth and job creation is important for understanding not only the depth of the recession, but also the slow productivity growth and economic recovery thereafter.

However, the decline in business dynamism in the United States preceded the Great Recession by a couple of decades, possibly masking more structural factors. These include some benign ones, for instance a transformation in business models within an industry (such as the one that occurred in the US retail trade sector in the 1980s and 1990s)⁴, but possibly also more worrisome developments such as increasing market distortions and frictions. Davis and Haltiwanger (2014) find that adjustment costs for employment (for example, occupational licenses) have risen in the United States, while Decker et al. (2014b) provide indirect evidence that the decline in business dynamism likely reflects increased adjustment frictions.⁵ Other possible explanations for the secular decline in business dynamism include lower growth in labour supply (Karahan et al. 2015) and demographic changes.⁶

The main contribution of our paper is to bring together many of the above alternative explanations for the dynamics of US labour productivity growth and to quantify their importance for the slowdown, particularly in recent years. Our study uses state-level data for labour productivity over the period 1999-2013. Our paper thus contributes to the empirical discussion on the determinants of US productivity in the spirit of Cardarelli and Lusinyan (2015), but puts more emphasis on exploring how *changes* in these determinants have affected the *dynamics* of labour productivity. The key findings are that US productivity growth is determined by changes in capital deepening, the availability of credit and the extent to which credit growth is excessive, as well as by the dynamism of the economy as measured by labour market churn and the firm entry rate. More than half of the slowdown in productivity growth in the period 2011-13 relative to its sample average can be attributed to a decline in the rate of capital deepening. The other major factor explaining the recent weakness in productivity growth - more closely related to TFP - is the slowdown in business dynamism experienced by the US economy. While financial factors had been important in holding back productivity growth during the Great Recession (i.e. in the period 2008-10), they now appear to have become supportive of productivity growth. Overall, part of the productivity slowdown appears to be cyclical, particularly in relation to capital investment, but some other aspects related to business dynamism, could prove more persistent.

The remainder of the paper is organised as follows. In the next section (Section 2), we

⁴See footnote 2.

⁵Similarly, Bartelsman et al. (2013) show how various types of producer-level distortions reduce the output-productivity correlation within an industry.

⁶While young cohorts are more likely to be entrepreneurs, recent data suggest that in 2014 it was no longer the case that the share of new entrepreneurs was higher in the age group below 45 than above, see Kauffman index of start-up activity.

present key stylised facts relating to the dynamics of productivity growth and its decomposition in the past. Section 3 outlines the data used in the empirical analysis, the variable definitions and sources. Section 4 introduces the empirical set-up, summarises the main empirical results and robustness checks and shows the model-based decomposition of the slowdown in productivity growth. Section 5 concludes.

2 Stylised facts

Before going into the causes of the productivity growth slowdown, it is useful to establish the key stylised facts. Labour productivity growth in the US business sector has been surprisingly weak since the Great Recession, except for a brief period of cyclical rebound in 2008-10, see Figure 1a. Productivity grew at an average of only 0.5% per year since 2011, compared with an annual long-run growth rate of 2.5%. Historically, labour productivity growth has varied greatly over time, with strong growth rates (of 3.3%) in the post-WWII reconstruction period 1949-73, followed by a sharp slowdown (to 1.6%) in the two decades that followed. The ICT boom led to the productivity miracle during the period 1996-2003, where the pace of labour productivity growth doubled again. By 2004, the gains from the ICT boom appeared to have largely been reaped, causing a renewed slowdown in productivity growth to 1.9% in the pre-crisis years (2004-07). While the Great Recession saw an initial rebound, this was followed by a disappointing performance since 2011. Comparing the current business cycle with past cycles reveals that developments in labour productivity growth during the last recession were broadly in line with past recessions, while it is the current expansion where the weakness is particularly pronounced, see Figure 1b.

In addition to its persistence, the slowdown in productivity growth was very broad-based across US states. Figure 2a shows labour productivity growth (defined as output per employee) for the US states, comparing the average growth rates in 2011-14 to the pre-crisis period 2004-07. The slowdown is evident for almost all states, with the main exceptions (Texas, Nevada, West Virginia, New Mexico) being states with a very large mining sector that has experienced a productivity boom since 2008 due to the shale oil revolution.

According to neoclassical growth accounting, labour productivity growth ($\Delta Y/H$) can be decomposed into contributions from capital deepening ($\Delta K/H$), labour quality ($\Delta L_{input}/H$) and total factor productivity (ΔTFP), see Equation (1), where H stands for labour quantity (total hours worked), α_k is the share of capital in output and α_l is the labour share. Capital is defined as capital services derived from the stock of physical assets and intellectual property assets,⁷ while labour quality (or composition) measures the effect of shifts in the age, education and gender composition of the workforce on the efficiency of hours worked. Finally, TFP growth is measured as a Solow residual and captures the increase in efficiency due to other factors, in particular the increase in the efficiency and intensity the inputs are utilised in production, deriving for example from new technologies, more efficient business processes and organisational improvements.

⁷Including fixed business equipment, structures, inventories, land and intellectual property products.

$$\Delta Y/H = \alpha_k \Delta K/H + \alpha_l \Delta L_{input}/H + \Delta TFP \quad (1)$$

The decomposition in Figure 1a shows that a decline in the contribution from capital deepening since 2011, and to a lesser extent slower TFP growth, particularly since 2004-07, explain most of the slowdown in US labour productivity growth. TFP growth slowed already prior to the global financial crisis in 2008, in part as the benefits from the ICT revolution had run their course, but the slowdown has been exacerbated since the last recession. By contrast, the contribution from capital deepening initially increased during the recession as the large drop in total hours worked led to a sharp rise in the amount of capital per hour (or worker). This was followed by a pronounced decline into negative territory over the period 2011-15. Meanwhile, the contribution from labour quality increased in recent years compared with past decades perhaps as the recession most strongly hit the low-skilled workers, thus raising the aggregate efficiency of those that remained employed.

