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THE VANISHING PROCYCLICALITY OF LABOUR PRODUCTIVITY*

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We document two changes in post-war US macroeconomic dynamics: the procyclicality of labour productivity vanished, and the relative volatility of employment rose. We propose an explanation for these changes that is based on reduced hiring frictions due to improvements in information about the quality of job matches and the resulting decline in turnover. We develop a simple model with hiring frictions and variable effort to illustrate the mechanisms underlying our explanation. We show that our model qualitatively and quantitatively matches the observed changes in business cycle dynamics.

The nature of business cycle fluctuations changes over time. There is a host of evidence for changes in the dynamics of post-war US macroeconomic time series (Blanchard and Watson, 1986; McConell and Pérez-Quirós, 2000; Stock and Watson, 2002; Hall, 2007; Galí and Gambetti, 2009). The present paper documents and discusses two aspects of these changes. First, the correlation of labour productivity with output or labour input has declined, by some measures dramatically so.[1] Second, the volatility of labour input measures has increased (relative to that of output).[2] Around the same time as these changes in business cycle dynamics were taking place, there was also a secular decline in labour market turnover. We seek to investigate the hypothesis that all three of these changes are linked, and that they reflect the US labour market becoming more flexible over this period, which allowed firms to adjust their labour force more easily in response to various kinds of shocks. Understanding the link between these three phenomena may shed some light on the nature of some of the structural changes experienced by the US economy over the past decades, which should be of interest to economists doing research on business cycles, labour markets and other related fields.

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[1] As far as we know, Stiroh (2009) was the first to provide evidence of a decline in the labour productivity–hours correlation. Galí and Gambetti (2009), Barnichon (2010), Gordon (2010) and Nucci and Riggi (2011), using different approaches, independently investigated the potential sources of that decline.

[2] To the best of our knowledge, Galí and Gambetti (2009) were the first to uncover that finding, but did not provide the kind of detailed statistical analysis found below. Independently, Hall (2007) offered some evidence on the size of the decline in employment in the most recent recessions that is consistent with our finding.

In order to illustrate the possible link between a reduction in labour market frictions and changes in business cycle dynamics, we develop a stylised model of fluctuations with a frictional labour market and investigate how its predictions vary with the level of labour market turnover. During the 1980s and early 1990s, unemployment in- and outflows in the US fell dramatically.[3] The decline in turnover is often interpreted as a cause for concern that the labour market has become more sclerotic (Davis *et al.*, 2010; Decker *et al.*, 2017), but the opposite is also consistent with the data. Mercan (2017) argues that improved job search technologies have led to a better functioning labour market, and shows that this ‘information channel’ can explain the decline in employer-to-employer (EE) transitions as well as the decline in turnover between employment and unemployment. We argue that the decline in turnover may have decreased hiring frictions, because adjustment costs in employment are convex. The size of the decline in turnover in the USA is well documented, and we show that the observed decline is sufficient to quantitatively generate the reduction in frictions needed to explain the changes in labour market dynamics.

The main intuition for our proposed explanation is straightforward. The idea goes back to a literature, starting with Oi (1962) and Solow (1964), which attributes the procyclicality of productivity to variations in effort, resulting in seemingly increasing returns to labour.[4] Suppose that firms have two margins for adjusting their effective labour input: (observed) employment and (unobserved) effort, which we denote (in logs) by n_t and e_t, respectively.[5] Labour inputs (employment and effort) are transformed into output according to a standard production function:

$$y_t = (1 - \alpha)(n_t + \psi e_t) + a_t,$$

where a_t is log total factor productivity and α is a parameter measuring diminishing returns to labour.

Measured labour productivity, or output per person, is given by

$$y_t - n_t = -\alpha n_t + (1 - \alpha)\psi e_t + a_t.$$

Labour market frictions make it costly to adjust employment n_t. Since these adjustment costs are convex, frictions are higher when the average level of hiring is higher. Effort e_t provides an alternative margin of adjustment of labour input and is not subject to those frictions (or is to a lesser degree). Thus, the larger the frictions, the less employment fluctuates and the more volatile fluctuations in effort. As a result, a decline in turnover reduces the average amount of hiring, reduces frictions, decreases the volatility of effort and therefore increases the relative volatility of employment with respect to output. The increased volatility of n_t also makes labour productivity less procyclical, and, in the presence of shocks other than shifts in technology, may even make productivity countercyclical, consistent with the evidence reported below.

Our argument that the vanishing procyclicality of labour productivity may have been driven by a reduction in hiring frictions is consistent with the observation that the relative volatility

[3] Fallick and Fleischman (2004), Davis *et al.* (2006), Davis (2008), Mukoyama and Şahin (2009), Davis *et al.* (2010), Davis *et al.* (2012), Lazear and Spletzer (2012), Cairó (2013), Hyatt and Spletzer (2013), Faberman (2017), Cairó and Cajner (2018) and Fujita (2018); see Cairó and Cajner (2018) for an overview of this literature.

[4] Contributions include studies by Fair (1969), Fay and Medoff (1985), Hall (1988), Rotemberg and Summers (1990), Bernanke and Parkinson (1991), Shapiro (1993), Burnside *et al.* (1993), Bils and Cho (1994), Basu (1996), Uhlig and Xu (1996), Basu and Fernald (1997), Basu and Kimball (1997), Shea (1999), Gordon (2004), Wen (2004), Arias *et al.* (2007) and Gordon (2010).

[5] To simplify the argument, we assume hours per worker are constant, consistent with the observation that in the US data most adjustments in total hours worked take place along the extensive margin.

of (a proxy for) effort decreased. Leading alternative explanations rely on changes in the relative importance of different drivers of business cycle fluctuations. Barnichon (2010) argues non-technology shocks became more important compared to technology shocks, and Garin *et al.* (2018) show a large decline in the importance of aggregate versus reallocative shocks around the mid 1980s and argue this can explain the vanishing procyclicality of labour productivity. The problem with these explanations is that they do not explain why similar changes in dynamics are observed also when conditioning on particular shocks, as in Galí and Gambetti (2009).

The vanishing procyclicality of labour productivity did not happen in isolation. Other changes in US labour market dynamics that happened around the same time and that may or may not be related include the great moderation in output volatility (Stock and Watson, 2002), the emergence of the slow recoveries (Galí *et al.*, 2012), and perhaps a change in the lead–lag structure of employment and output or jobless recoveries (van Rens, 2004; Bachmann, 2012; Brault and Khan, 2020). We do not claim to have an explanation for all labour market phenomena, and a comprehensive analysis of all of these changes is outside the scope of this paper. However, we briefly discuss why we believe that slow recoveries are unrelated to the vanishing procyclicality of productivity in our concluding Section 4.

The remainder of the paper is organised as follows. Section 1 documents the changes in the patterns of fluctuations in labour productivity and employment. Section 2 develops the basic model. Section 3 describes the outcome of simulations of a calibrated version of the model, and discusses its consistency with the evidence. Section 4 concludes.

1. Changes in Labour Market Dynamics

We document two stylised facts regarding post-war changes in US economic fluctuations. The changes that motivate our investigation pertain to the cyclical behaviour of labour productivity and labour input. The facts we report are not new. However, and to the best of our knowledge, this paper is the first to provide a joint explanation for both of these changes.

We use quarterly time series for output and labour input over the period 1948:1–2015:4 from the BLS Labor Productivity and Costs (LPC) database, and calculate labour productivity as the ratio between output and labour input.[6] To illustrate the changes in the different statistics considered, we split the sample period into two subperiods, pre-1984 (1948:1–1984:4) and post-1985 (1985:1–2015:4). The break date is chosen to be halfway the decade, in which the decline in labour market turnover started, and roughly halfway between the 1981–2 and 1990–1 recessions.[7] This choice is fairly arbitrary, and we do not make any claims about the specific timing of the various changes in labour market dynamics.

We apply three alternative transformations on the logarithms of all variables in order to render the original time series stationary. Our preferred transformation uses the bandpass (BP) filter to remove fluctuations with periodicities below 6 and above 32 quarters, as in Stock and Watson (1999). We also apply the fourth-difference (4D) operator, which is the transformation favoured

[6] The series IDs are PRS85006093 (output per hour) and PRS85006163 (output per worker) for productivity, PRS85006043 for output, PRS85006033 for hours and PRS85006013 for employment.

[7] The decline in the separation rate seems to start immediately after the 1981–2 recession; see, e.g., figure 1 in Cairó and Cajner (2018). However, we are reluctant to split the sample right at the end of a recession.

