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Short title: Vanishing Procyclicality of Productivity

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Abstract

We document two changes in postwar 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.

Keywords: labour hoarding, hiring frictions, effort choice

JEL classification: E24 E32

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1 Introduction

The nature of business cycle fluctuations changes over time. There is a host of evidence for changes in the dynamics of postwar 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 U.S. economy over the past decades, which should of interest to economists doing research on business cycles, labour markets and other related fields.

In order to illustrate the possible link between a reduction in 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, Faberman,

[1]As far as we know, Stiroh (2009) was the first to provide evidence of a decline in the labour productivity-hours correlation. Gordon (2010), Barnichon (2010), Galí and Gambetti (2009), 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.

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

Haltiwanger, Jarmin, and Miranda (2010), Decker, Haltiwanger, Jarmin, and Miranda (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 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 US 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

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

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 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 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, Pries, and Sims (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, Smets, and Wouters (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 a 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 5.

The remainder of the paper is organised as follows. Section 2 documents the changes in the patterns of fluctuations in labour productivity and employment. Section 3 develops the basic model. Section 4 describes the outcome of simulations of a calibrated version of the model, and discusses its consistency with the evidence. Section 5 concludes.

2 Changes in Labour Market Dynamics

We document two stylised facts regarding postwar 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 Labour Productivity and Cost (LPC) program, 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-84 (1948:1-1984:4) and post-85 (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 1981-82 and 1990-91 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 favored by Stock and Watson (2002) in their analysis of changes in output volatility, as well as the more common HP filter with

[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 1981-82 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.

smoothing parameter 1600.

2.1 The Vanishing Procyclicality of Labour Productivity

Figure 1 shows the fluctuations at business cycle frequencies in labour productivity in the US over the postwar 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-84 and post-85 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 results in this Table.

2.1.1 Correlation with Output

Independently of the detrending procedure, the correlation of output per hour with output in the pre-84 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-85 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-84 estimates is highly

[8] We use least squares (GMM) to estimate the second moments (variances and and 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.

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-85 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]

2.1.2 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-84 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 RBC literature, using data up to the mid 80s.[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-85 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-84 period are again highly significant.

[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.

2.1.3 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, Hamermesh, and Stewart (2013)). We do not take a strong stance on whether or not the correlation of productivity with the cycle changed sign. Our finding that the cyclicality of productivity declined strongly over time is highly significant, robust, and consistent with other studies.

2.2 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-84 and post-85 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-84 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.

2.3 Conclusion and Further Evidence

Summarizing, we showed that the cyclicality of labour productivity in the US declined strongly some time in the 80s. 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 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 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 US, and there is no evidence for a similar reversal of the cyclicality of labour productivity in other countries, see appendix B.2. Lewis, Villa, and Wolters (2018) document differences in the procyclicality of productivity between Europe and the US, 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

[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.

volatility of employment can indeed be explained by a reduction in hiring costs resulting from the decline in labour market turnover.

3 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]

3.1 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

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

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 workweek, 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.

[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, Guren, Manoli, and Weber (2012).

3.2 Firms

Firms produce a homogenous 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 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 $g\left(.\right)$, 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 4 below, 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 $g\left(.\right)$. As a limiting case, we will also consider a frictionless labour market, setting $g\left(H\right) = 0$ for all H.

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

3.3 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, maximizing the total surplus generated by each match.[14] This efficient effort level, in each period and for each worker, equates 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:

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

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

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

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

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

[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.

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.

Maximizing 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,

$$\begin{aligned} S_t^F &= (1-\Psi_F)\,\frac{(1-\alpha)\,Y_t}{N_t} - W_t + (1-\delta)\,E_t\left[Q_{t,t+1}S_{t+1}^F\right] && (14)\\ &= E_t\sum_{s=0}^{\infty}(1-\delta)^s\,Q_{t,t+s}\left[(1-\Psi_F)\,\frac{(1-\alpha)\,Y_{t+s}}{N_{t+s}} - W_{t+s}\right] && (15)\end{aligned}$$

where the second equality follows from iterating forward (and defining $Q_{t,t}=1$). This

[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 appendix C for details on the derivation of equation (12).

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.

3.4 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 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 negotations 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

[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.

of effort. This marginal disutility of employment, expressed in terms of consumption, is given by,[17]

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

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.

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

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

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

Nash bargaining assumes that the wage is set such that the total surplus from the match

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

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

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

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

3.5 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 negotations 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.

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

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 7 equations in the endogenous variables H_t, $\mathcal{E}_t$, W_t, W_t^{UB}, W_t^{LB}, N_t and C_t, or 9 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 $AR(1)$

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

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.

4 Implications of the Reduction in Labour Market Frictions

We now proceed to use our model to analyze 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.

4.1 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

[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), footnote 7 on page 2.

due to employer-to-employer (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 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, Faberman, Haltiwanger, Jarmin, and Miranda (2010)), decreased job security (Fujita (2018)), increased specificity of human capital (Cairó (2013)) and the aging 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 section 4.4 below. 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.

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

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

[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 appendix D.

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 normalizing 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 implica-

[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).

tions for the second moments of interest. In particular we have

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

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

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 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:

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

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.

4.3 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. $g\left(H\right) = \infty$ 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 normalizing 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:

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

These predictions are consistent with the data, as we documented in section 2. 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 intuition is more subtle, see appendix E. To answer

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

the question whether we can also quantitatively match those patterns for reasonable parameter values, we now turn to a numerical analysis.

4.4 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 κ such that

[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 tangientially 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 irreversibilty 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, Muehlemann, and Schenker (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

hiring costs are 3% of output in calibration for the pre-84 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, Faberman, Haltiwanger, Jarmin, and Miranda (2010), Fujita (2018), Cairó and Cajner (2018)).[25] Using these estimates, we calibrate the gross separation rate δ in our model to 35% per quarter for the pre-84 subsample and to 20% per quarter for the post-85 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

results.

[25] The estimates in Fujita (2018) differ from those in Davis, Faberman, Haltiwanger, Jarmin, and Miranda (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 appendix F.

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 to illustrate the qualitative changes in the business cycle moments that the model can generate, we set this parameter fairly abitrarily 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.

4.5 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 US, 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 $201,000$ 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 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.

4.6 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, Fernald, and Kimball (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

[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.

[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 microdata, there is enormous "bunching" of hours worked around 40 hours per week. And in aggregate data, hours per worker are slower to fall in recesions and slower to recover

fact, the standard deviation of hours per worker relative to output increases in the 80s. 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) program, 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 breakdate of 1985 (we would have only 8 observations for the pre-84 period after first-differencing). Therefore, we use 1995 as the breakdate, 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 breakdate 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 re-documents our basic stylised facts using annual data

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, Slemrod, and Giertz (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 1976-1988, 1989-2001, 2002, 2003-2013, and 2014-2016. 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.

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 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 fall 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 breakdate. Since we did not target this statistic in our simulations, we take the falling volatility of effort as strong evidence in favor of the mechanism we put forward in this paper.