The growth of capital deepening is at its lowest level in over 60 years, see Figure 2b. Decomposing the ratio of capital deepening further into capital accumulation (nominator) and hours worked (denominator) indicates that it was the combination of a sharp slowdown and weak recovery in business investment and the cyclical recovery in hours worked that explain the negative contributions from capital deepening to labour productivity growth since 2011.

3 Data and variables

In the empirical analysis, we use annual US state-level data over the period 1999-2013, with the sample period being dictated by data availability. Our dependent variable is labour productivity growth, defined as the annual growth rate of the ratio of real GDP divided by non-farm employment by state. According to the literature, labour productivity growth depends on a plethora of factors (for a synopsis, Syverson 2011); taking its components, capital deepening is largely determined by capital investment (mostly in tangible but also in some intangible assets like software), overall demand and long-term economic prospects. Meanwhile, TFP - the residual unobservable component of labour productivity growth that aims at capturing the efficiency of combined input utilisation - is influenced by technological progress, financial conditions and allocative efficiency (for a summary, Isaksson 2007).

Our selection of explanatory variables is motivated by previous studies on the determinants of productivity, some of which were outlined in Section 1. In our model we control directly for capital intensity at the US aggregate level, given the lack of capital data at the state-level. In addition, and to analyse empirically the determinants of TFP growth, we incorporate four broad sets of drivers inferred from the literature as important. These aim to capture changes in (i) the technological progress, (ii) the economy's sectoral composition, (iii) financial conditions and (iv) business dynamism.⁸

⁸We have also investigated the role of corporate tax rates (higher corporate taxes can reduce the incentives for productivity-enhancing innovations and for risk-taking incentives by lowering post-tax returns) and government capital expenditure, but have not found a robust role for these variables in our sample. Due to a lack of data, we have not tested for the effect of labour quality, via for example the level of educational attainment or the skill composition of the workforce. But since there is no evidence of a significant change in the educational attainment at least for the US economy as a whole (see Figure A.1c in the Appendix), this is unlikely to have been a major

Starting with technological progress and innovation, we investigate whether the extent of R&D spending (as a percentage of GDP) is positively associated with productivity growth, as suggested by a large body of empirical literature, see CBO (2005) for a review.

As regards sectoral composition, we control for the impact on productivity growth of sectors that were highly innovative or dynamic during our sample period by including in our specification the share of IT-producing and mining sectors in total value added. Our definition of IT-producing industries follows that of Fernald (2014). We expect both sectors to have a positive relation with aggregate productivity growth across states.

Turning to financial factors as the third bloc of productivity determinants, we focus on two main channels: first, the link between balance sheet and credit variables with allocative efficiency and, thus, productivity growth (for example, Fort et al. 2013, Greenstone et al. 2014, Chodorow-Reich 2014, Barlevy 2003, Osotimehin and Pappada 2016, Borio et al. 2015) and second, the effect of credit conditions on innovation, see Redmond and Van Zandwhege (2016). More concretely, we test whether a net tightening of bank credit standards on lending to SMEs, which typically include the young and most dynamic firms, is associated with lower productivity growth and whether excessive household debt is also associated with lower productivity growth. In particular, in our sample, the housing and credit boom prior to the Great Recession that caused the household debt-to-income ratio to rise above equilibrium levels (Albuquerque et al. 2015) may have drawn in excessive resources, thus lowering allocative efficiency.

Moving to business dynamism as the fourth set of factors, and building on the extensive literature on the significance of start-ups and labour market fluidity in enhancing productivity, we investigate the role of business birth and job reallocation rates for productivity growth. We expect both variables to be positively associated with productivity growth.

Finally, a well-established finding in the literature is that productivity growth has an important cyclical component. In the words of Basu and Fernald (2001) in Hulten et al. (2001): *“Productivity is procyclical. That is, whether measured as labor productivity or total factor productivity, productivity rises in booms and falls in recessions.”*⁹ While we have tried including a variable capturing the US business cycle in the regressions, this was in most cases not statistically significant, probably as some of the other explanatory variables (such as capital deepening, credit standards, the debt gap and to some extent the indicators capturing business dynamism) have a strong cyclical component. As a result, it is important to note that we cannot entirely separate cyclical from more secular changes in the drivers of productivity growth.

The following list summarises the variables employed in our empirical analysis, including in parentheses the expected sign in the regressions, and their data source. Meanwhile, Figure A.1 and Tables A.1 and A.2 in the Appendix show charts for the US aggregate of some of the key variables as well as descriptive statistics and pairwise correlation coefficients.

factor in explaining the productivity slowdown after the Great Recession.

⁹The authors suggest a number of reasons that explain the movement of productivity growth with the business cycle, including the procyclicality of technology shocks (as in real business cycle models), the variation of input utilisation over the business cycle (“factor hoarding”) as well as the reallocation of resources across uses with different marginal products. More recent papers, however, suggest a countercyclical shift in productivity growth after the mid-1980s (Stiroh 2009, Fernald and Wang 2015). Causes of this change in the relationship include a reduction in the variation of factor utilisation, which itself may have been driven by increased economic/labour market flexibility, changes in the structure of the economy (such as a declining share of manufacturing in output) and shifts in the relative variances of technology and demand shocks.

1. Capital

- **Capital deepening (dklratio)**: percentage growth in capital services per hour of all persons in the business sector at the US aggregate level. Source: Bureau of Labor Statistics. (+)

2. Technological progress

- **R&D spending (rnd)**: federal spending on R&D activities as percentage of nominal GDP.¹⁰ Sources: National Science Board, Science and Engineering Indicators 2016 and Bureau of Economic Analysis. (+)

3. Sectoral composition

- **Share of IT-producing sectors (itprod)**: the nominal GDP of IT-producing industries as a percentage share of the nominal GDP of total industries at state level. The definition of IT-producing industries follows that of Fernald (2014), and includes Computer and electronic product manufacturing, Publishing (incl. software), and Computer systems design. Source: Bureau of Economic Analysis. (+)
- **Share of mining sector (mining)**: the nominal GDP of mining and petroleum manufacturing industries as a percentage share of the nominal GDP of total industries at state level. Source: Bureau of Economic Analysis. (+)