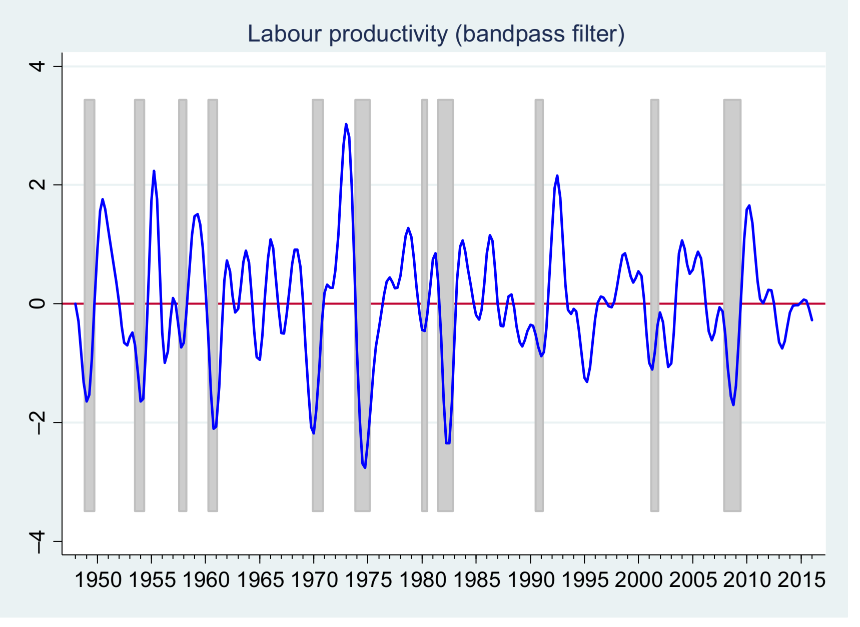

Fig. 1. *The Vanishing Procyclicality of Labour Productivity.*
Notes: Output per hour in the US private sector. Shaded areas are NBER recessions.

by Stock and Watson (2002) in their analysis of changes in output volatility, as well as the more common Hodrick Prescott (HP) filter with smoothing parameter 1600.

1.1. *The Vanishing Procyclicality of Labour Productivity*

Figure 1 shows the fluctuations at business cycle frequencies in labour productivity in the USA over the post-war period. It is clear from the graph that in the earlier part of the sample, productivity was significantly below trend in each recession. However, in the later years this is no longer the case. When we calculate the correlation of productivity with output or employment, as in Figure 2, it is clear that there is a sharp drop in the cyclicality of productivity. The correlation of productivity with output, which used to be strongly positive, fell to a level close to zero, while the correlation of productivity with employment, which was zero or slightly positive in the earlier period of the sample became negative.

These findings are formalised in Table 1, which reports the contemporaneous correlation between labour productivity and output and employment, for alternative transformations and time periods. In each case, we report the estimated correlation for the pre-1984 and post-1985 subsamples, as well as the difference between those estimates. The standard errors, reported in brackets, are computed using the delta method.[8] We now turn to a short discussion of the table's results.

[8] We use least squares (GMM) to estimate the second moments (variances–covariances) of each pair of variables, as well as the (asymptotic) variance–covariance matrix of this estimator. Then, we calculate the standard errors for the standard deviations, the relative standard deviations and the correlation coefficient using the delta method.

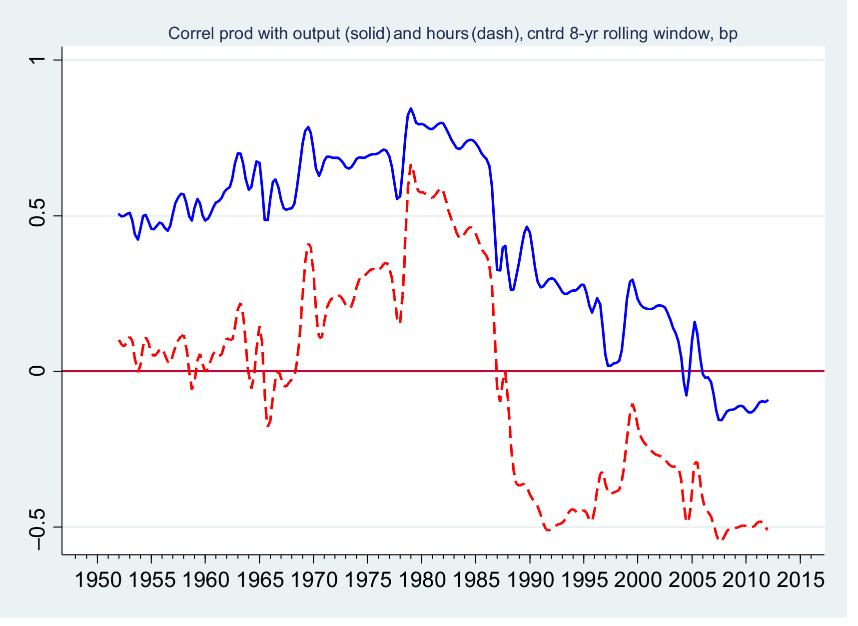

Fig. 2. *The Vanishing Procyclicality of Labour Productivity: Rolling Correlations.*
Notes: Correlations are calculated in a centred eight-year rolling window of quarterly bandpass-filtered data.

Table 1. *The Vanishing Procyclicality of Labour Productivity.*

	Corr. with output			Corr. with labour input		
	Pre-1984	Post-1985	Change	Pre-1984	Post-1985	Change
Output per hour						
BP	0.63	0.07	−0.56	0.23	−0.43	−0.66
	[0.05]	[0.08]	[0.10]	[0.08]	[0.07]	[0.11]
4D	0.65	0.18	−0.47	0.18	−0.42	−0.60
	[0.05]	[0.09]	[0.10]	[0.07]	[0.09]	[0.11]
HP	0.64	−0.09	−0.73	0.21	−0.56	−0.77
	[0.05]	[0.09]	[0.10]	[0.07]	[0.06]	[0.10]
Output per worker						
BP	0.78	0.50	−0.27	0.29	−0.13	−0.42
	[0.03]	[0.07]	[0.07]	[0.08]	[0.09]	[0.12]
4D	0.77	0.44	−0.33	0.19	−0.20	−0.39
	[0.03]	[0.08]	[0.09]	[0.07]	[0.12]	[0.14]
HP	0.77	0.31	−0.46	0.24	−0.30	−0.54
	[0.03]	[0.09]	[0.09]	[0.07]	[0.09]	[0.11]

Notes: SE in brackets are calculated from the variance–covariance matrix of the second moments using the delta method. Data are from the BLS Labor Productivity and Costs (LPC) database and refer to the private sector (non-farm business sector). Labour input is total hours worked in the first panel and employment in the second panel, consistent with the definition of labour productivity. The sample period is 1948–2015.

1.1.1. *Correlation with output*

Independently of the detrending procedure, the correlation of output per hour with output in the pre-1984 period is high and significantly positive, with a point estimate around 0.63. In other words, in the early part of the sample labour productivity was clearly procyclical.

In the post-1985 period, however, that pattern changed considerably. The estimates of the productivity–output correlation dropped to a value close to (and not significantly different from) zero. The difference with the corresponding pre-1984 estimates is highly significant. Thus, on the basis of those estimates labour productivity has become an acyclical variable (with respect to output) over the past two decades.

When we use an employment-based measure of labour productivity, output per worker, the estimated correlations also drop substantially but remain significantly greater than zero in the post-1985 period. This should not be surprising given that hours per worker are highly procyclical in both subperiods and that their volatility relative to employment-based labour productivity has increased considerably.[9]

1.1.2. *Correlation with labour input*

The right-hand side panels in Table 1 display several estimates of the correlation between labour productivity and labour input. The estimates for the pre-1984 period are low, but still significantly greater than zero. Thus, labour productivity was procyclical with respect to labour input in that subperiod, although much less so than with respect to output. This low correlation is consistent with the evidence reported in the early Real Business Cycle (RBC) literature, using data up to the mid 1980s.[10]

As was the case when using output as the cyclical indicator, the estimated correlations between labour productivity and employment decline dramatically in the post-1985 period. In fact these correlations become significantly negative, with a point estimate ranging from −0.42 to −0.56 for output per hour and from −0.13 to −0.30 for output per worker, depending on the filter. By this measure, labour productivity in the past two decades appears to have become strongly countercyclical. The changes with respect to the pre-1984 period are again highly significant.

1.1.3. *Discussion*

The finding that labour productivity may have become countercyclical is controversial. We showed that the change in sign only occurs if we use the correlation of productivity with output rather than labour input as the measure of cyclicality. Moreover, the correlation of productivity with labour input also stays positive if we use the Current Population Survey (CPS) rather than the Current Employment Statistics (CES) to measure employment (Hagedorn and Manovskii, 2011; Ramey, 2012), and labour productivity is overall more procyclical if we use the American Time Use Survey (ATUS) data to measure hours worked (Burda *et al.*, 2013). We do not take a strong stance on whether or not the correlation of productivity with the cycle changed sign.