5 Conclusions

In this paper, we documented two changes in labour market dynamics over the postwar period in the US: 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 80s, 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 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 utilization 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, Smets, and Wouters (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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Table 1. The Vanishing Procyclicality of Labour Productivity

	Corr with output			Corr with labour input		
	Pre-84	Post-85	Change	Pre-84	Post-85	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]

Standard errors in brackets are calculated from the variance-covariance matrix of the second moments using the delta method. Data are from the BLS labour productivity and cost program (LPC) 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.

Table 2. The Rising Volatility of Labour Input

	Std. Dev.			Relative Std. Dev.		
	Pre-84	Post-85	Ratio	Pre-84	Post-85	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]

Standard errors in brackets are calculated from the variance-covariance matrix of the second moments using the delta method. Data are from the BLS labour productivity and cost program (LPC) and refer to the private sector (non-farm business sector). The sample period is 1948-2015.

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:	$\zeta = 0.299$	normalization: frictionless $\overline{\mathcal{E}} = 1$
	$\phi = 0$	normalization 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-84
Shocks:	$\rho_A = 0.97$, $\sigma_A = 0.186$	normalization: $\mathrm{sd}(y) = 1\%$
	$\rho_z = 0.97$, $\sigma_z = 0.173$	$\mathrm{sd}(n)/\mathrm{sd}(y) = 0.66$

Table 4. Simulation results

	frictions (% GDP)	empl/pop ratio $\bar{N}$	correlation productivity with output	with empl	relative std.dev. empl n_t	wage w_t	std.dev. output y_t
Data							
Pre-84			0.78	0.29	0.66	0.30	
Post-85			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

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.

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

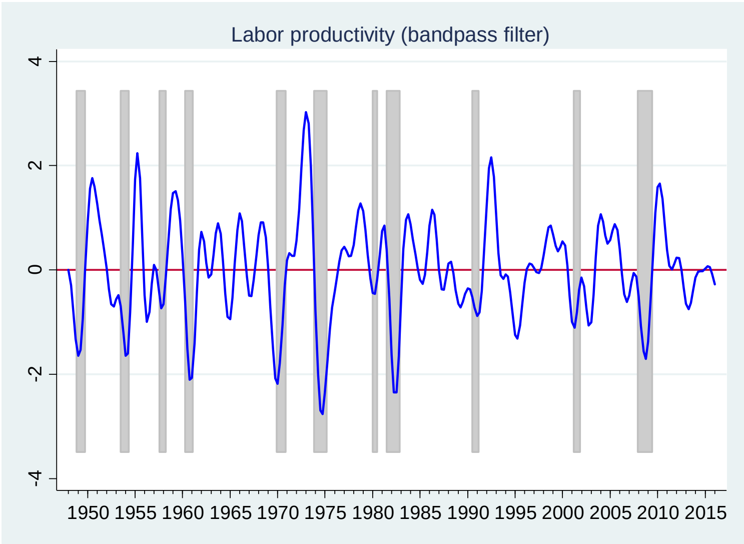
	Std. Dev.			Relative Std. Dev.		
	Pre-94	Post-95	Ratio	Pre-94	Post-95	Ratio
BP	1.15	1.24	1.08	0.65	0.94	1.44
	[0.14]	[0.14]	[0.18]	[0.09]	[0.11]	[0.27]
FD	2.15	2.09	0.97	0.80	0.99	1.24
	[0.27]	[0.57]	[0.29]	[0.11]	[0.10]	[0.21]
HP	2.28	2.30	1.01	0.80	1.05	1.32
	[0.27]	[0.28]	[0.17]	[0.13]	[0.10]	[0.25]

C. The Falling Volatility of Effort

	Std. Dev.			Relative Std. Dev.		
	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]

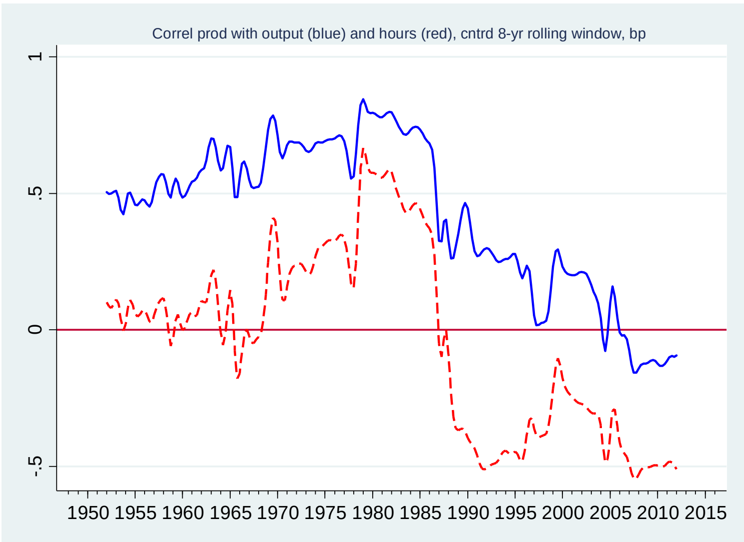
Standard errors in brackets are calculated from the variance-covariance matrix of the second-moments using the delta method. Labour productivity is output per worker and labour input is employment. The proxy for effort is the injury incidence rate from the BLS Injuries, Illnesses, and Fatalities (IIF) program, as in Shea (1988). Data are annual and the sample period is 1977-2016.

Figure 1. The Vanishing Procyclicality of Labour Productivity



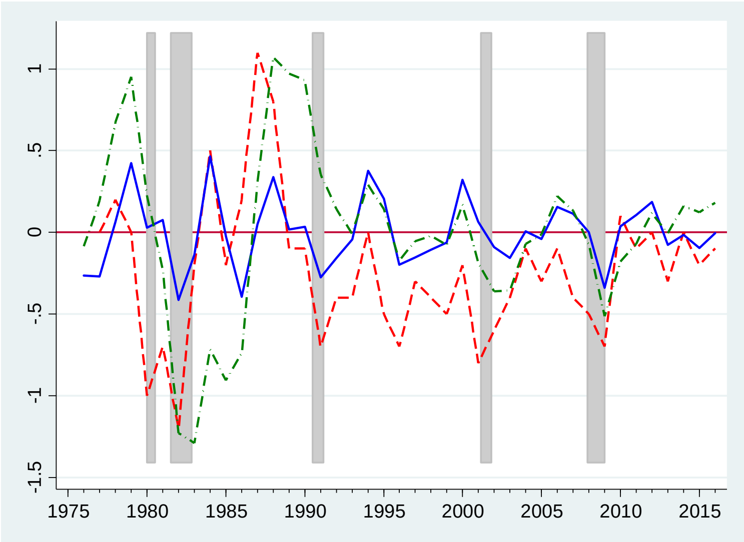
Output per hour in the US private sector. Shaded areas are NBER recessions.

Figure 2. The Vanishing Procyclicality of Labour Productivity: Rolling Correlations



Correlations are calculated in a centered 8-year rolling window of quarterly bandpass-filtered data.