4. Financial factors

- **Credit standards (crdst)**: percentage of banks tightening credit standards for commercial and industrial loans to small firms at US aggregate level. Source: Federal Reserve Board, Senior Loan Officer Opinion Survey on Bank Lending Practices. (-)
- **Debt gap (debtgap)**: the difference between the actual household debt-to-income ratio and its estimated equilibrium at a state level.¹¹ Source: Albuquerque et al. (2015). (-)

5. Business dynamism

- **Job reallocation rate (jobrer)**: the sum of the job creation rate and the job destruction rate minus the absolute net job creation rate for the private sector at a state level. The job creation rate is defined as the gains from all expanding establishments including start-ups over average employment. Similarly the job destruction rate is defined as the employment losses from all contracting establishments including shut-downs over average employment. Source: US Census Bureau, Business Dynamics Statistics. (+)
- **Business entries (bentr)**: the rate of establishment births from the prior year to the selected year at a state level. Source: US Census Bureau, Business Dynamics Statistics. (+)

¹⁰We have also experimented with private business R&D spending and the sum of private business and federal R&D spending as percentage of GDP.

¹¹The estimated equilibrium in Albuquerque et al. (2015) is time-varying and determined by income expectations, uncertainty, the demographic structure of the population and the availability and cost of credit.

4 Empirical setup and results

4.1 Empirical setup and specification tests

We estimate a panel model with fixed effects for the 50 US states over the period 1999-2013. In the model, labour productivity growth at the state level is related to the set of explanatory variables explained in Section 3. The estimated Equation (2) takes the following form:

$$\begin{aligned} dprod_{it} = & \alpha_i + \beta_1 dklratio_{t-1} + \beta_2 rnd_{it} + \beta_3 itprod_{it} + \beta_4 mining_{it} + \beta_5 crdst_t \\ & + \beta_6 debtgap_{it} + \beta_7 jobrer_{it} + \beta_8 bentr_{it} + \gamma tdum_t + \epsilon_{it} \end{aligned} \quad (2)$$

where α_i is the state fixed effect and $dklratio(t-1)$ is the growth rate of capital deepening, which is only available at the US national level and lagged by a year to minimise potential reverse causality with productivity growth. $tdum$ is a vector of time dummies that controls for time fixed effects that have a common impact on the US states. A Wald test confirms the joint significance of the time dummies, see Table A.3 in the Appendix.¹² ϵ_{it} is the error term and the subscripts i and t denote the panel of 50 states and the years, respectively. The other variable names are as defined in Section 3.

Further specification tests suggest the presence of heteroskedasticity in the errors (see Table A.3 in the Appendix for the results of the Wald test of group-wise heteroskedasticity). To address this issue, we use the Huber/White or sandwich estimator of the variance. To decide between random and fixed effects, we conduct the Hausman test. The results (see Table A.3 in the Appendix) suggest a systematic difference between the coefficients, implying that random effects estimator is inconsistent, which determined our choice of the fixed effects estimator.

4.2 Regression results

The results of the fixed effects estimates, shown in Table 1, suggest that all of the determinants considered above are relevant in explaining labour productivity growth in recent years and have the expected sign, except for R&D spending, for which we do not find a statistically significant role in our sample period.¹³

First, an increase in the growth rate of US aggregate capital deepening is associated with higher productivity growth as indicated by the positive coefficient on $dklratio$. This could be due both to the mechanical impact of capital deepening on labour productivity growth via the production function, and by the fact that some types of capital investment (notably intellectual property, which includes R&D and software) may reinforce TFP growth and increase human

¹²Without time dummies, the Pesaran test reveals evidence of severe cross-sectional dependence in the disturbances, see Table A.3 in the Appendix. Including time dummies leads to a rejection of cross-sectional dependence at a 5% level. In Section 4.3, the fixed effects estimator with Driscoll and Kraay standard errors (robust to cross-sectional dependence) is employed as a robustness check.

¹³We have tested rnd contemporaneously and with its first lag, and find a slightly higher significance when it is lagged. A possible explanation of the finding of no statistically significant role in our regressions is the variable's high correlation with the variable $itprod$, see Table A.2 in the Appendix. The finding of no statistical significance of R&D spending in explaining productivity growth is not uncommon in studies that use economy-wide data, perhaps as aggregate R&D expenditures do not exhibit much variation over time, see CBO (2005). By contrast, most studies using firm-level data find a statistically and economically significant relationship between productivity growth and R&D spending.

and informational capital. Second, states with a faster expansion in IT production or mining sectors relative to total value added tend to have higher productivity growth, as shown by the positive coefficients on and statistical significance of *itprod* and *mining*.

We also find evidence that financial factors influence productivity growth. On the one hand, a net tightening in credit standards to small and medium enterprises (reflected in a rise in *crdst*) is associated with lower productivity growth, as more restricted access to credit by these firms likely reduces their entrepreneurial activity. On the other hand, we find that excessive household debt, measured by the gap of actual household-debt-to-income relative to its estimated equilibrium, is associated with lower productivity growth. This is in line with the findings by Borio et al. (2015), who show that credit booms tend to weaken aggregate productivity growth by inducing a reallocation towards low-productivity sectors. While column (4) of Table 1 uses only the available estimates of the household debt gap that end in 2012, these data are extended into 2013 (assuming the debt gap remains unchanged at 2012 levels for all states) in the regressions in column (5), with the coefficients remaining broadly unchanged.¹⁴

In addition, we find a role for firm and labour market dynamism in explaining productivity growth. Both the job reallocation rate *jobrer* and the rate of business entries *bentr* are positively and significantly associated with productivity growth, most likely by leading to a more efficient allocation of resources. This result suggests that the pace of innovation creation, and more importantly, the degree of technological diffusion heavily rely on business and labour market dynamism, with young firms and easy access to affordable financing playing a central role. Finally, as we do not find a statistically significant relationship between R&D spending and productivity growth in our sample, in what follows, we drop the variable *rnd* from the estimation with column (8) of Table 1 being our preferred specification.