[9] Letting n and h denote employment and total hours respectively, a straightforward algebraic manipulation yields the identity:

$$\rho(y-n, y) = \frac{\sigma_{y-h}}{\sigma_{y-n}}\rho(y-h, y) + \frac{\sigma_{h-n}}{\sigma_{y-n}}\rho(h-n, y).$$

Thus, even in the case of acyclical hours-based labour productivity, i.e., $\rho(y-h, y) \simeq 0$, we would expect $\rho(y-n, y)$ to remain positive if hours per worker are procyclical, i.e., $\rho(h-n, y) > 0$.

[10] Christiano and Eichenbaum (1992) used data up to 1983:4 (which coincides with the cut-off date for our first subperiod), but starting in 1955:4. Their estimates of the correlation between labour productivity and hours were −0.20 when using household data and 0.16 using establishment data.

Table 2. *The Rising Volatility of Labour Input.*

	SD			Relative SD		
	Pre-1984	Post-1985	Ratio	Pre-1984	Post-1985	Ratio
Hours (private sector)						
BP	2.02	1.53	0.76	0.80	1.10	1.38
	[0.10]	[0.09]	[0.06]	[0.03]	[0.05]	[0.08]
4D	3.05	2.45	0.80	0.77	1.08	1.40
	[0.16]	[0.27]	[0.10]	[0.03]	[0.06]	[0.10]
HP	2.04	1.78	0.87	0.79	1.20	1.52
	[0.10]	[0.10]	[0.07]	[0.03]	[0.05]	[0.09]
Employment (private sector)						
BP	1.66	1.20	0.72	0.66	0.87	1.33
	[0.08]	[0.07]	[0.06]	[0.03]	[0.05]	[0.10]
4D	2.58	2.06	0.80	0.65	0.92	1.41
	[0.13]	[0.23]	[0.10]	[0.03]	[0.06]	[0.11]
HP	1.72	1.46	0.85	0.66	1.00	1.51
	[0.09]	[0.08]	[0.07]	[0.03]	[0.06]	[0.11]

Notes: SE in brackets are calculated from the variance–covariance matrix of the second moments using the delta method. Data are from the BLS Labor Productivity and Costs (LPC) database and refer to the private sector (non-farm business sector). The sample period is 1948–2015.

Our finding that the cyclicality of productivity declined strongly over time is highly significant, robust and consistent with other studies.

1.2. *The Rising Relative Volatility of Labour Input*

The left-hand panel of Table 2 displays the standard deviation of several measures of labour input in the pre-1984 and post-1985 periods, as well as the ratio between the two. The variables considered include employment and hours in the private sector. The decline in the volatility of hours, like that of other major macro variables, is seen to be large and highly significant, with the standard deviation falling between 13% and 24% and always significantly so.

A more interesting piece of evidence is the change in the *relative* volatility of labour input, measured as the ratio of the standard deviation of labour input to the standard deviation of output. These estimates are presented in the right-hand panel of Table 2. Labour input experienced an increase in its relative volatility in the post versus pre-1984 period. In other words, the decline in the variability of labour input has been less pronounced than that of output. The increase in the relative volatility of hours worked ranges from 38% to 52%. The corresponding increase for employment is slightly smaller, ranging from 33% to 51%, and in both cases the decline is statistically significant.

The previous evidence points to a rise in the elasticity of labour input with respect to output. Put differently, firms appear to have relied increasingly on labour input adjustments in order to meet their changes in output.

1.3. *Conclusion and Further Evidence*

Summarising, we showed that the cyclicality of labour productivity in the USA declined strongly some time in the 1980s. Labour productivity became less procyclical or acyclical with respect to output, and perhaps even countercyclical with respect to employment. In addition, the relative volatility of employment and hours increased. For completeness, we also report that the relative volatility of labour productivity increased, and the correlation between employment and output decreased slightly, see Online Appendix A.[11]

The decline in the procyclicality of productivity is observed within industries as well (Wang, 2014; Fernald and Wang, 2016), and is therefore not driven by changes in the industry composition. The industry-level evidence also support our observation that the decline in the procyclicality of labour productivity may be related to the rise in the relative volatility of labour input. Using data on industry productivity from the BLS labour productivity and cost program (US KLEMS data), we show in Online Appendix B.1 that industries that experienced a larger decline in the correlation between productivity and output also saw a larger increase in the relatively volatility of employment and hours.

The changes in business cycle dynamics that we documented roughly coincided with the decline in labour market turnover. This strong decline in labour market turnover appears to be specific to the USA, and there is no evidence for a similar reversal of the cyclicality of labour productivity in other countries, see Online Appendix B.2. Lewis *et al.* (2018) document differences in the procyclicality of productivity between Europe and the USA, and argue these can be explained with a model with variable effort similar to ours.

In the remainder of this paper, we explore whether the observed changes in business cycle dynamics may be explained by a structural change in the labour market. We show that the vanishing procyclicality of labour productivity and the increasing relative volatility of employment can indeed be explained by a reduction in hiring costs resulting from the decline in labour market turnover.

2. A Model of Fluctuations with Labour Market Frictions and Endogenous Effort

Having documented in some detail the changing patterns of labour productivity and labour input, we turn to possible explanations. More specifically, and as anticipated in the introduction, we explore the hypothesis that the changes documented above may have, at least partly, been caused by a reduction in labour market frictions.

To formalise this explanation, we develop a model of fluctuations with labour market frictions, modelled as adjustment costs in employment (hiring costs). The crucial element in this model is an endogenous effort choice, which provides an intensive margin for labour adjustment that is not subject to the adjustment costs. Since the purpose of the model is to illustrate the main mechanisms at work, we keep the model as simple as possible in dimensions that are likely to be orthogonal to the factors emphasised by our analysis. Thus, we abstract from endogenous capital accumulation, trade in goods and assets with the rest of the world, and imperfections in the goods and financial markets. We also ignore any kind of monetary frictions, even though we recognise that these, in conjunction with changes in the conduct of monetary policy in the Volcker–Greenspan years, may have played an important role in changes in business cycle dynamics.[12]

[11] These observations are completely determined by the statistics already reported and do not contain independent information. We emphasised the statistics that we consider easiest to interpret.

[12] See, e.g., Clarida *et al.* (2000) for a discussion of the possible role of monetary policy in the Great Moderation.

2.1. *Households*

Households are infinitely lived and consist of a continuum of identical members represented by the unit interval. The household is the relevant decision unit for choices about consumption and labour supply. Each household member's utility function is additively separable in consumption and leisure, and the household assigns equal consumption C_t to all members in order to share consumption risk within the household. Thus, the household's objective function is given by[13]

$$E_0 \sum_{t=0}^{\infty} \beta^t \left[\frac{Z_t C_t^{1-\eta}}{1-\eta} - \gamma L_t \right], \tag{1}$$

where $\beta \in (0, 1)$ is the discount factor, $\eta \in [0, 1]$ is the inverse of the intertemporal elasticity of substitution, $\gamma > 0$ can be interpreted as a fixed cost of working and Z_t is a preference shock. The second term in the period utility function is disutility from effective labour supply L_t, which depends on the fraction N_t of household members that are employed, as well as on the amount of effort $\mathcal{E}_{it}$ exerted by each employed household member i. Formally

$$L_t = \int_0^{N_t} \frac{1 + \zeta \mathcal{E}_{it}^{1+\phi}}{1+\zeta} di = \frac{1 + \zeta \mathcal{E}_t^{1+\phi}}{1+\zeta} N_t, \tag{2}$$

where the second equality imposes the equilibrium condition that all working household members exert the same level of effort, $\mathcal{E}_{it} = \mathcal{E}_t$ for all i. The parameter $\zeta \geq 0$ measures the importance of effort for the disutility of working, and the elasticity parameter $\phi \geq 0$ determines the degree of increasing marginal disutility from exerting effort. For simplicity we assume a constant work week, thus restricting the intensive margin of labour input adjustment to changes in effort.

The household maximises its objective function above subject to the sequence of budget constraints

$$C_t = \int_0^{N_t} W_{it} di + \Pi_t, \tag{3}$$

where Π_t represents firms' profits, which are paid out to households in the form of lump-sum dividends, and W_{it} are wages accruing to employed household member i. The household takes into account the effect of its decisions on the level of effort exerted by its members.

2.2. *Firms*

Firms produce a homogeneous consumption good using a production technology that uses labour and effort as inputs

$$Y_t = A_t \left(\int_0^{N_t} \mathcal{E}_{it}^{\psi} di \right)^{1-\alpha} = A_t \left(\mathcal{E}_t^{\psi} N_t \right)^{1-\alpha}, \tag{4}$$

where Y_t is output, $\mathcal{E}_{it}$ is effort exerted by worker i, $\alpha \in (0, 1)$ is a parameter that measures diminishing returns to total labour input in production, $\psi \in [0, 1]$ measures additional diminishing returns to effort, and A_t is a technology shock common to all firms. Since all firms are identical, we normalise the number of firms to the unit interval, so that Y_t and N_t denote output and employment

[13] We assume utility is linear in effective labour for simplicity. The implication that the Frisch elasticity of labour supply is infinity is of course counterfactual, but our results are very similar if we assume a Frisch elasticity of 0.25, as advocated by Chetty *et al.* (2012).

of each firm as well as aggregate output and employment in the economy. The second equality imposes the equilibrium condition that all workers in a firm exert the same level of effort, $\mathcal{E}_{it} = \mathcal{E}_t$ for all i.