Figure 3. The Cyclicality of Effort



Injury incidence rate (the number of total recordable injuries per 200,000 paid hours worked) in the US. Annual data filtered with bandpass filter (blue solid), first differences (red dash) and Hodrick-Prescott (green dash-dot) filter. Shaded areas are NBER recessions.

The Vanishing Procyclicality of Labour Productivity

Jordi Galí and Thijs van Rens

January 2019

Appendices
(for online publication)

A Additional Business Cycle Statistics for the US

Table 6. Additional Business Cycle Statistics

A. Volatility output and productivity

	Std. Dev.			Relative Std. Dev.		
	Pre-84	Post-85	Ratio	Pre-84	Post-85	Ratio
Output						
BP	2.53	1.39	0.55			
	[0.13]	[0.09]	[0.05]			
4D	3.95	2.26	0.57			
	[0.20]	[0.28]	[0.08]			
HP	2.59	1.48	0.57			
	[0.14]	[0.10]	[0.05]			
Output per worker						
BP	1.49	0.85	0.57	0.59	0.62	1.05
	[0.08]	[0.05]	[0.05]	[0.03]	[0.05]	[0.10]
4D	2.54	1.41	0.55	0.64	0.62	0.97
	[0.13]	[0.08]	[0.04]	[0.03]	[0.08]	[0.13]
HP	1.57	0.90	0.57	0.61	0.60	1.00
	[0.08]	[0.07]	[0.05]	[0.03]	[0.05]	[0.10]

B. Correlations

	Corr with output			Corr with employment		
	Pre-84	Post-85	Change	Pre-84	Post-85	Change
Employment (private sector)						
BP	0.83	0.79	−0.03			
	[0.02]	[0.03]	[0.04]			
4D	0.78	0.79	0.02			
	[0.03]	[0.05]	[0.06]			
HP	0.81	0.82	0.01			
	[0.03]	[0.03]	[0.04]			

Standard errors in brackets are calculated from the variance-covariance matrix of the second moments using the delta method. See tables 1 and 2 for data sources and sample period.

B The Cyclicality of Productivity across Industries and Countries

B.1 Evidence from Industry-level Data

We use data on industry productivity from the BLS labour productivity and cost program,[31] also known as the US KLEMS data, and drop the sectors agriculture and government in order to focus on the non-farm business sector. This gives us annual data on output per hour, output per worker, output, hours worked and employment for 49 industries at the 3-digit level over the 1987-2016 period. To make the data stationary, we take (annual) first differences.

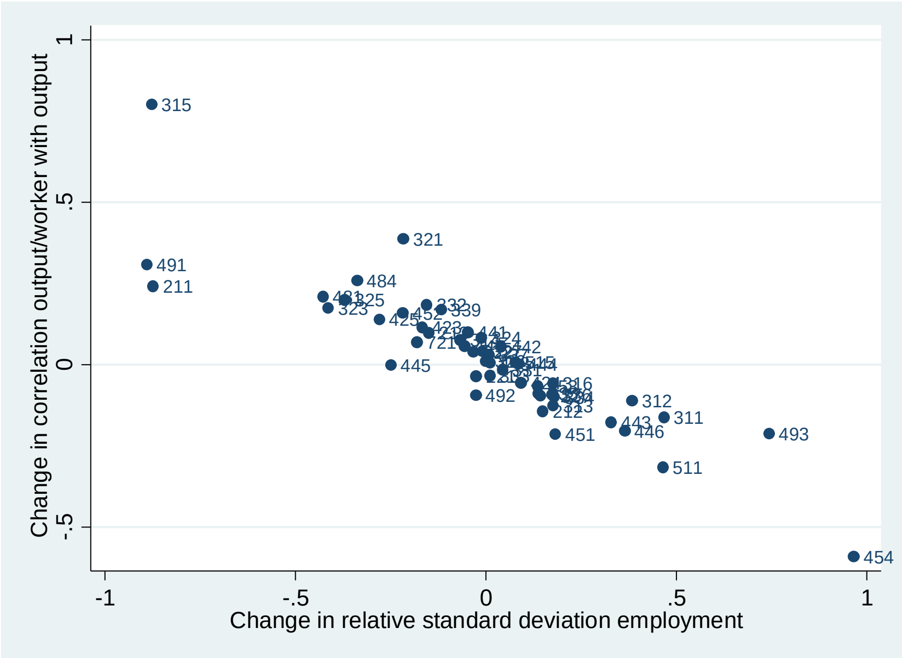
The time period for which industry-level data are available is different from the period we use for aggregate data in the main text. This is not a big problem, because here we are interested in cross-sectional correlations in business cycle statistics. In order to control for fixed industry characteristics, we arbitrarily split the sample in half, and consider the variation in changes in these statistics between the 1987-1999 and 2000-2016 periods across industries. The patterns we document look very similar if we use the level of these statistics instead.

Figure 4 plots the change in the cyclicality of labour productivity against the change in the relative volatility of labour input. The cyclicality of productivity is measured as the correlation between output per worker and output, and the relative volatility of labour is measured as the relative standard deviation of employment with respect to output. The graph looks very similar if we use total hours worked as the measure of labour input, and if we measure the cyclicality of productivity as its correlation with labour.

Industries that experienced a larger decline in the procyclicality of productivity (or a smaller increase in procyclicality) on average also experienced a larger increase in the relative volatility of labour input (or smaller decrease). This finding is consistent with our hypothesis that the vanishing procyclicality of labour productivity and the rising relative volatility of labour input are related, in the sense that they are both the result of the US labour market becoming more flexible.

[31] https://www.bls.gov/lpc/

Figure 4. Changes in Labour Market Dynamics across Industries, 1987-2016



All series are in annual first-differences and refer to the non-farm business sector. Data were taken from the industry-level database of the BLS labour productivity and cost program. Labels refer to 3-digit NAICS numbers.

B.2 International Evidence

Although in this paper we focus on the US, it is worth exploring whether the same patterns hold for other countries as well. For many countries, data are not available for our sample period. However, Ohanian and Raffo (2012) collected data on output, employment and hours worked from the OECD Economic Outlook database and national statistics offices, for many countries starting from 1960. Table 7 reports the cyclicality of labour productivity and the relative volatility of labour input for the four major European economies using these data. For comparison, we also report the statistics for the US over the same period.

The change in labour market dynamics in the US is much more pronounced than in almost all other countries. In fact, the drop in the procyclicality of labour productivity in the US looks even more dramatic over the 1960-2013 period than over our baseline period (1948-2015). In the majority of other countries, the procyclicality of labour productivity decreases much less, or even increases slightly. Notable exceptions are Spain, and to a lesser degree also Ireland, Sweden and perhaps Norway and the UK, where the procyclicality of labour productivity also declined substantially.

Next, we look at the change in labour market turnover in these countries, using international time series data for worker flows calculated by Elsby, Hobijn, and Şahin (2013). Unfortunately, for most countries these data start only in 1983, so that the best we can do is to compare the 1985-90 period to the 2002-2007 period. These statistics are reported in (the left-hand side panel of) Table 8.