4.3 Robustness

We now investigate further the robustness of the model to alternative assumptions. First, as mentioned above, there may be an issue of reverse causality between the growth in capital deepening and productivity growth, which so far we have dealt with by lagging *dkratio*. An alternative approach is to employ the fixed effects instrumental variable (IV) estimator, where the lags of the growth in capital deepening, as well as of the unemployment rate and US GDP growth, are used as instruments. Column (2) of Table 2 shows the results of the fixed effects IV estimation.¹⁵ While the coefficient on growth in capital deepening increases slightly, the other coefficients remain broadly unchanged and statistically significant, except for the coefficient on the household debt gap, which loses its statistical significance. Overall, the results suggest that the endogeneity may not be a major issue in our preferred model in column (1) of Table 2 as it is appropriately dealt with by using the first lag of the growth rate of capital deepening.

In our preferred model, we minimise the issue of cross-sectional dependence in the error terms by including time dummies. This is a valid approach if the cross-sectional correlations are the same for every pair of cross-sectional units (or, in our case, states). Since ignoring

¹⁴We do this simple extension of the data as we are mostly interested in understanding the slowdown in productivity growth since 2011, so any additional year can provide further evidence.

¹⁵When conducting the Davidson-MacKinnon test of exogeneity of the growth of capital deepening, the null hypothesis of exogeneity is not rejected (see Table A.3 in the Appendix), suggesting the validity of the instruments.

cross-sectional correlation in panel models can lead to severely biased estimates, however, we investigate this issue further by employing the cross-sectional dependence-consistent Driscoll-Kraay estimator (Driscoll and Kraay 1998).¹⁶ This estimator allows for an error structure that is heteroskedastic, autocorrelated up to the order of 2 (in our case) and correlated between states. The results are shown in column (3) of Table 2. Again, the results remain broadly unchanged, with only the debt gap losing its statistical significance.¹⁷

A further issue that we investigate is whether our results are robust across different quantiles of states. The preferred fixed effects regressions show the mean value of the response variable (labour productivity growth) for given levels of the predictor variables. However, since productivity developments may diverge substantially across states (for example, one can think of California with the tech hub Silicon Valley at the extreme, compared with less advantaged states), it is important to explore whether the mean results are driven by certain groups of states. Figure 3a shows the distribution of productivity growth rates across states and over time. While the level of productivity growth across percentiles varies substantially, ranging from around -2% to over 4%, the dynamics of productivity growth across the different percentiles is actually very similar and the mean is close to the median.

We investigate this issue empirically by comparing our preferred regressions to median regressions. Column (4) in Table 2 shows the pooled median regression results with robust standard errors as in Machado et al. (2011). The results remain relatively robust for the median regressions, except for the variables *mining* and *jobrer*, which lose their statistical significance. We interpret the former finding as that there are large differences in the scale of the mining sector across US states, with the mean results therefore likely to be driven by those states with an important mining sector. Meanwhile a high job reallocation rate may be less positive for productivity growth in the states with many firms that are close to the productivity frontier, while more important for the catch-up states.

Figure 3b provides additional evidence on the difference in productivity growth for high versus low technology states, where the State Technology & Science Index (for the year 2014) by the Milken Institute is used to differentiate the states. This suggests that the states with a State Technology & Science Index value above the 75th percentile had significantly stronger productivity growth rates compared with the lower tech states (defined as those with an Index value below the 25th percentile) during the ICT boom in the late 1990s. In the early 2000s, the low tech states caught up in terms of productivity growth, which could reflect a lagged diffusion of the ICT technology to those states. Thereafter, however, the productivity dynamics of high versus low tech states were surprisingly similar.

4.4 What factors explain the recent decline in productivity growth?

The estimates of the fixed effects model and the developments in the underlying variables can now be used to decompose the deviation of labour productivity growth from its sample

¹⁶As shown by the Monte Carlo simulations in Hoechle (2007), the Driscoll-Kraay standard errors are well calibrated when cross-sectional dependence is present.

¹⁷In our sample with relatively large number of states i and a short time span t , one has to be cautious in applying this estimator, however, since it relies on asymptotic theory. For this reason, we do not use it as preferred estimator.

average into the contributions from the different factors. The results are shown in Figure 4. Focusing on the most recent period 2011-13, they reveal that the weakness in aggregate US capital deepening explains a large part (-1pp) of the difference of the deviation of labour productivity growth from its average over this period. An additional 0.7pp is explained by a reduced dynamism of the US economy, both via less churning in the labour market (-0.3pp) and via a reduced rate of business entries (-0.4pp).

Our regression results corroborate the view expressed by many authors, including Cardarelli and Lusinyan (2015) and OECD (2015) that the degree of technological diffusion in the economy and the capacity of states and firms to efficiently combine resources and internalise new technologies matter for the productivity slowdown. To this end, policies that promote ICT-relevant and ICT-complementary skills are essential.

In line with Decker et al. (2016) and Haltiwanger et al. (2016), our results provide further evidence of the importance of new businesses to overall productivity growth. We find that business dynamism contributed negatively to productivity growth in the crisis and post-crisis periods. Although part of the decline in business dynamism likely reflects secular factors, the financial crisis might have exacerbated the downward trend, probably leaving a more persistent mark. This could, for example, be associated with a structural levelling-off in the risk-taking appetite of entrepreneurs, partly due to higher economic and policy uncertainty. Bloom (2013) reiterates that uncertainty not only reduces the level of investment (as also reflected in our analysis by the drag from capital deepening on productivity growth in 2011-13), but also makes firms less sensitive to business conditions and drivers like demand, prices and productivity. This could imply a vicious circle that may prolong firms' cleansing process and, by extension, delay the recovery of productivity growth.