Firms choose how many workers to hire H_t in order to maximise the expected discounted value of profits

$$E_0 \sum_{t=0}^{\infty} Q_{0,t} \left[Y_t - W_t N_t - g\left(H_t\right) \right], \tag{5}$$

where the function $g(.)$, with $g' > 0$ and $g'' > 0$, represents the costs (in terms of output) of hiring new workers, subject to a law of motion for employment implied by the labour market frictions,

$$N_t = \left(1 - \delta\right) N_{t-1} + H_t, \tag{6}$$

where δ is the gross separation rate (employment exit probability). In Section 3, we will model the reduction in labour market turnover as a reduction in the parameter δ, which will reduce labour market frictions because of the convexity of the cost function $g(.)$. As a limiting case, we will also consider a frictionless labour market, setting $g(H) = 0$ for all H.

The stochastic discount factor is defined recursively as $Q_{0,t} \equiv Q_{0,1} Q_{1,2}, \ldots, Q_{t-1,t}$, where

$$Q_{t,t+1} \equiv \beta \frac{Z_{t+1}}{Z_t} \left(\frac{C_t}{C_{t+1}} \right)^{\eta}, \tag{7}$$

measures the marginal rate of substitution between two subsequent periods. Like the household, the firm takes into account the effect of its decisions on the level of effort exerted by its workers.

2.3. *Effort Choice and Job Creation*

The household and the firm jointly decide the wage and the level of effort that the worker will put into the job. In equilibrium, the effort level of all workers is set efficiently, maximising the total surplus generated by each match.[14] This efficient effort level, in each period and for each worker, equates to the cost of exerting more effort, higher disutility to the household, to the benefit, higher production and therefore profits for the firm.

Consider a worker i, who is a member of household h and is employed in firm j. The marginal disutility to the household from that worker exerting more effort, expressed in terms of consumption, is obtained from equation (2) for total effective labour supply and equals:

$$\frac{\gamma C_{ht}^{\eta}}{Z_t} \frac{\partial L_{ht}}{\partial \mathcal{E}_{it}} = \frac{\left(1 + \phi\right) \zeta}{1 + \zeta} \frac{\gamma C_{ht}^{\eta} \mathcal{E}_{it}^{\phi}}{Z_t} di. \tag{8}$$

The marginal product of that additional effort to the firm is found from production function (4):

$$\frac{\partial Y_{jt}}{\partial \mathcal{E}_{it}} = \left(1 - \alpha\right) \psi A_t \left(\int_0^{N_{jt}} \mathcal{E}_{vt}^{\psi} dv \right)^{-\alpha} \mathcal{E}_{it}^{-(1-\psi)} di. \tag{9}$$

In equilibrium, the marginal disutility from effort must equal its marginal product for all workers i. Also, because all firms and all households are identical, it must be that $C_{ht} = C_t$ and $N_{jt} = N_t$ in equilibrium. Therefore, it follows that all workers exert the same level of effort in equilibrium,

[14] Suppose not. Then, household and firm could agree on a different effort level that increases total match surplus, and a modified surplus sharing rule (wage) that would make both parties better off.

$\mathcal{E}_{it} = \mathcal{E}_t$ for all i. Imposing this property, we obtain the following equilibrium condition for effort:

$$\mathcal{E}_t = \left[\frac{(1-\alpha)\,\psi\,(1+\zeta)}{(1+\phi)\,\zeta} \frac{Z_t}{\gamma C_t^{\eta}} A_t N_t^{-\alpha} \right]^{\frac{1}{1+\phi-(1-\alpha)\psi}}, \tag{10}$$

or, using production function (4) to simplify:

$$\mathcal{E}_t^{1+\phi} = \frac{\psi}{1+\phi} \frac{1+\zeta}{\zeta} \frac{Z_t}{\gamma C_t^{\eta}} \frac{(1-\alpha)\,Y_t}{N_t}. \tag{11}$$

When considering whether to hire a worker, firms take into account the impact of the resulting increase in employment on the effort level exerted by their workers. Thus, the marginal product of a new hire is given by[15]

$$\frac{dY_{jt}}{dN_{jt}} = \frac{\partial Y_{jt}}{\partial N_{jt}} + \frac{\partial Y_{jt}}{\partial \mathcal{E}_{jt}} \frac{\partial \mathcal{E}_{jt}}{\partial N_{jt}} = (1-\Psi_F) \frac{(1-\alpha)\,Y_t}{N_t}, \tag{12}$$

where $\Psi_F = \frac{\alpha\psi}{1+\phi-(1-\alpha)\psi}$ measures the additional (negative) effect from a new hire on output that comes from the endogenous response of the effort level in the firm.

Maximising the expected net present value of profits (5), where output is given by production function (4) and the stochastic discount factor by (7), subject to the law of motion for employment implied by the matching technology (6) and the equilibrium condition for effort (11), gives rise to the following first-order condition:

$$g'(H_t) = S_t^F, \tag{13}$$

where S_t^F is the marginal value to the firm of having an additional worker in period t, which is given by

$$S_t^F = (1-\Psi_F) \frac{(1-\alpha)\,Y_t}{N_t} - W_t + (1-\delta)\, E_t \left[Q_{t,t+1} S_{t+1}^F \right] \tag{14}$$

$$= E_t \sum_{s=0}^{\infty} (1-\delta)^s\, Q_{t,t+s} \left[(1-\Psi_F) \frac{(1-\alpha)\,Y_{t+s}}{N_{t+s}} - W_{t+s} \right], \tag{15}$$

where the second equality follows from iterating forward (and defining $Q_{t,t} = 1$). This is a job creation equation, which states that the marginal costs of hiring a new worker $g'(H_t)$, must equal the expected net present value of marginal profits (additional output minus the wage) of the filled job, S_t^F.

2.4. *Wage Bargaining*

Employment relationships generate a strictly positive surplus. This property of our model comes from the assumption that wages and effort levels are determined after employment adjustment costs are sunk: if firm and worker cannot agree to continue their relationship, then the firm

[15] With a slight abuse of notation, $\mathcal{E}_{jt}$ denotes the effort level exerted by all workers (from different households) in a particular firm j. Firm j considers employing N_{jt} workers, given that all other firms employ the equilibrium number of workers N_t. Because there are infinitely many firms, firm j's decision to employ $N_{jt} \neq N_t$ workers does not affect the fraction of household h's members that are employed, so that by the assumption of perfect risk-sharing within the household, the consumption of workers in firm j, $C_{ht} = C_t$, is not affected. Therefore, the relation between effort and employment that the firm faces if all other firms (and all households) play equilibrium strategies, is given by equation (10), keeping C_t fixed. See Online Appendix C for details on the derivation of equation (12).

has to pay the hiring costs again in order to find another worker to match with. We make this timing assumption in order to generate wage setting under bilateral monopoly, as in a search and matching model, which we believe to be a realistic feature of the labour market.[16] Firms and households bargain over the wage as a way to share the match surplus. These negotiations are limited only by the outside option of each party. The lower bound of the bargaining set is given by the reservation wage of the household, the wage offer at which the household is indifferent between accepting the offer and looking for another job. Similarly, the upper bound of the bargaining set is the reservation wage of the firm, the wage offer that makes the firm indifferent between accepting the offer and hiring a different worker. The bounds of the bargaining set are endogenous variables, for which we now derive equilibrium conditions. Then, the bargained wage can be written simply as a linear combination of the upper and lower bounds of the bargaining set.

The part of the match surplus that accrues to the firm S_t^F, as a function of the wage, is given by equation (14). In order to derive a similar expression for the household's part of the surplus S_t^H, we must first calculate the marginal disutility to the household of having one additional employed member, taking into account the endogenous response of effort. This marginal disutility of employment, expressed in terms of consumption, is given by[17]

$$\begin{aligned}\frac{\gamma C_t^\eta}{Z_t}\frac{dL_{ht}}{dN_{ht}} &= \frac{1}{1+\zeta}\frac{\gamma C_t^\eta}{Z_t}\left(1+\zeta\frac{(1+\phi)\,\Psi_H}{\psi}\mathcal{E}_t^{1+\phi}\right)\\ &= \frac{1}{1+\zeta}\frac{\gamma C_t^\eta}{Z_t}+\Psi_H\frac{(1-\alpha)\,Y_t}{N_t},\end{aligned} \tag{16}$$

where the second equality follows from substituting equation (11), and where $\Psi_H = \frac{\psi}{1+\phi}\frac{(1-\eta)(1+\phi)-\psi}{1+\phi-\psi}$ captures the effect on utility of one more employed member in the household through the endogenous response of effort. Using this expression, we can take a derivative of the household's objective function (1) with respect to N_t and divide by the marginal utility of consumption, to obtain the following expression for S_t^H:

$$S_t^H = W_t - \frac{1}{1+\zeta}\frac{\gamma C_t^\eta}{Z_t} - \Psi_H\frac{(1-\alpha)\,Y_t}{N_t} + (1-\delta)\,E_t\left[Q_{t,t+1}S_{t+1}^H\right]. \tag{17}$$

The value to the household of having one more employed worker, equals the wage minus the disutility expressed in terms of consumption, plus the expected value of still having that worker next period, which is discounted by the probability that the worker is still employed next period.