The US is the country with by far the largest decline in the separation rate, followed at a distance by Ireland. Other countries not only experience a much smaller (or no) decline in turnover, but the level of the separation rate is much lower as well, which –with quadratic adjustment costs– implies that even for the same decline in turnover the effect on frictions would be much smaller. Therefore, in light of the explanation we propose in this paper, it should not be surprising that labour productivity became much less procyclical in the US, whereas there was no such change in many other countries.

Finally, how is it possible that the dynamics of productivity, output and employment in Spain (and Sweden, Norway and the UK) changed as much as it did, whereas there is no evidence for a decline in labour market turnover in these countries? We argue the reason is simply that there were other changes than the separation rate affecting labour market frictions. The decline in turnover may have been the main driver of the reduction in labour market frictions in the US, but other countries, like Spain, experienced a huge liberalization of the labour market over this period, which reduced frictions for entirely different reasons. Comparing the OECD employment protection index for the same countries and the same time periods as the separation rates (right-hand side panel of Table 8), we see that Spain is with distance the country that experienced the greatest change in employment protection.

Table 7. Changes in Labour Market Dynamics in European and other OECD Countries, 1960-2013

	Correlation Productivity						Relative Std. Dev.		
	with output			with employment			employment		
	Pre-84	Post-85	Change	Pre-84	Post-85	Change	Pre-84	Post-85	Ratio
US, baseline	0.78	0.60	−0.18	0.31	−0.15	−0.47	0.66	0.81	1.23
US, OR	0.76	0.48	−0.28	0.25	−0.20	−0.45	0.67	0.90	1.33
Austria	0.83	0.86	0.02	−0.15	0.34	0.49	0.56	0.55	0.99
Finland	0.68	0.73	0.05	−0.25	−0.08	0.17	0.76	0.69	0.91
France	0.93	0.85	−0.08	0.42	0.31	−0.11	0.40	0.56	1.38
Germany	0.86	0.92	0.07	0.31	0.28	−0.02	0.54	0.40	0.74
Ireland	0.87	0.61	−0.26	−0.17	−0.33	−0.16	0.50	0.84	1.66
Italy	0.93	0.82	−0.11	0.35	0.02	−0.33	0.40	0.58	1.43
Norway	0.87	0.58	−0.29	−0.41	−0.43	−0.02	0.53	0.90	1.70
Spain (1961-)	0.72	−0.06	−0.78	−0.25	−0.57	−0.31	0.47	1.20	2.54
Sweden	0.83	0.64	−0.19	0.01	−0.19	−0.20	0.55	0.78	1.42
UK	0.92	0.81	−0.11	−0.05	−0.10	−0.04	0.40	0.59	1.49
Australia (1964-)	0.65	0.50	−0.15	−0.34	−0.57	−0.23	0.73	1.04	1.43
Canada	0.44	0.83	0.40	−0.27	0.21	0.48	0.94	0.56	0.60
Japan	0.95	0.96	0.02	0.16	0.34	0.18	0.32	0.29	0.89
Korea (1970-)	0.93	0.80	−0.13	−0.03	0.40	0.44	0.35	0.65	1.85

All data are bandpass filtered and refer to the private sector. Data for the baseline results for the US are from the BLS labour productivity and cost program (LPC), see Tables 1, 2 and 3 for details. Data for all other countries were collected by Ohanian and Raffo (2012) from the OECD Economic Outlook database and national statistics offices. For consistency with our baseline results, productivity is real output per worker and employment is in persons, although the Ohanian-Raffo data also allow to calculate output per hour and total hours.

Table 8. Changes in Labour Market Institutions in European and other OECD Countries, 1985-2007

	Separation rate				Employment protection			
	1985-90	2002-07	Change	Ratio	1985-90	2002-07	Change	Ratio
US	3.8	2.9	−0.9	0.76	25.7	25.7	0.0	1.00
Austria					275.0	244.5	−30.5	0.89
Finland					278.6	216.7	−61.9	0.78
France	0.8	0.8	0.0	1.00	242.4	244.3	1.8	1.01
Germany	0.4	0.6	0.2	1.41	258.3	279.3	21.0	1.08
Ireland	0.7	0.4	−0.3	0.56	143.7	140.4	−3.3	0.98
Italy	0.4	0.4	0.0	1.11	276.2	276.2	0.0	1.00
Norway	1.2	1.8	0.6	1.47	233.3	233.3	0.0	1.00
Spain	0.9	0.9	0.0	0.99	354.8	235.7	−119.1	0.66
Sweden	0.8	1.4	0.7	1.84	279.8	260.7	−19.1	0.93
UK	0.9	0.9	0.0	1.11	103.2	119.8	16.6	1.16
Australia	1.7	1.8	0.1	1.04	116.7	141.7	25.0	1.21
Canada	2.3	2.5	0.2	1.09	92.1	92.1	0.0	1.00
Japan	0.5	0.8	0.2	1.44	170.2	170.2	0.0	1.00
Korea						236.9		

Data for the separation rate are from Elsby, Hobijn, and Şahin (2013). Employment protection is the EPRC index (version 1) from the OECD. The begin and end year of the sample were chosen to obtain consistent results for both the separation rates and the employment protection index for as many countries as possible, while spanning a time period that is as close as possible to the results on labour market dynamics. The EHS start in 1983 for most countries, and run to 2007. Data on employment protection run from 1985 to 2013. The index is very persistent over time, so changing the end year of the sample makes very little difference.

C Marginal Product and Disutility of Effort

This appendix derives the marginal product of employment to the firm, equation (12), and the marginal disutility from employment, expressed in consumption terms, to the household, equation (16), if effort adjusts endogenously. From equations (4) and (2), it is straightforward differentation to decompose the total effect of employment on output and total effective labour supply into a direct effect and an effect through the endogenous response of effort.

$$\frac{dY_{jt}}{dN_{jt}} = \frac{\partial Y_{jt}}{\partial N_{jt}} + \frac{\partial Y_{jt}}{\partial \mathcal{E}_{jt}} \frac{\partial \mathcal{E}_{jt}}{\partial N_{jt}} = \frac{(1-\alpha)\, Y_{jt}}{N_{jt}} \left(1 + \psi \frac{N_{jt}}{\mathcal{E}_{jt}} \frac{\partial \mathcal{E}_{jt}}{\partial N_{jt}}\right) \tag{36}$$

$$\frac{dL_{ht}}{dN_{ht}} = \frac{\partial L_{ht}}{\partial N_{ht}} + \frac{\partial L_{ht}}{\partial \mathcal{E}_{ht}} \frac{\partial \mathcal{E}_{ht}}{\partial N_{ht}} = \frac{1}{1+\zeta} \left[1 + \zeta \mathcal{E}_{ht}^{1+\phi} \left(1 + (1+\phi) \frac{N_{ht}}{\mathcal{E}_{ht}} \frac{\partial \mathcal{E}_{ht}}{\partial N_{ht}}\right)\right] \tag{37}$$

Here, $\mathcal{E}_{jt}$ denotes the effort of all workers i that are employed in firm j and $\mathcal{E}_{ht}$ the effort of all workers that are members of household h.