Meanwhile, easier credit standards for small and medium enterprises have supported productivity growth (+0.4pp) in the period 2011-13. This follows a significant drag from credit conditions in the period 2008-10 covering the downturn and early stages of the recovery (-0.5pp), when credit standards had tightened substantially. This corroborates the general finding by Redmond and Van Zandwhege (2016) that tight credit conditions have temporarily restrained TFP growth during the crisis, although in contrast to their paper, we do not find a lasting effect in the sense that the drag on productivity growth was reversed once credit standards eased.¹⁸ Our empirical evidence also supports the argument that financial factors have hindered the effective reallocation of labour and capital during the crisis, delaying the initial recovery from the shock. In the Great Recession, the intensity of job reallocation fell in the United States, which we find to have lowered productivity growth as the financial collapse seems to have affected disproportionately young businesses (as also discussed in Foster et al. (2014)). Moreover, in the period 2008-10, the household debt overhang posed a significant though small drag on productivity growth, most likely reflecting the earlier misallocation of resources towards the housing sector. This negative impact on productivity growth is in line with the BIS (2015), who finds that the misallocation due to the credit boom reduced annual US labour productivity growth once the boom turned to bust (by 0.4pp in 2008-13).¹⁹ Our results suggest a more important role

¹⁸The results by Redmond and Van Zandwhege (2016) are based on different measures of credit conditions (the excess bond premium and the TED spread). They also use the net percentage of banks tightening conditions for C&I loans to *large* firms, for which they find only a short-lived effect on TFP growth.

¹⁹However, our results differ for the period 2004-07, where in contrast to the BIS, we find a small positive

for the housing bubble in explaining the productivity slowdown than found by Fernald (2014). Apart from restricting the financing of new and young firms via lower home equity (Fort et al. 2013), the housing bubble has likely caused a wider, deeper and more persistent misallocation of resources in the US economy.

Finally, changes in the share of IT production and mining sectors have been supportive of productivity growth in the period 2011-13 (0.0pp and +0.2pp, respectively), but explain only a small fraction of the deviation of US productivity growth from its average. Similar to the findings by Cardarelli and Lusinyan (2015) using TFP estimates, our model-based decomposition of labour productivity growth suggests that changes in the IT-producing sector do not explain the productivity slowdown since the mid-2000s. This is because the share of the IT-producing sector in total value added remained broadly unchanged on average across states over our sample period 1999-2013. Only a handful of states (in the 90th percentile), such as California, saw a significant rise and subsequent drop in the shares of their IT-producing sectors in 2004-07, but this decline was not widespread across different percentiles of states (see Figure A.2 in the Appendix). In addition, states with lower productivity growth tended to be “innovation-takers” rather than “innovation-makers”, with the IT-producing sector playing a marginal, if any, role.

5 Concluding remarks

Our paper shows that changes in capital deepening, the dynamism of the economy (as measured by labour market churn and the firm entry rate), the availability of credit and the extent to which credit growth is excessive have been important determinants of productivity growth in the United States. More than half of the slowdown in productivity growth in the period 2011-13 relative to its sample average can be attributed to a decline in the rate of capital deepening. The other major factor explaining the recent weakness in productivity growth - more closely related to TFP - is the slowdown in business dynamism experienced by the US economy.

While financial factors were important in holding back productivity growth during the Great Recession (i.e. in the period 2008-10), they now appear to have become overall supportive of productivity growth. In addition, although it is important to control for the sectors where productivity has been growing particularly rapidly, we do not find evidence for changes in the sectoral composition of growth (at least via the IT production and mining sectors) to have held back productivity growth in recent years. If anything, the shale energy boom has supported aggregate productivity growth via rising productivity in the mining sector.

Overall, some aspects of the productivity growth slowdown, in particular those related to business dynamism, could prove somewhat persistent. Understanding the drivers and the evolution of business dynamism is thus crucial and a priority for future research, as the speed at which labour productivity is able to grow in the medium term may be limited by the extent to which impaired allocation of resources continues to be a binding constraint.

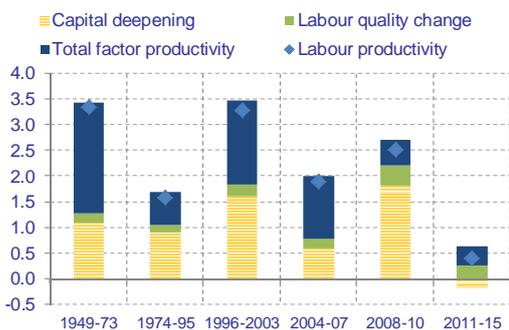
Our results also lead to a number of policy implications. First, promoting capital investment in tangibles (such as infrastructure, automation equipment and machinery) and, more

impact of the debt gap on changes in productivity growth.

critically, in intangibles (such as ICT-relevant skills, managerial and organisational abilities) via education and training could benefit productivity growth and facilitate the diffusion of innovation. Other “incentive regulation” measures, such as tax cuts for specific productivity-enhancing types of human and physical investment, as well as subsidies, could accelerate the development and wide adoption of commercial uses of new technology, boosting productivity growth. While the existing institutional framework in the United States seems to adequately support innovation creation and R&D spending, it appears less supportive for innovation transfer. Further trade integration at global and regional levels could also contribute to increased knowledge transmission and productivity spillovers, as extensively documented also in the literature. Second, it is important to re-invigorate business dynamism by mitigating uncertainty and addressing regulatory and competitive hurdles, such as firm collusion, occupational licensing requirements or immigration rules that raise barriers to entrepreneurship. Furthermore, policies to provide credit to small young firms/start-ups would ensure an uninterrupted pace of business creation, higher competition for incumbents, improvements in allocative efficiency and increased absorptive capacity of new technologies by firms, ultimately yielding significant gains in TFP growth.

Figure 1: Labour productivity in the United States

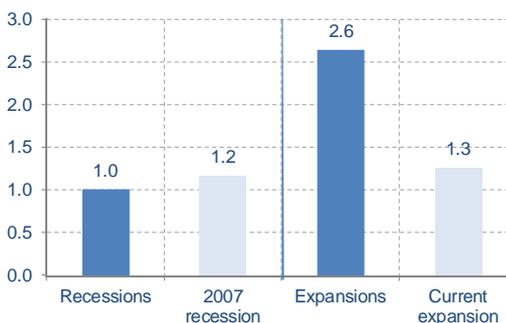
a. Decomposition of labour productivity growth
(pp contribution to annual percentage change, period averages)



Source: Bureau of Labor Statistics.