The upper bound of the bargaining set W_t^{UB} is the highest wage such that $S_t^F \geq 0$, whereas the lower bound W_t^{LB} is the lowest wage such that $S_t^H \geq 0$. Using equations (14) and (17), we get $S_t^F = W_t^{UB} - W_t$ and $S_t^H = W_t - W_t^{LB}$. Substituting back into equations (13), (14) and (17), we can explicitly write the equilibrium of the model in terms of the wage and the bounds of the bargaining set

[16] Specifically, the within-period timing we assume is the following. First, aggregate shocks realise and a randomly chosen fraction δ of employed workers is separated from their jobs. Second, firms that want to hire pay employment adjustment costs $g(H_t)$ and are randomly matched with H_t non-employed workers. Third, firm and worker bilaterally and with full commitment decide on the effort the worker will put into the job and the wage she will be paid for doing it. If a firm and a worker cannot agree, the worker is placed back into the unemployment pool and the firm pays $g'(H_t)$ in order to get another random draw from that pool. Since all unemployed workers are identical, this never happens in equilibrium. When a firm and worker do reach an agreement, the worker is hired and added to the pool of employed workers. Finally, production, consumption and utility are realised.

[17] The derivation of this expression is similar to that of equation (12) (see Online Appendix C for details).

$$g'(H_t) = W_t^{UB} - W_t \tag{18}$$

$$W_t^{UB} = (1-\Psi_F)\frac{(1-\alpha)Y_t}{N_t} + (1-\delta)E_t\left[Q_{t,t+1}\left(W_{t+1}^{UB} - W_{t+1}\right)\right] \tag{19}$$

$$W_t^{LB} = \frac{1}{1+\zeta}\frac{\gamma C_t^{\eta}}{Z_t} + \Psi_H\frac{(1-\alpha)Y_t}{N_t} + (1-\delta)E_t\left[Q_{t,t+1}\left(W_{t+1}^{LB} - W_{t+1}\right)\right]. \tag{20}$$

Nash bargaining assumes that the wage is set such that the total surplus from the match is split in equal proportions between household and firm.[18] It is straightforward to see that in our framework, $S_t^H = \frac{1}{2}\left(S_t^H + S_t^F\right) = \frac{1}{2}\left(W_t^{UB} - W_t^{LB}\right)$, so that

$$W_t = \tfrac{1}{2}\left(W_t^{UB} + W_t^{LB}\right), \tag{21}$$

the wage is the average of the lower and upper bounds of the bargaining set.

2.5. *Equilibrium*

We conclude the description of the model by listing the conditions that characterise the equilibrium. The equilibrium level of effort is determined by efficiency condition (11). Vacancy posting decisions by firms are summarised by the job creation equation (18). Wage negotiations are described by equation (21), and stochastic difference equations for the upper and lower bounds of the bargaining set (19) and (20). Employment evolves according to its law of motion (6). Finally, goods market clearing requires that consumption equals output minus hiring costs:

$$C_t = Y_t - g(H_t). \tag{22}$$

Output is defined as in production function (4), the stochastic discount factor as the marginal rate of intertemporal substitution (7), and the parameters $\Psi_F = \frac{\alpha\psi}{1+\phi-(1-\alpha)\psi}$ and $\Psi_H = \frac{\psi}{1+\phi}\frac{(1-\eta)(1+\phi)-\psi}{1+\phi-\psi}$ are functions of the structural parameters. In total, we have seven equations in the endogenous variables H_t, $\mathcal{E}_t$, W_t, W_t^{UB}, W_t^{LB}, N_t and C_t, or nine equations including the definitions for Y_t and $Q_{t,t+1}$.

Without an endogenous effort choice ($\psi = 0$ so that effort is not useful in production, $\Psi_F = \Psi_H = 0$, and $\mathcal{E}_t = 0$ for all t in equilibrium), the model reduces to a standard RBC model with labour market frictions. However, unlike in the standard model, fluctuations in our model are driven by technology shocks as well as non-technology shocks or preference shocks. The two driving forces of fluctuations, log total factor productivity $a_t \equiv \log A_t$ and log preferences over consumption $z_t \equiv \log Z_t$ follow stationary $AR(1)$ processes

$$a_t = \rho_a a_{t-1} + \varepsilon_t^a \tag{23}$$

$$z_t = \rho_z z_{t-1} + \varepsilon_t^z, \tag{24}$$

where ε_t^a and ε_t^z are independent white noise processes with variances given by σ_a^2 and σ_z^2 respectively.

[18] The symmetry assumption is not crucial, but simplifies the solution of the model substantially. We show in Online Appendix G that our results are virtually unchanged for bargaining power well below and above 0.5.

3. Implications of the Reduction in Labour Market Frictions

We now proceed to use our model to analyse the possible role of a reduction in labour market frictions in generating the observed changes in the cyclical patterns of labour productivity and labour input. First, we briefly discuss the possible causes of the reduction in frictions and the coinciding decline in labour market turnover and argue that these are plausibly exogenous to our model. We then start our analysis of the implications of this change with a version of our model with a frictionless labour market. The frictionless model provides a useful benchmark that we can solve for in closed form. Then, we rely on numerical methods to simulate the model with frictions for different values of the parameters.

3.1. *Innovations in Job Search and the Decline in Turnover*

One of the most striking changes on the labour market over the past few decades are innovations in job search technology.[19] Mercan (2017) argues these improved technologies have led to a better functioning labour market characterised by better information and lower turnover. Increased information among employers and workers about each other and about their prospective matches means that low-quality matches are less frequent. Matches that are being formed are thus of higher quality, and there is less incentive for firm and worker to separate. The result is a reduction in separations, both due to EE transitions and separations leading to unemployment (EU flows). Mercan (2017) shows that a formal model of improved information can quantitatively match the large observed reduction in EE flows.[20]

In our model, a reduction in labour market turnover may be represented by a reduction in the exogenous separation rate δ. It is possible, as we show in Online Appendix D, to incorporate Mercan (2017)'s information channel into our model and thus endogenise the reduction in turnover. However, in order to not distract from the contribution of this paper, we instead model an exogenous decline in δ, calibrated directly to the observed decline in the data. In fact, it is not important for the purposes of this paper that the entire decline in turnover is caused by an improvement in information, as long as it is exogenous to our model. Other reasons why turnover may have declined that have been proposed in the literature are decreased business volatility (Davis *et al.*, 2010), decreased job security (Fujita, 2018), increased specificity of human capital (Cairó, 2013) and the ageing of the workforce (Karahan and Rhee, 2014). These are all exogenous changes in the context of our model.

In response to the decline in turnover, labour market frictions decrease in our model. This effect arises because of our assumption that adjustment costs in employment are convex, and we discuss this crucial assumption in Subsection 3.4. We show below that the observed decline in turnover is sufficient to quantitatively generate the reduction in frictions needed to explain the changes in labour market dynamics.

3.2. *Frictionless Labour Market*

Consider the limiting case of an economy without labour market frictions, i.e., $g(H) = 0$ for all H. The first thing to note is that in this case the width of the bargaining set collapses to zero, and

[19] Examples are internet-based vacancy posting, online platforms with insider reviews on work environment, background checks, employee referrals and professional hiring services (see Mercan, 2017, p. 2, fn. 7).

[20] The model also predicts a reduction in EU flows, but can only account for a fraction of the observed decline. However, this may be due to the absence of job-to-job moving costs from the model (see Online Appendix D).

the job creation equation (18) and the wage block of the model, equations (21), (19) and (20), imply

$$W_t = W_t^{UB} = W_t^{LB} = (1 - \Psi_F)\,\frac{(1-\alpha)\,Y_t}{N_t} = \frac{1}{1+\zeta}\,\frac{\gamma C_t^{\eta}}{Z_t} + \Psi_H\,\frac{(1-\alpha)\,Y_t}{N_t}, \tag{25}$$

for all t. Employment becomes a choice variable, so that its law of motion (6) is dropped from the system and employment is instead determined by the static condition (25)

$$N_t = (1-\alpha)\,(1 - \Psi_F - \Psi_H)\,\frac{(1+\zeta)\,Z_t Y_t}{\gamma C_t^{\eta}}. \tag{26}$$

Substituting into the equilibrium condition for effort (11), we obtain

$$\mathcal{E}_t^{1+\phi} = \frac{\psi}{1+\phi}\,\frac{1}{\zeta}\,\frac{1}{1-\Psi_F-\Psi_H}, \tag{27}$$

implying an effort level that is invariant to fluctuations in the model's driving forces. Since effort has stronger diminishing returns in production and stronger increasing marginal disutility than employment, this intensive margin of adjustment is never used if the extensive margin is not subject to frictions.