To find the response of effort to changes in employment that firm and household face, we use the condition that the marginal disutility from effort of a given worker i (expressed in consumption terms) from equation (8), in equilibrium must equal the marginal productivity of that worker to the firm from equation (9).

$$\mathcal{E}_{it}^{1+\phi-\psi} = \frac{\psi\,(1+\zeta)}{(1+\phi)\,\zeta} \frac{Z_t}{\gamma C_{ht}^{\eta}} (1-\alpha)\, A_t \left(\int_0^{N_{jt}} \mathcal{E}_{vt}^{\psi} dv\right)^{-\alpha} \tag{38}$$

First, suppose 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 is not affected, $C_{ht} = C_t$. Substituting this, as well as the condition that all workers in firm j exert the same amount of effort, $\mathcal{E}_{it} = \mathcal{E}_{jt}$ for all $i \in [0, N_{jt}]$, the effort condition becomes,

$$\mathcal{E}_{jt}^{1+\phi-\psi} = \frac{\psi\,(1+\zeta)}{(1+\phi)\,\zeta} \frac{Z_t}{\gamma C_t^{\eta}} (1-\alpha)\, A_t \left(\mathcal{E}_{jt}^{\psi} N_{jt}\right)^{-\alpha} \tag{39}$$

so that the elasticity of effort in a given firm j with respect to employment in that firm, is given by

$$\frac{N_{jt}}{\mathcal{E}_{jt}} \frac{\partial \mathcal{E}_{jt}}{\partial N_{jt}} = -\frac{\alpha}{1+\phi-(1-\alpha)\,\psi} \tag{40}$$

Substituting this elasticity into equation (36) above, gives expression (12) in the text.

Next, suppose household h considers having N_{ht} employed workers, given that all other households have N_t employed workers. Because there are infinitely many households, household's h's decision to have a fraction of $N_{ht} \neq N_t$ of its members employed, does not affect the level of employment in any firm $N_{jt} = N_t$. Furthermore, although the effort level of worker i may change because of household h's decision, effort of all other workers in firm j, who are members of different households, is unaffected, $\mathcal{E}_{it} = \mathcal{E}_{ht}$ and $\mathcal{E}_{i't} = \mathcal{E}_t$ for $i' \neq i$. Thus, the effort condition becomes,

$$\mathcal{E}_{ht}^{1+\phi-\psi} = \frac{\psi\left(1+\zeta\right)}{\left(1+\phi\right)\zeta}\frac{Z_t}{\gamma C_{ht}^{\eta}}\left(1-\alpha\right)A_t\left(\mathcal{E}_t^{\psi}N_t\right)^{-\alpha} \tag{41}$$

and the elasticity of effort exerted by members of household h with respect to employment in that household, using equation (3), is given by,

$$\frac{N_{ht}}{\mathcal{E}_{ht}}\frac{\partial\mathcal{E}_{ht}}{\partial N_{ht}} = \frac{C_{ht}}{\mathcal{E}_{ht}}\frac{\partial\mathcal{E}_{ht}}{\partial C_{ht}}\cdot\frac{N_{ht}}{C_{ht}}\frac{\partial C_{ht}}{\partial N_{ht}} = -\frac{\eta}{1+\phi-\psi}\frac{W_{ht}N_{ht}}{C_{ht}} = -\frac{\eta}{1+\phi-\psi} \tag{42}$$

Substituting this elasticity into equation (37) above, gives expression (16) in the text.

D The Information Channel and the Decline in Labour Market Turnover

To see how the information channel reduces labour maket turnover and hiring frictions in an extension of our model, we make the following assumptions, following Mercan (2017), in addition to the assumptions in section 3.

- There is an idiosyncratic component of productivity $\mu \in \{\mu_G, \mu_B\}$, so that match productivity equals μA_t, which is unobservable. The (objective) probability that $\mu = \mu_G$ is p_G, and we normalise $p_G \mu_G + (1 - p_G)\mu_B = 1$ so that aggregate productivity is still A_t.
- Workers and firms receive signals about μ, and based on these signals form their belief $p' \sim G(p'|p)$ about the probability that $\mu = \mu_G$, where p is the belief before the last signal. These beliefs are formed through normal Bayesian learning.
- At the start of a match, n signals are received immediately, based on which worker and firm form their initial belief $p_0 \sim G(p'|p)$ that their prospective match will be highly productive.

Note that the assumption of normal Bayesian learning with two possible outcomes gives closed-form expressions for p' as a function of p and output, as well as for the distributions $G(p_0)$ and $G(p'|p)$, see section 3.4 in Mercan (2017).

With these additional assumptions, job creation condition (13) becomes

$$g'(H_t) = \int_0^1 \max\left\langle 0, S_t^F(p_0)\right\rangle dG(p_0) \tag{43}$$

where the max operator captures that some matches are not created because the prior belief that match is of good quality is too low. Firm surplus $S_t^F(p)$, as in equation (14), is now given by

$$\begin{aligned} S_t^F(p) &= (1-\Psi_F)(p\mu_G + (1-p)\mu_B)\frac{(1-\alpha)Y_t}{N_t} - W_t(p) \\ &\quad + (1-\delta)E_t\left[Q_{t,t+1}\int_0^1 \max\left\langle 0, S_{t+1}^F(p')\right\rangle dG(p'|p)\right] \end{aligned} \tag{44}$$

Here, the max operator captures endogenous match destruction if beliefs about match quality become too low.[32]

[32] To close the model, i.e. in order to solve for the wage, we also need to modify the equation for household surplus, as in equation (17), as follows.

$$\begin{aligned} S_t^H(p) &= W_t(p) - \frac{1}{1+\zeta}\frac{\gamma C_t^\eta}{Z_t} - \Psi_H(p\mu_G + (1-p)\mu_B)\frac{(1-\alpha)Y_t}{N_t} \\ &\quad + (1-\delta)E_t\left[Q_{t,t+1}\int_0^1 \max\left\langle 0, S_{t+1}^H(p')\right\rangle dG(p'|p)\right] \end{aligned} \tag{45}$$

Better information about prospective job matches due to improved search technologies is modeled as an increase in n, the number of signals about match quality that worker and firm receive prior to deciding whether or not to form a match. An increase in n reduces the the variance of p_0, because prior beliefs are based on more information and therefore more accurate, and $p'|p$, because there is less learning and updating of beliefs after a larger number of signals has already been received, see section 3.4.3 in Mercan (2017) for a proof using the expressions for normal Bayesian learning. By equation (44), a lower variance of $p'|p$ implies a reduction in job destruction. The effect of this reduction in turnover on (un)employment is counteracted by a reduction in job creation due to the lower variance of p_0, see equation (43), which implies that some (relatively low quality) matches are not created.