Note: Labour productivity is defined as output in the business sector per hour.

b. Labour productivity in recessions and expansions
(annual percentage change, period averages)

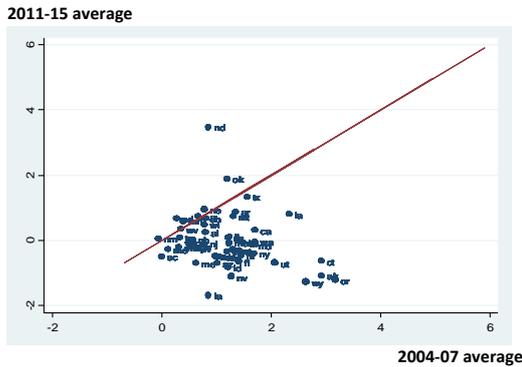


Sources: Bureau of Labor Statistics and National Bureau of Economic Research (NBER).

Note: Recessions and expansions as defined by the NBER. The last recession lasted from December 2007 to June 2009, when the current expansion started.

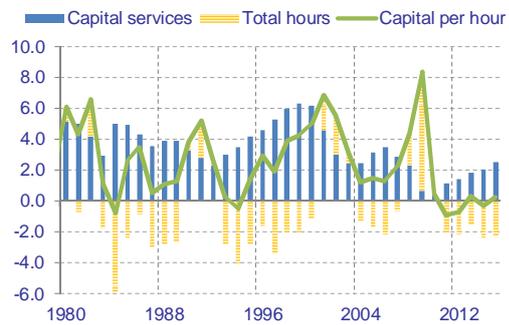
Figure 2: Slowdown in productivity by US states and decomposition of capital deepening

a. Productivity growth slowdown 2004-07 to 2011-14
(average annual percentage change, period averages)



Sources: Bureau of Economic Analysis, Bureau of Labor Statistics and author calculations.
Note: Labour productivity is defined as output per employee.

b. Contributions to capital deepening
(pp contribution to annual percentage change)

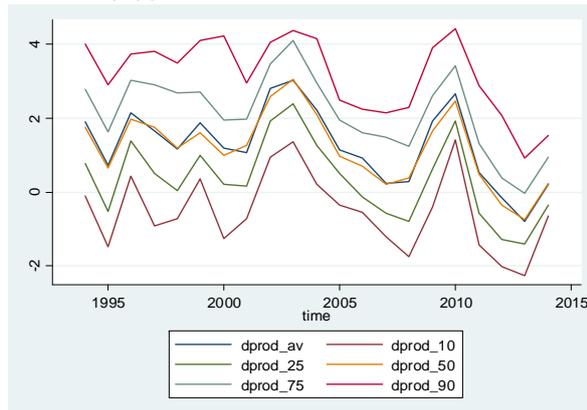


Source: Bureau of Labor Statistics.

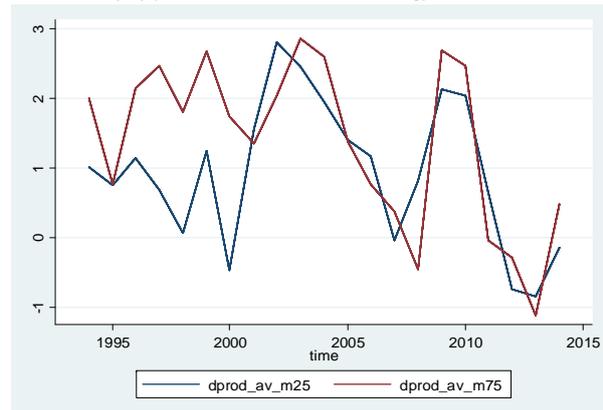
Note: Capital per hour is defined as capital services divided by total hours. Hence a rise in hours leads to a negative bar/contribution to capital deepening.

Figure 3: Productivity growth distribution
(annual percentage changes)

a. Productivity by percentiles



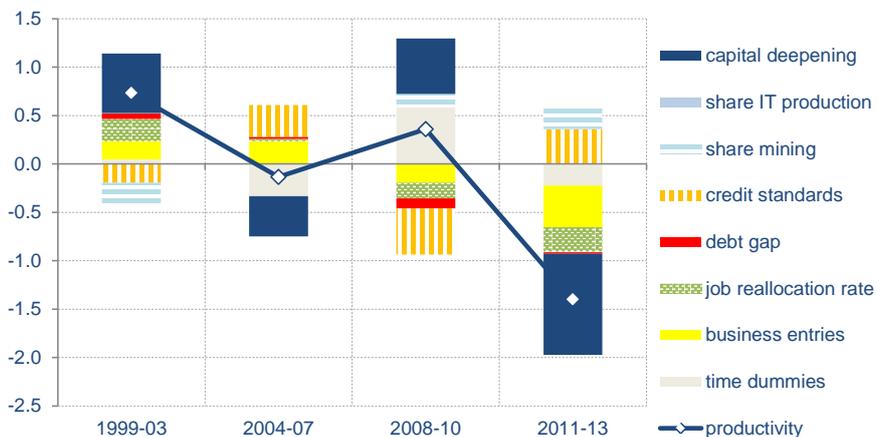
b. Productivity by percentiles of the State Technology & Science Index



Sources: Bureau of Economic Analysis, Bureau of Labor Statistics, Milken Institute and authors' calculations.

Figure 4: Model-based decomposition of productivity growth

(pp contribution to annual percentage change; deviation from average over the sample; period averages)



Source: Authors' calculations.