Without hiring costs, the aggregate resource constraint (22) reduces to $C_t = Y_t$. Combining the resource constraint and equations (26) and (27) with the production function (4), we can derive closed-form expressions for equilibrium employment, output, wages and labour productivity. Using lower-case letters to denote the natural logarithms of the original variables, ignoring constant terms and normalising the variance of the shocks,[21] we get

$$n_t = (1-\eta)\,a_t + z_t \tag{28}$$

$$y_t = a_t + (1-\alpha)\,z_t \tag{29}$$

$$w_t = y_t - n_t = \eta a_t - \alpha z_t. \tag{30}$$

A useful benchmark is the model with logarithmic utility over consumption ($\eta = 1$). In this case, employment fluctuates in proportion to the preference shifter z_t but does not respond to technology shocks.[22]

From the previous equations, it is straightforward to calculate the model's implications for the second moments of interest. In particular we have

$$\operatorname{cov}(y_t - n_t, y_t) = \eta\,\operatorname{var}(a_t) - \alpha\,(1-\alpha)\operatorname{var}(z_t) \tag{31}$$

$$\operatorname{cov}(y_t - n_t, n_t) = \eta\,(1-\eta)\operatorname{var}(a_t) - \alpha\,\operatorname{var}(z_t)\,. \tag{32}$$

In the absence of labour market frictions, labour productivity is unambiguously countercyclical in response to preference shocks. The intuition for this result is that output responds to preference shocks only through employment, and this response is less than proportional because of diminishing returns in labour input ($\alpha > 0$). Since productivity is unambiguously procyclical in response to technology shocks, the unconditional correlations depend on the relative variances

[21] If the original shocks are $\tilde{a}_t$ and $\tilde{z}_t$, then we define $a_t = \Omega\tilde{a}_t$ and $z_t = \Omega\tilde{z}_t$, where $\Omega = 1/[1 - (1-\alpha)(1-\eta)]$.

[22] This result is an implication of the logarithmic or 'balanced growth' preferences over consumption in combination with the absence of capital or any other intertemporal smoothing technology, and is similar to the 'neutrality result' in Shimer (2010).

of the shocks and the model parameters. For a wide range of parameter values, e.g., with logarithmic utility over consumption ($\eta = 1$), productivity is procyclical with respect to output but countercyclical with respect to employment.

The relative volatility of employment with respect to output is given by the following expression:

$$\frac{\mathrm{var}\,(n_t)}{\mathrm{var}\,(y_t)} = \frac{(1-\eta)^2\,\mathrm{var}\,(a_t) + \mathrm{var}\,(z_t)}{\mathrm{var}\,(a_t) + (1-\alpha)^2\,\mathrm{var}\,(z_t)}. \tag{33}$$

The relative volatility depends again on the relative importance of the shocks, as well as on the size of α, the parameter determining the degree of diminishing returns to labour.

3.3. *Preview of the Results*

We can contrast the predictions of the frictionless model above, with the opposite extreme case of infinitely large labour market frictions, i.e., $g(H) = \infty$ if $H > 0$. In this case, no new workers will be hired, so that by the aggregate resource constraint (22) $C_t = Y_t$, as in the frictionless case. For simplicity, also assume that the separation rate equals zero, $\delta = 0$, so that employment is fixed. In this case, combining the production function (4) with the equilibrium condition for effort (11), and taking logarithms, ignoring constant terms and normalising the variance of the shocks,[23] we get

$$e_t = (1-\eta)\,a_t + z_t \tag{34}$$

$$y_t = y_t - n_t = (1+\phi)\,a_t + (1-\alpha)\,\psi\,z_t. \tag{35}$$

Since employment is fixed, effort is now procyclical in response to both types of shocks, as all of the adjustment of labour input occurs on the intensive margin. With infinitely large frictions, labour productivity is perfectly (positively) correlated with output. The correlation between productivity and employment, as well as the relative volatility of employment with respect to output equal zero.

Comparing the predictions of the model with very high turnover and therefore very large labour market frictions, to the model with a very low separation rate and therefore with hiring frictions close to zero, it is clear that for a sufficiently large decline in labour market turnover:

(*i*) Labour productivity becomes less procyclical with respect to output.
(*ii*) Labour productivity goes from acyclical to countercyclical with respect to employment, depending on parameter values (a sufficient condition is logarithmic utility over consumption).
(*iii*) The relative volatility of employment increases.

These predictions are consistent with the data, as we documented in Section 1. Three elements of our model are crucial for this result: convex employment adjustment costs, multiple shocks and endogenous effort.

We are not arguing, of course, that labour market turnover fell so much that labour market frictions went from infinity to zero. Rather, the argument so far is meant to illustrate that if the decline in labour market turnover was large enough, it can qualitatively explain the patterns we observe in the data. We will show that the same result holds in the full model, although the

[23] In this case, the normalisation factor is $1/[1+\phi-(1-\alpha)(1-\eta)\psi]$.

Table 3. *Model Calibration.*

	Parameter	Target
Utility:	$\beta = 0.99$	quarterly data
	$\eta = 1$	log utility over consumption
	$\gamma = 1.24$	frictionless employment population ratio $\bar{N} = 0.7$
Production:	$f(N) = N^{1-\alpha}$, $\alpha = 1/3$	capital share
Effort:	$\zeta = 0.299$	normalisation: frictionless $\overline{\mathcal{E}} = 1$
	$\phi = 0$	normalisation so that $\mathcal{E}$ is in utils
	$\psi = 0.3$	total curvature $\phi + \psi$ is a free parameter
Frictions:	$\delta = 0.35 - 0.20$	gross quarterly separations, decline in turnover
	$g(H) = \frac{\kappa}{1+\mu} H^{1+\mu}$, $\mu = 1.5$	convex adjustment costs
	$\kappa = 3.19$	frictions 3% of output pre-1984
Shocks:	$\rho_A = 0.97$, $\sigma_A = 0.186$	normalisation: SD(y) = 1%
	$\rho_z = 0.97$, $\sigma_z = 0.173$	SD(n)/SD(y) = 0.66

intuition is more subtle, see Online Appendix E. To answer the question whether we can also quantitatively match those patterns for reasonable parameter values, we now turn to a numerical analysis.

3.4. *Calibration*

We simulate data at quarterly frequency and calibrate accordingly. The calibration is summarised in Table 3. Many of the model's parameters can be easily calibrated to values that are standard in the literature. In this vein, we set the discount factor β equal to 0.99, assume logarithmic utility over consumption ($\eta = 1$), and assume $\alpha = 1/3$ for the curvature of the production function to match the capital share in GDP. In the model there is no difference between unemployment and non-participation. Therefore, we set the marginal utility from leisure γ to match the employment–population ratio. Since the amount of labour market frictions affects this ratio as well, we calibrate to an employment–population ratio of 0.7 in the frictionless model.

The calibration of the labour market frictions is crucial for the simulation exercise. Estimates of the convexity of employment adjustment costs vary, with the exponent $1 + \mu$ of the cost function $g(H) = \frac{\kappa}{1+\mu} H^{1+\mu}$ ranging from 1.6 to 3.4. The lower end of this range corresponds to a specification, in which we interpret the adjustment costs as search frictions, vacancy posting costs are linear and the matching function has an elasticity with respect to unemployment of 0.6, as in Mortensen and Nagypal (2007). The upper end of the range is the point estimate of the convexity of employment adjustment costs in Merz and Yashiv (2007). In our benchmark specification, we use the midpoint of this range and assume an exponent of $1 + \mu = 2.5$, but we explore the implications for our results if adjustment costs are less or more convex than that.[24] We calibrate

[24] Here, we mean convex in the sense that we assume that hiring an additional worker is most costly if starting from a higher rather than a lower baseline level of hiring, i.e., $g(H_1 + \varepsilon) - g(H_1) < g(H_0 + \varepsilon) - g(H_0)$, for a small $\varepsilon > 0$ and realistic levels of hiring H_0 and $H_1 < H_0$. Perhaps the easiest way to justify this assumption is as a representation of diminishing returns in the matching function (Blanchard and Galí, 2010), a standard assumption in the labour market literature. This concept of convexity is only tangentially related to the literature on whether adjustment costs are 'convex' or 'non-convex'. In that literature, many authors have advocated a discontinuity or a kink in the adjustment cost function around zero, resulting in irreversibility and lumpy adjustment at least at the plant level (Caballero and Engel, 2004; Varejao and Portugal, 2007), while others have argued that a smooth (convex) adjustment costs function provides a good approximation for the aggregate dynamics for capital (Cooper and Haltiwanger, 2006; Khan and Thomas, 2008) and employment (Cooper and Willis, 2004; Ejarque and Nilsen, 2008; Blatter *et al.*, 2012). Since the aggregate level of hiring, including replacement hiring, is well above zero in all periods, a non-convexity at zero is not important for our results.