Further extending the model allows to match a wider set of statistics in the data. Importantly, by adding on-the-job search the model generates predictions about the EE flow, and by adding wage renegotiation based on outside offers, it generates realistic wage profiles as well. Mercan (2017) uses this extended model to show that the improved information story described here can match at least half of the observed decline in the EE flow, as well as wage growth for job switchers, whereas competing stories, in particular decline in the efficiency of on-the-job search, cannot.

Quantitatively, improved information cannot explain the entire observed decline in the separation rate. In Mercan's calibration, the model predicts a decline in the separation rate from 2.0 to 1.8%, only 10% of the observed drop from 4.0 to 2.0%.[33] It is possible that the predicted decline is larger once costs from moving from job to job are taken into account (Mercan, private conversation).

However, this expression is not needed to understand the intuition for the mechanism. All other equations of our model remain unchanged.

[33] We are grateful to Yusuf Mercan for providing these numbers, which are not (yet) in the publicly available version of the paper.

E Intuition for the Main Result

We can use the job creation condition to get a better intuition for this mechanism. For simplicity, we first write the job creation condition in terms of total match surplus. Substituting (21) into (18), we get

$$g'(H_t) = W_t^{UB} - W_t = \tfrac{1}{2}\left(W_t^{UB} - W_t^{LB}\right) \equiv \tfrac{1}{2}S_t \tag{46}$$

and combining (19) and (20) gives an expression for total match surplus S_t

$$S_t = (1 - \Psi_F - \Psi_H)\frac{(1-\alpha)Y_t}{N_t} - \frac{1}{1+\zeta}\frac{\gamma C_t^{\eta}}{Z_t} + (1-\delta)E_t\left[Q_{t,t+1}S_{t+1}\right] \tag{47}$$

Since the link between turnover and frictions is unrelated to effort or preference shocks, we simplify further by assuming away these elements of the model, setting $\psi = 0$ so that $\Psi_F = \Psi_H = 0$, $\zeta = 0$ and $Z_t = 0$, as well as assuming linear utility over consumption, $\eta = 0$. Then, the expression for match surplus simplifies to,

$$S_t = p_t - \gamma + (1-\delta)E_t\left[\beta S_{t+1}\right] \tag{48}$$

where $p_t = (1-\alpha)Y_t/N_t$. This is a standard job creation condition found in many labour market models. Finally, assuming that productivity p_t is close to a random walk (or, alternatively, that surplus S_t is in steady state in each period), we get that approximately

$$S_t = E_t\sum_{s=0}^{\infty}\beta^s(1-\delta)^s\left[\frac{(1-\alpha)Y_{t+s}}{N_{t+s}} - \gamma\right] \simeq \frac{1+r}{r+\delta}\left[\frac{(1-\alpha)Y_t}{N_t} - \gamma\right] \tag{49}$$

where $r = (1-\beta)/\beta$.

In the absence of other shocks, a good measure for the volatility of hiring relative to productivity is the elasticity of H_t with respect to p_t. This "steady state elasticity" (Mortensen and Nagypal (2007), Hornstein, Krusell, and Violante (2005)) can be calculated by log-linearizing equations (46) and (49)

$$\frac{d\log H_t}{d\log p_t} = \frac{\bar{H}g''(\bar{H})}{g'(\bar{H})}\frac{d\log S_t}{d\log p_t} = \frac{\bar{H}g''(\bar{H})}{g'(\bar{H})}\frac{\bar{p}}{\bar{p}-\gamma} \tag{50}$$

Assuming that $g(.)$ is an iso-elastic function, $g(H) = \frac{\kappa}{1+\mu}H^{1+\mu}$, $\bar{H}g''(\bar{H})/g'(\bar{H}) = \mu$ is constant, so that the only way in which a decline in δ can increase the relative volatility of hiring with respect to productivity is through a reduction in steady state match surplus $\bar{p} - \gamma$, as you suspected.

To see how δ affects match surplus, we need to solve out for the steady state of the model. Combining the steady state version of JCC, $g'(\bar{H}) = \frac{1}{2}\bar{S} = \frac{1}{2}\frac{1+r}{r+\delta}[\bar{p} - \gamma]$, with the definition of productivity and the production function, $\bar{p} = (1-\alpha)\bar{Y}/\bar{N} = (1-\alpha)\bar{A}\bar{N}^{-\alpha}$, and the law of motion for employment, $N_t = (1-\delta) N_{t-1} + H_t \Rightarrow \delta \bar{N} = \bar{H}$, we get an expression for the steady state level of hiring

$$(1-\alpha)\bar{A}\left(\frac{\bar{H}}{\delta}\right)^{-\alpha} - \gamma = 2\frac{r+\delta}{1+r}\bar{H}^{\mu} \tag{51}$$

There are two effects of δ on $\bar{H}$. First, assuming $\mu = 0$ (constant marginal hiring costs, as in the standard search model), a lower δ unambiguously reduces hiring one-for-one. This is the turnover effect: a lower separation rate implies less replacement hiring. Second, for $\mu > 0$ (convex adjustment costs), there is a counteracting effect: lower δ implies more hiring because marginal hiring costs are lower. However, this effect never offsets the direct effect.

Match surplus, by the steady state JCC, depends on δ both directly and through the steady state level of hiring, which affects marginal hiring cost.

$$\bar{p} - \gamma = 2\frac{r+\delta}{1+r}g'\left(\bar{H}\right) \tag{52}$$

The direct effect of a decline in δ is to lower surplus and thus to amplify the relative volatility of hiring. This goes in the direction or our story. The indirect effect is what we mean when we write that the decline in turnover decreased hiring frictions, because adjustment costs in employment are convex: a lower δ reduces $\bar{H}$ which reduces $g'\left(\bar{H}\right)$ and therefore surplus, also amplifying the relative volatility of hiring.

F Calibration: Quarterly versus Weekly Frequency

We simulate the model at quarterly frequency, as is common in the business cycle literature. In order to incorporate a frictionless labour market as a special case of our model, we make a timing assumption, following Blanchard and Galí (2010), that workers that are separated may find another job within the quarter, see equation (6). Given that median unemployment duration in the US is around 10 weeks, i.e. much less than a quarter, any other assumption would impose unrealistic frictions on the model. In this appendix we explain some of the technical details associated with this assumption, and show that it does not greatly affect our results.

F.1 Calculation Quarterly Gross Separation Probability

Our timing assumption raises an issue how to calibrate the gross separation or employment exit probability δ, which is the fractions of jobs that are destroyed in a quarter. Empirical measures based on worker surveys, like the CPS, tend to give the net separation or employment exit probability s, i.e. the probability that an employed worker who is employed at the beginning of the quarter is no longer employed at the end of the quarter. The difference between the two is that gross separations also include those workers who after losing their job find another job within the quarter. In order to translate the net employment exit probability into a gross employment exit probability, we use a comparable measure for the employment inflow probability. In a 2-state labour market model, this measure is the unemployment outflow or job finding probability f. Shimer (2012) provides measures of s and f from the CPS, at monthly frequency.