Table 1: Fixed effects model estimates of productivity growth

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
L.dklratio	0.294*** (0.000)	0.370*** (0.000)	0.133** (0.027)	0.496*** (0.000)	0.650*** (0.000)	0.557*** (0.000)	0.291*** (0.007)	0.291*** (0.007)	0.263** (0.012)
itprod		0.215** (0.027)	0.212*** (0.005)	0.235*** (0.002)	0.205** (0.012)	0.212*** (0.007)	0.211*** (0.008)	0.211*** (0.008)	0.212*** (0.006)
mining		0.145*** (0.000)	0.213*** (0.000)	0.230*** (0.000)	0.193*** (0.000)	0.202*** (0.000)	0.202*** (0.000)	0.202*** (0.000)	0.206*** (0.000)
crdst			-0.027*** (0.001)	-0.018** (0.015)	-0.012* (0.072)	-0.012* (0.075)	-0.022*** (0.005)	-0.022*** (0.005)	-0.024*** (0.002)
debtgap				-0.016*** (0.007)					
debtgap_ext					-0.013** (0.030)	-0.014** (0.027)	-0.011* (0.075)	-0.011* (0.075)	-0.011* (0.078)
jobrer						0.083* (0.084)	0.082* (0.099)	0.082* (0.099)	0.095* (0.072)
bentr							0.261** (0.011)	0.261** (0.011)	0.326*** (0.001)
L.rnd									0.362 (0.133)
Constant	0.540*** (0.000)	-1.002*** (0.008)	-0.079 (0.889)	-1.337*** (0.000)	-1.784*** (0.000)	-3.804*** (0.003)	-5.763*** (0.000)	-5.763*** (0.000)	-7.000*** (0.000)
Observations	1,092	915	915	711	813	762	762	762	747
R-squared	0.150	0.233	0.324	0.31	0.344	0.345	0.349	0.349	0.355
No of states	52	51	51	51	51	51	51	51	50

Notes: Fixed effects regressions with robust p-values in parentheses. The dependent variable is the annual percentage change in labour productivity growth. Asterisks, *, **, ***, denote, respectively, statistical significance at the 10, 5 and 1% levels.

Table 2: Fixed effects - alternative specifications

	(1) Preferred model	(2) IV estimator	(3) Driscoll-Kraay standard errors	(4) Pooled median regression
L.dklratio	0.291*** (0.007)	0.469*** (0.000)	0.317*** (0.000)	0.374*** (0.000)
itprod	0.211*** (0.008)	0.211*** (0.000)	0.211* (0.058)	0.091** (0.045)
mining	0.202*** (0.000)	0.202*** (0.000)	0.202*** (0.000)	0.021 (0.174)
crdst	-0.022*** (0.005)	-0.016*** (0.009)	-0.023*** (0.004)	-0.009*** (0.010)
debtgap_ext	-0.011* (0.075)	-0.011 (0.199)	-0.011 (0.170)	-0.016*** (0.000)
jobrer	0.082* (0.099)	0.082* (0.057)	0.082* (0.058)	-0.032 (0.131)
bentr	0.261** (0.011)	0.261** (0.032)	0.261** (0.039)	0.081* (0.060)
Constant	-5.763*** (0.000)	-6.489*** (0.000)	-5.741*** (0.002)	-0.202*** (0.662)
Observations	762	762	762	762
R-squared	0.349	0.349	0.349	0.247
No of states	51	51	51	51

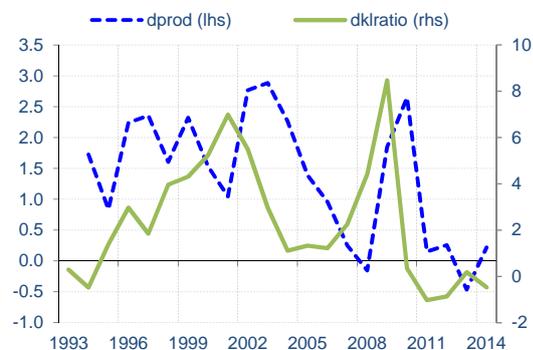
Notes: Fixed effects regressions with robust p-values in parentheses. The dependent variable is the annual percentage change in labour productivity growth. Asterisks, *, **, ***, denote, respectively, statistical significance at the 10, 5 and 1% levels. Instruments used in column (2) include all exogenous variables and the unemployment rate (contemporaneous and first lag), the second and third lags of the growth of capital deepening and the second lag of US GDP growth.

Appendix

Figure A.1: Main variables, US aggregate

a. Productivity and capital deepening

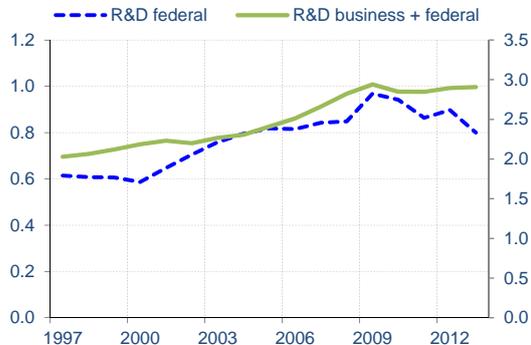
(annual percentage change)



Sources: Bureau of Labor Statistics and Bureau of Economic Analysis.

b. R&D spending

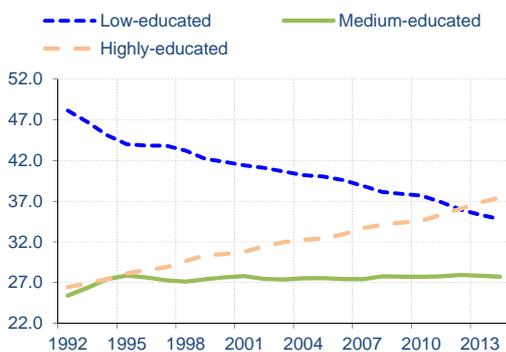
(percent of GDP)



Sources: National Science Board and Bureau of Economic Analysis.

c. Labour force by education level

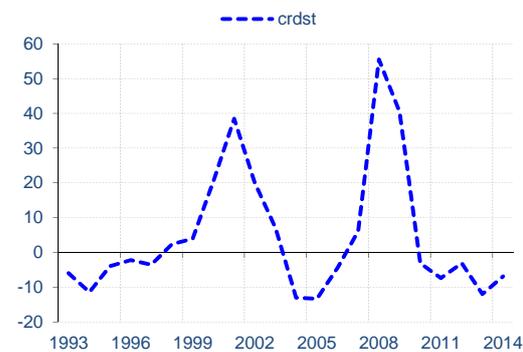
(percent of total labour force above 25 years)



Source: Bureau of Labor Statistics.