κ such that hiring costs are 3% of output in calibration for the pre-1984 period, consistent with the estimates in Silva and Toledo (2009), see also Hagedorn and Manovskii (2008, p. 1699).

The employment outflow rate declined by about 50%, from 4% per month in the early 1980s to 2% per month in the mid 1990s (Davis *et al.*, 2010; Cairó and Cajner, 2018; Fujita, 2018).[25] Using these estimates, we calibrate the gross separation rate δ in our model to 35% per quarter for the pre-1984 subsample and to 20% per quarter for the post-1985 period.[26] In equilibrium, the decline in the separation rate implies a decline in job creation because the amount of replacement hiring that is necessary to maintain a certain level of employment decreases. This effect is dampened, however, by the lower cost of hiring, which raises equilibrium employment by about 14%.

For the model's driving forces, we assume high persistence in both shocks, setting $\rho_a = 0.97$ to match the first-order autocorrelation in Solow residuals, and $\rho_z = 0.97$ to make sure that none of the results are driven by differences in persistence. Given those values, we calibrate σ_a^2 and σ_z^2 so that the frictionless version of the calibrated model matches the relative volatility of employment and predicts a standard deviation of log output of 1%. The first target is justified by the observation that in this very simple model, preference shocks are a stand-in for all sources of misspecification that result in the unemployment volatility puzzle. The second target is arbitrarily chosen to emphasise that we consider this model mostly illustrative and not able to generate realistic predictions for the overall level of volatility in the economy.

For the parameters related to effort, we have very little guidance from previous literature. We normalise $\phi = 0$ and ζ such that effort is expressed in utility units and equals 1 in the frictionless steady state. We treat the curvature of the production function in effort ψ as a free parameter. Since we are mostly interested in illustrating the qualitative changes in the business cycle moments that the model can generate, we set this parameter fairly arbitrarily to $\psi = 0.3$, so that the model roughly replicates the second moments in the data. The testable prediction here is not whether the model can quantitatively match some or most of the second moments, but whether it can qualitatively generate *all* observed changes, changing *only* the level of labour market frictions.

3.5. *Quantitative Results*

We now simulate the calibrated model in order to calculate the second moments of interest. The aim is to show that a decline in labour market turnover of the same size as observed in the USA, roughly matches the change in the cyclicality of labour productivity and the relative volatility of labour input in the data. We simulate the second-order approximation of the model 201,000

[25] The estimates in Fujita (2018) differ from those in Davis *et al.* (2010) and Cairó and Cajner (2018) because Fujita calculates worker flows from matching the labour force status of workers in the monthly CPS files, whereas the other two studies use data on unemployment duration following Shimer (2012). The size of the proportional decline in the separation rate is very similar in both approaches, but the level of the separation rate is different. Starting with Shimer (2005), it is common in the literature to calibrate models to the level of the separation rate as calculated from the unemployment duration data, resulting in a post-war sample average of about 3% per month.

[26] The quarterly separation probability is the probability that a worker who is employed at the beginning of the quarter is no longer employed at the end of the quarter. Using a monthly job finding probability of $f_m = 0.45$, see Shimer (2012), and a monthly separation probability of $s_m = 0.04$, we get a quarterly separation probability of $s = s_m(1-f_m)^2 + (1-s_m)s_m(1-f_m) + (1-s_m)^2 s_m + s_m^2 f_m = 0.07$ and a quarterly job finding probability of $f = f_m(1-s_m)^2 + (1-f_m)f_m(1-s_m) + (1-f_m)^2 f_m + f_m^2 s_m = 0.80$. The gross separation rate is the average number of times that a worker who is employed at the beginning of the quarter loses her job over the quarter. Since workers that are separated in a given quarter may find another job within that quarter, the quarterly gross separation rate is given by $\delta = s/(1-f) = 0.35$. For more detail and robustness analysis, see Online Appendix F.

Table 4. *Simulation Results.*

	Frictions (% GDP)	Empl./pop. ratio $\bar{N}$	Correlation productivity		Relative SD		SD
			with output	with empl.	empl n_t	wage w_t	output y_t
Data							
Pre-1984			0.78	0.29	0.66	0.30	
Post-1985			0.50	−0.13	0.87	0.88	
Model							
$\delta = 0.40$	3.69	0.52	0.79	0.10	0.61	0.87	1.00
$\delta = 0.35$ (Pre)	**3.00**	0.56	0.75	0.01	**0.66**	0.88	**1.00**
$\delta = 0.30$	2.30	0.59	0.71	−0.08	0.71	0.88	1.00
$\delta = 0.25$	1.63	0.62	0.66	−0.17	0.76	0.88	1.01
$\delta = 0.20$ (Post)	1.02	0.65	0.61	−0.24	0.82	0.88	1.01
$\delta = 0.15$	0.53	0.67	0.57	−0.30	0.86	0.87	1.02
Frictionless	0.00	**0.70**	0.48	−0.39	0.95	0.85	1.04

Notes: Moments for the model are based on simulated time series of 200,000 quarters. We simulate the model for 201,000 quarters but ignore the first 1,000 quarters to eliminate the effect of the initial conditions. Numbers in bold are calibration targets.

periods, discarding the first 1,000 observations to eliminate the effect of the initial conditions. The results of this exercise are reported in Table 4.

Labour productivity is strongly procyclical in terms of its correlation with output in the model and its procyclicality falls substantially as we reduce labour market turnover. The correlation of productivity with employment also falls, from around zero in the labour market with high turnover to a negative value in the calibration with low turnover. Both observations are qualitatively as well as quantitatively consistent with the evidence. The reason for the decline in the procyclicality of productivity is the increase in the relative volatility of employment, a result that is consistent with the data as well. These results are robust to variations in the specification and calibration of the model, as documented in Online Appendix G.

Three elements in the model are crucial for these results. First, the convexity of the employment adjustment costs implies that hiring costs fall from 3% to around 1% of output with the decline in labour market turnover. Second, the effort choice provides an intensive margin of adjustment for labour input. As frictions fall, it becomes optimal to adjust labour more through employment and less through effort. Thus, the volatility of employment increases more than that of output, as the volatility of effort falls.

The third element in the model that is important for the results is that fluctuations in the model are driven by two types of shocks: technology shocks and preference shocks or labour supply shocks. In a one-shock model, the correlations between all variables would be close to either 1 or −1.[27] In addition, if fluctuations were driven only by technology shocks then productivity could never be countercyclical, since employment would only fluctuate because of changes in labour demand, and the direct effect of technology on productivity would always prevail over the indirect effect of employment. It is important to stress, however, that our results are *not* driven by changes in the relative importance of both shocks, which we keep constant, but by the reduction in frictions, which changes the response of the economy conditional on each shock.

[27] This is exactly true in a static, linear model. Our model is close to (log)linear and the version without capital and with flexible wages has only one state variable (employment), which has very fast transition dynamics.

3.6. *Evidence for the Mechanism: The Cyclicality of Effort*

Our model predicts that the volatility of effort should have decreased as the volatility of labour input increased. We use this prediction as an over-identifying restriction to test our story. However, since it is not directly observable, we need a proxy measure for effort.

The most commonly used proxy for effort is hours per worker (Basu *et al.*, 2006; Fernald and Wang, 2016). However, this is a valid proxy only if adjusting hours per worker, like adjusting effort in our model, is costless to firms. The evidence suggests that there are frictions associated with adjusting work hours.[28] In fact, the standard deviation of hours per worker relative to output increases in the 1980s. This is consistent with our story if we think of hours per worker as part of the extensive margin (labour input) rather than the intensive margin (effort) in the context of our model.

We use the injury incidence rate from the BLS as a proxy for effort.[29] Shea (1990) shows that the incidence of injuries, like effort in our model, is procyclical (over his sample period, which runs until 1988), and statistically explains a large part of the excess procyclicality of productivity. He argues that the injury rate proxies for work effort and supports this argument by showing that the procyclicality of the series survives even when controlling for overtime and labour turnover (the leading alternatives to effort as explanations for why injuries are procyclical). The BLS still gathers statistics on injuries as part of its Injuries, Illnesses, and Fatalities (IIF) database, and we were able to replicate Shea's preferred series (the number of total recordable injuries per 200,000 paid hours worked) over the period 1976–2016.[30] Figure 3 plots the cyclical component of this proxy for effort.

Our proxy for effort is available only at annual frequency from 1976 onwards, so that we cannot estimate the change in the volatility of effort around our break date of 1985 (we would have only eight observations for the pre-1984 period after first-differencing). Therefore, we use 1995 as the break date, which is roughly halfway the sample for the injury rate. We start by showing that the changes in the business cycle dynamics of labour productivity and employment around this break date are similar to those in our baseline sample, and then complete the picture by documenting that the volatility of effort fell at the same time.