A second issue arises how to aggregate the monthly measures to quarterly probabilities. In the search literature, the solution is often to circumvent this problem by simulating the model at monthly or even weekly frequency, so that probabilities are close to Poisson arrival rates and within-period transitions may be ignored. In this paper, we instead follow the custom in the business cycle literature and simulate our model at quarterly frequency. We aggregate monthly probabilities s_m and f_m into quarterly ones by assuming a 2-state model of the labour market, in which workers may be either employed or unemployed (or non-employed). Under this assumption, the quarterly probabilities s_q and f_q can simply be calculated as the sum of the probabilities of all possible within period transitions.

Let u_q and e_q denote the end of quarter q labour market state unemployed and employed, respectively, and let $u_{1,q}$, $u_{2,q}$, $u_{3,q}$ and $e_{1,q}$, $e_{2,q}$, $e_{3,q}$ denote unemployment or employment in months 1, 2 and 3 of quarter q. Then,

$$
\begin{aligned}
s_q &= P\left[u_q \left| e_{q-1}\right.\right] \equiv P\left[e_{q-1}u_q\right] && (53)\\
&= P\left[e_{3,q-1}u_{1,q}u_{2,q}u_{3,q}\right] + P\left[e_{3,q-1}e_{1,q}u_{2,q}u_{3,q}\right] + P\left[e_{3,q-1}e_{1,q}e_{2,q}u_{3,q}\right] + P\left[e_{3,q-1}u_{1,q}e_{2,q}u_{3,q}\right] && (54)\\
&= s_m\left(1-f_m\right)^2 + \left(1-s_m\right)s_m\left(1-f_m\right) + \left(1-s_m\right)^2 s_m + s_m f_m s_m && (55)
\end{aligned}
$$

and similarly

$$
\begin{aligned}
f_q &= P\left[e_q \left| u_{q-1}\right.\right] \equiv P\left[u_{q-1}e_q\right] && (56)\\
&= P\left[u_{3,q-1}e_{1,q}e_{2,q}e_{3,q}\right] + P\left[u_{3,q-1}u_{1,q}e_{2,q}e_{3,q}\right] + P\left[u_{3,q-1}u_{1,q}u_{2,q}e_{3,q}\right] + P\left[u_{3,q-1}e_{1,q}u_{2,q}e_{3,q}\right] && (57)\\
&= f_m\left(1-s_m\right)^2 + \left(1-f_m\right)f_m\left(1-s_m\right) + \left(1-f_m\right)^2 f_m + f_m s_m f_m && (58)
\end{aligned}
$$

Once we have the quarterly net probabilities, we can calculate the gross quarterly separation probability as

$$\delta = \frac{s_q}{1-f_q} \tag{59}$$

to include those workers who after losing their job find another job within the quarter.

F.2 Robustness of the Simulations

To make sure our results do not depend on the choice of the time period, we re-do our baseline simulations at monthly frequency.

We start with simulating the model at quarterly frequency, as in the benchmark. In the main text, we rounded the quarterly gross separation probabilities in the pre- and post-85 period to 0.35 and 0.20. Using monthly probabilities $s_m = 0.04$ and 0.02 and $f_m = 0.45$, the exact values for the quarterly gross separation rate using equations (59), (55) and (56) are 0.34801 and 0.19567 in the pre-84 and post-85 periods, respectively. Recalibrating all other parameters to match the same targets as in the main text, our benchmark quarterly simulation results are summarised in the table below.

	frictions (% GDP)	empl/pop ratio $\bar{N}$	correlation productivity with output	with empl	relative std.dev. empl n_t	wage w_t	std.dev. output y_t
$\delta = 0.3480$ (Pre)	**3.00**	0.56	0.75	0.01	**0.66**	0.88	**1.00**
$\delta = 0.1957$ (Post)	0.99	0.65	0.61	-0.25	0.82	0.87	1.01
$\delta = 0$	0.00	**0.70**	0.48	-0.39	0.95	0.85	1.04

These results are basically the same as those in table 4 in the main text, i.e. the rounding makes very little difference.

The monthly gross separation probabilities by (59) in the pre-84 and post-85 periods are 0.07273 and 0.03636. We also simulated the model at the monthly frequency, using these values for δ. To make the calibration consistent with the monthly frequency, we recalibrated the discount factor $\beta = \exp\left(\frac{1}{3}\ln(0.99)\right) = 0.9967$, the autocorrelation of the shocks $\rho_A = \rho_z = \exp\left(\frac{1}{3}\ln(0.97)\right) = 0.9899$, the standard deviations of the shocks σ_A and σ_z to $\sqrt{\frac{1}{3}}$ of the quarterly variances, and recalibrated the importance of hiring frictions κ so that hiring costs are 3% of output, as in the quarterly benchmark simulations. All other parameters were left unchanged. We then simulated the model for $600,000$ instead of $200,000$ periods, and aggregated the monthly simulations to quarterly by keeping every third time period. This last step reduces the autocorrelations, as we would expect, but does not affect the statistics of interest (relative standard deviations and correlations). The results are summarised in the table below.

	frictions (% GDP)	empl/pop ratio $\bar{N}$	correlation productivity with output	with empl	relative std.dev. empl n_t	wage w_t	std.dev. output y_t
$\delta = 0.07273$ (Pre)	**3.00**	0.55	0.78	0.05	0.62	0.89	0.98
$\delta = 0.03636$ (Post)	0.77	0.66	0.62	-0.25	0.81	0.89	1.00
$\delta = 0$	0.00	**0.70**	0.50	-0.38	0.94	0.86	1.02

These monthly simulation results are not identical to the quarterly simulations, but they are very similar and economically no different.

We argued above that our timing assumption makes it necessary to calibrate δ to the gross rather than the net separation probability. But as the time period becomes shorter enough, the difference decreases. Therefore, to further explore the robustness of our results, we also simulated a version of our model with a timing assumption that is more common in the labour search literature, which we can calibrate to the net separation probabilities. In the modified model, equation (6) is replaced by,

$$N_t = (1 - \delta)(N_{t-1} + H_t) \tag{60}$$

which changes first-order condition (13) to $g'(H_t) = (1-\delta) S_t^F$ and therefore equilibrium condition (18) to $g'(H_t) = (1-\delta)\left(W_t^{UB} - W_t\right)$. Simulating this model at the monthly frequency, we calibrate δ to 0.04 and 0.02 in the pre-84 and post-85 periods, and again recalibrate κ to match 3% of output going to hiring costs in the pre-84 period.

	frictions (% GDP)	empl/pop ratio $\bar{N}$	correlation productivity with output	with empl	relative std.dev. empl n_t	wage w_t	std.dev. output y_t
$\delta = 0.04$ (Pre)	**3.00**	0.55	0.83	0.12	0.56	0.90	0.95
$\delta = 0.02$ (Post)	0.74	0.66	0.68	-0.20	0.75	0.91	0.96
$\delta = 0$	0.00	**0.70**	0.54	-0.36	0.90	0.87	0.99

The results are again very similar, even though in this case not only the calibration target for the separation probability, but also the model equations are different.