d. Net tightening of credit standards on small business loans

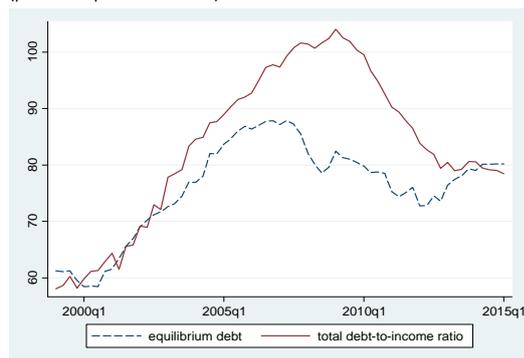
(net percentage of banks tightening standards)



Source: Federal Reserve Board.

e. Actual and equilibrium household debt

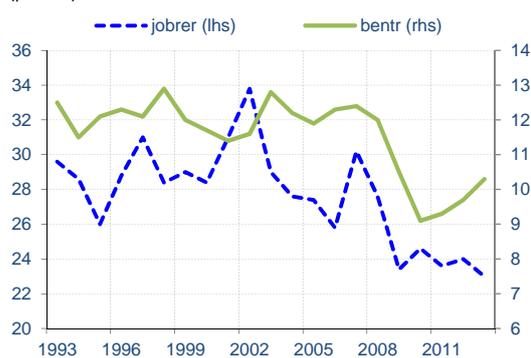
(percent of personal income)



Sources: FRBNY/Equifax Consumer Credit Panel and Albuquerque et al (2015).

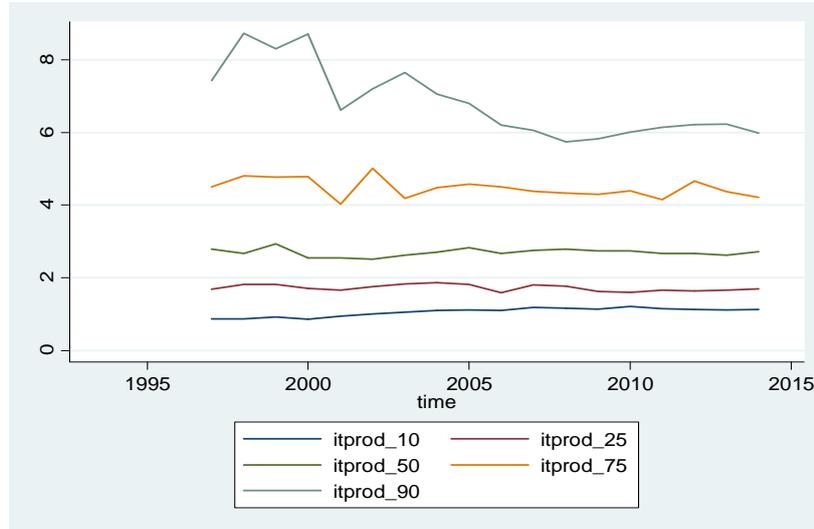
e. Job reallocation and business entry rate

(percent)



Source: Census Bureau.

Figure A.2: Share of IT-producing sector in total output by percentiles (percent)



Source: Bureau of Economic Analysis.

Note: The definition of IT-producing sectors follows that of Fernald (2014).

Table A.1: Summary statistics of the main variables

Variable	Observations	Number of years	Number of states	Mean	Standard deviation	Minimum	Maximum
dprod	1092	21	51	1.3	2.0	-6.5	11.8
dkratio_us	1144	22	51	2.4	2.6	-1.0	8.5
itprod	918	18	51	3.6	2.9	0.4	26.4
mining	915	18	51	2.8	5.9	0.0	38.9
crdst	1144	22	51	4.7	18.4	-13.4	55.5
debtgap	816	16	51	2.7	10.2	-32.1	92.1
jobrer	1092	21	51	26.8	3.6	18.4	39.8
bentr	1092	21	51	11.4	1.9	6.9	19.3
rnd	884	17	51	0.8	1.1	0.1	17.5

Table A.2: Pairwise correlation coefficients and significance levels

	dprod	dgdg_us	klratio_us	itprod	mining	crdst	debtgap	jobrer	bentr	rnd
dprod	1.00									
dgdg_us	0.13 [0.00]	1.00								
klratio_us	0.17 [0.00]	-0.37 [0.00]	1.00							
itprod	0.17 [0.00]	0.03 [0.38]	-0.01 [0.74]	1.00						
mining	-0.04 [0.18]	-0.08 [0.01]	-0.08 [0.02]	-0.26 [0.00]	1.00					
crdst	0.02 [0.49]	-0.63 [0.00]	0.82 [0.00]	-0.02 [0.61]	-0.01 [0.74]	1.00				
debtgap	-0.10 [0.01]	-0.41 [0.00]	0.00 [0.97]	0.13 [0.00]	0.01 [0.81]	0.21 [0.00]	1.00			
jobrer	0.14 [0.00]	0.28 [0.00]	0.26 [0.00]	0.08 [0.02]	0.08 [0.02]	0.13 [0.00]	-0.16 [0.00]	1.00		
bentr	0.10 [0.00]	0.28 [0.00]	0.15 [0.00]	0.14 [0.00]	0.04 [0.27]	0.02 [0.58]	-0.07 [0.06]	0.61 [0.00]	1.00	
rnd	-0.01 [0.70]	-0.13 [0.00]	-0.04 [0.22]	0.48 [0.00]	-0.27 [0.00]	0.03 [0.46]	0.06 [0.08]	-0.07 [0.05]	-0.08 [0.02]	1.00

Table A.3: Specification tests

<i>a. Wald test for the joint significance of time fixed effects</i>		
H0: Coefficients on time dummies are jointly = 0	F(12,50) 6.41	P-value (0.00)
<i>b. Modified Wald test for groupwise heteroskedasticity in fixed effects model</i>		
H0: $\sigma_i^2 = \sigma_i^2$ for all i	Chi2(51) 3081.3	P-value (0.00)
<i>c. Hausman test for random versus fixed effects</i>		
H0: Difference in coefficients is not systematic	Chi2(7) 47.36	P-value (0.00)
<i>d. Pesaran test of cross-sectional independence without time dummies</i>		
H0: Cross-sectional units are independent	CD test statistic 11.334	P-value (0.00)
<i>e. Pesaran test of cross-sectional independence with time dummies</i>		
H0: Cross-sectional units are independent	CD test statistic -2.004	P-value (0.05)

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