Panels A and B in Table 5 redocuments our basic stylised facts using annual data over the 1977–2016 period. Since the Great Moderation happened well before 1995, the volatility of employment is roughly constant in this period. However, the vanishing procyclicality of labour productivity and the rising volatility of employment relative to output are clearly visible. In fact, the decline in the correlation of productivity with output and employment and the increase in the relative standard deviation of employment are surprisingly similar to

[28] While adjusting hours per worker is clearly not subject to the same frictions that affect adjusting employment, e.g., search frictions and training costs, there are other frictions that will (also) affect this intensive margin of labour adjustment, e.g., norms, other forms of status quo bias or inattention. While these frictions may be smaller than those affecting the extensive margin, the data suggest they are nevertheless important. In micro data, there is enormous 'bunching' of hours worked around 40 hours per week. And in aggregate data, hours per worker are slower to fall in recessions and slower to recover in booms even than employment (van Rens, 2012). Chetty (2012) shows that even relatively small frictions may have a large effect on the elasticity of labour supply, because the utility loss of deviations from the optimal hours worked is relatively modest, which may explain why the literature trying to estimate this elasticity, surveyed in Saez *et al.* (2012), has found values close to zero.

[29] We are grateful to Evi Pappa for this suggestion.

[30] The industry-level data are only consistent over the subperiods 1976–88, 1989–2001, 2002, 2003–13 and 2014–16. However, we were able to find aggregate rates for the private manufacturing sector that are consistent over the entire period. We also constructed a few alternative series (only injuries that led to lost workdays, as suggested by Shea as an alternative, and the same two series for injuries and illnesses combined), but the period, for which we were able to obtain these data is much shorter.

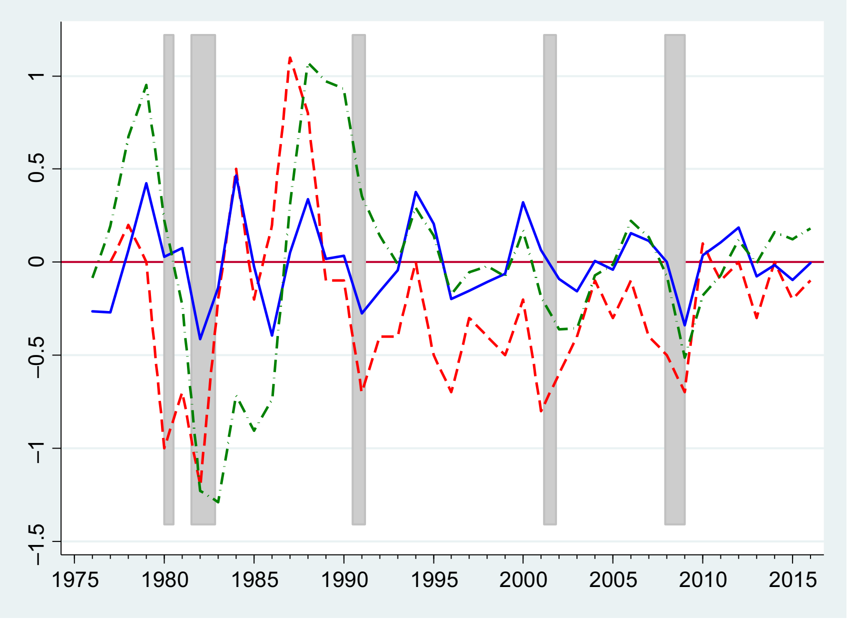

Fig. 3. *The Cyclicality of Effort.*
Notes: Injury incidence rate (the number of total recordable injuries per 200,000 paid hours worked) in the USA. Annual data filtered with bandpass filter (solid), first differences (dash) and Hodrick–Prescott (dash-dot) filter. Shaded areas are NBER recessions.

these estimates in our baseline sample for the 1948–2015 period, and are still significant at the 10% level, although the standard errors are of course much larger than in the longer quarterly sample.

Panel C in Table 5 shows the absolute and relative standard deviations of the injury incidence rate, as a proxy for effort. The volatility of effort falls dramatically and significantly, both in absolute terms and relative to the volatility of output. This finding is robust for all three filters that we used throughout this paper as well as to changes in the break date. Since we did not target this statistic in our simulations, we take the falling volatility of effort as strong evidence in favour of the mechanism we put forward in this paper.

4. Conclusions

In this paper, we documented two changes in labour market dynamics over the post-war period in the USA: the strong procyclicality of labour productivity has vanished, and the volatility of employment has increased with respect to output. From the vantage point of the early 1980s, the procyclicality of labour productivity was a well-established empirical fact. This observation lent support to business cycle theories that assigned a central role to technology shocks as a source of fluctuations. The relative volatility of labour input in these models was lower than in the data, which posed one of the main challenges for these models, see King and Rebelo (1999) or Hall (1997). From today's perspective, things look distinctly worse for real business cycle theory. The

Table 5. *Changes in Labour Market Dynamics 1977–2016.*

	A. The vanishing procyclicality of labour productivity					
	Corr. with output			Corr. with labour input		
	Pre-94	Post-95	Change	Pre-94	Post-95	Change
BP	0.80	0.38	−0.42	0.39	−0.17	−0.56
	[0.11]	[0.17]	[0.20]	[0.24]	[0.26]	[0.35]
FD	0.60	0.32	−0.28	−0.01	−0.29	−0.28
	[0.14]	[0.17]	[0.22]	[0.23]	[0.18]	[0.29]
HP	0.61	0.14	−0.47	0.09	−0.34	−0.44
	[0.18]	[0.19]	[0.27]	[0.23]	[0.18]	[0.29]
	B. The rising volatility of labour input					
	SD			Relative SD		
	Pre-94	Post-95	Ratio	Pre-94	Post-95	Ratio
BP	1.15	1.24	1.08	0.65	0.94	1.44
	[0.14]	[0.14]	[0.18]	[0.09]	[0.11]	[0.27]
FD	2.15	2.09	0.97	0.80	0.99	1.24
	[0.27]	[0.57]	[0.29]	[0.11]	[0.10]	[0.21]
HP	2.28	2.30	1.01	0.80	1.05	1.32
	[0.27]	[0.28]	[0.17]	[0.13]	[0.10]	[0.25]
	C. The falling volatility of effort					
	SD			Relative SD		
	Pre-94	Post-95	Ratio	Pre-94	Post-95	Ratio
BP	0.26	0.15	0.57	0.15	0.11	0.77
	[0.03]	[0.02]	[0.12]	[0.02]	[0.01]	[0.15]
FD	0.58	0.26	0.45	0.21	0.12	0.58
	[0.10]	[0.03]	[0.10]	[0.04]	[0.03]	[0.18]
HP	0.74	0.20	0.27	0.26	0.09	0.35
	[0.08]	[0.03]	[0.05]	[0.03]	[0.01]	[0.07]

Notes: SE in brackets are calculated from the variance–covariance matrix of the second moments using the delta method. Labour productivity is output per worker and labour input is employment. The proxy for effort is the injury incidence rate from the BLS Injuries, Illnesses, and Fatalities (IIF) database, as in Shea (1990). Data are annual and the sample period is 1977–2016.

relative volatility of labour input increased even further and productivity is now barely procyclical or may even be countercyclical.

We presented a model to argue that these changes might be explained by the US labour market having become more flexible. The intuition for why a decline in labour market turnover increases the relative volatility of employment and reduces the procyclicality of labour productivity is straightforward and compelling. If employment adjustment costs are convex, then lower turnover implies lower hiring costs. If there is another input into production that can be used at least partly as a substitute for labour, then a reduction in hiring frictions will make that input less volatile, so that employment becomes more volatile with respect to output. In this paper, we refer to this other factor input as effort, but a very similar argument can be made for capacity utilisation of capital. Given that capital does not fluctuate much at business cycle frequencies, the fact that the comovement of labour and output—and therefore labour productivity—has changed almost unavoidably leads to the conclusion that there must be another input into the production process.

Around the same time that the procyclicality of productivity vanished, there were other changes in US business cycle dynamics, perhaps most notably the reduction in output volatility (Stock and Watson, 2002) and the emergence of the slow recoveries (Galí *et al.*, 2012). A reduction in volatility or an increase in persistence across all macroeconomic aggregates does not affect the business cycle statistics we focused on in this paper. However, some have argued that the slow recoveries are 'jobless', in the sense that they are associated with a slower response of employment to changes in output (Bachmann, 2012; Jaimovich and Siu, 2018). If this is the case, then this change would tend to make labour productivity more procyclical. We therefore do not believe the possible emergence of jobless recoveries is related to the vanishing procyclicality of productivity.

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Additional Supporting Information may be found in the online version of this article:

Online Appendix
Replication Package

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