What makes our results robust to small modifications in the calibration or the model specification, is that we always recalibrate κ to match the target that hiring costs are 3% of output in the pre-84 period. This calibration target, in combination with the convexity of the hiring cost function, guarantees that the reduction in hiring frictions between the pre-84 and post-85 period is always similar, regardless of the model frequency or the calibration targets for the separation probability. By extension, if we were to use different numbers for the monthly transition probabilities, e.g. if we were to set $f_m = 0.25$ instead of 0.45 to reflect that the non-employment state includes non-participants as well as unemployed workers, as a referee has suggested, we would again find very similar results.

G Robustness Analysis: Additional Simulation Results

Table 9. Simulation results, less convex adjustment costs ($1+\mu = 1.6$)

	frictions (% GDP)	empl/pop ratio $\bar{N}$	correlation productivity with output	with empl	relative std.dev. empl n_t	wage w_t	std.dev. output y_t
Data							
Pre-84			0.78	0.29	0.66	0.30	
Post-84			0.50	−0.13	0.87	0.88	
Model							
$\delta = 0.40$	3.60	0.60	0.76	−0.05	0.65	0.89	1.01
$\delta = 0.35$ (Pre)	**3.00**	0.62	0.75	−0.09	**0.66**	0.90	**1.00**
$\delta = 0.30$	2.42	0.63	0.74	−0.13	0.67	0.90	1.00
$\delta = 0.25$	1.86	0.65	0.73	−0.17	0.69	0.91	0.99
$\delta = 0.20$ (Post)	1.33	0.66	0.72	−0.20	0.70	0.91	0.99
$\delta = 0.15$	0.86	0.68	0.72	−0.23	0.72	0.91	0.99
$\delta = 0$	0.00	**0.70**	0.74	−0.26	0.70	0.93	0.96

Table 10. Simulation results, less convex adjustment costs (quadratic)

	frictions (% GDP)	empl/pop ratio $\bar{N}$	correlation productivity with output	with empl	relative std.dev. empl n_t	wage w_t	std.dev. output y_t
Data							
Pre-84			0.78	0.29	0.66	0.30	
Post-84			0.50	-0.13	0.87	0.88	
Model							
$\delta = 0.40$	3.66	0.57	0.78	0.02	0.63	0.88	1.01
$\delta = 0.35$ (Pre)	**3.00**	0.59	0.75	-0.05	**0.66**	0.88	**1.00**
$\delta = 0.30$	2.35	0.61	0.73	-0.11	0.69	0.89	1.00
$\delta = 0.25$	1.73	0.64	0.71	-0.16	0.72	0.89	1.00
$\delta = 0.20$ (Post)	1.16	0.66	0.68	-0.21	0.75	0.90	0.99
$\delta = 0.15$	0.68	0.67	0.66	-0.25	0.77	0.90	0.99
$\delta = 0$	0.00	**0.70**	0.66	-0.25	0.77	0.90	0.99

Table 11. Simulation results, more convex adjustment costs ($1 + \mu = 3.4$)

	frictions (% GDP)	empl/pop ratio $\bar{N}$	correlation productivity with output	correlation productivity with empl	relative std.dev. empl n_t	relative std.dev. wage w_t	std.dev. output y_t
Data							
Pre-84			0.78	0.29	0.66	0.30	
Post-84			0.50	−0.13	0.87	0.88	
Model							
$\delta = 0.40$	3.62	0.45	0.82	0.24	0.59	0.87	0.99
$\delta = 0.35$ (Pre)	**3.00**	0.50	0.75	0.12	**0.66**	0.88	**1.00**
$\delta = 0.30$	2.31	0.54	0.67	−0.02	0.75	0.87	1.02
$\delta = 0.25$	1.60	0.59	0.55	−0.17	0.85	0.86	1.05
$\delta = 0.20$ (Post)	0.93	0.64	0.41	−0.31	0.96	0.83	1.09
$\delta = 0.15$	0.41	0.67	0.28	−0.42	1.06	0.80	1.13
$\delta = 0$	0.00	**0.70**	0.09	−0.55	1.19	0.74	1.20

Table 12. Simulation results (quadratic adjustment costs), asymmetric Nash bargaining

	frictions (% GDP)	empl/pop ratio $\bar{N}$	correlation productivity with output	with empl	relative std.dev. empl n_t	wage w_t	std.dev. output y_t
Data							
Pre-84			0.78	0.29	0.66	0.30	
Post-84			0.50	−0.13	0.87	0.88	
Model, $\xi = 0.2$							
$\delta = 0.40$	3.77	0.62	0.77	−0.09	0.64	0.97	1.01
$\delta = 0.35$ (Pre)	**3.00**	0.64	0.76	−0.13	**0.66**	0.96	**1.00**
$\delta = 0.30$	2.28	0.65	0.74	−0.17	0.68	0.95	1.00
$\delta = 0.25$	1.64	0.67	0.73	−0.20	0.70	0.94	1.00
$\delta = 0.20$ (Post)	1.08	0.68	0.72	−0.23	0.71	0.94	1.00
$\delta = 0.15$	0.62	0.69	0.71	−0.25	0.73	0.93	0.99
$\delta = 0$	0.00	**0.70**	0.70	−0.28	0.75	0.92	0.99
Model, $\xi = 0.7$							
$\delta = 0.40$	3.51	0.47	0.79	0.19	0.63	0.76	1.00
$\delta = 0.35$ (Pre)	**3.00**	0.50	0.76	0.10	**0.66**	0.77	**1.00**
$\delta = 0.30$	2.45	0.54	0.72	0.00	0.70	0.79	1.00
$\delta = 0.25$	1.89	0.58	0.67	−0.09	0.74	0.81	1.00
$\delta = 0.20$ (Post)	1.33	0.61	0.63	−0.18	0.79	0.82	1.00
$\delta = 0.15$	0.81	0.65	0.58	−0.25	0.84	0.83	1.00
$\delta = 0$	0.00	**0.70**	0.51	−0.37	0.93	0.85	1.00

Here, we use the following expression for the flexible wage instead of equation (21)

$$W_t^* = \xi W_t^{UB} + (1-\xi)\, W_t^{LB}$$

where ξ is workers bargaining power. We use values for ξ that are well out of the range of values that are commonly used in the literature, to show that this parameter is not important for our results.

Table 13. Simulation results (quadratic adjustment costs), Frisch elasticity 0.25

	frictions (% GDP)	empl/pop ratio $\bar{N}$	correlation productivity with output	with empl	relative std.dev. empl n_t	wage w_t	std.dev. output y_t
Data							
Pre-84			0.78	0.29	0.66	0.30	
Post-84			0.51	−0.11	0.87	0.88	
Model							
$\delta = 0.40$	3.76	0.64	0.77	−0.07	0.64	0.96	1.00
$\delta = 0.35$ (Pre)	**3.00**	0.65	0.75	−0.12	**0.66**	0.96	**1.00**
$\delta = 0.30$	2.29	0.66	0.74	−0.16	0.68	0.95	1.00
$\delta = 0.25$	1.64	0.67	0.73	−0.19	0.70	0.94	1.00
$\delta = 0.20$ (Post)	1.07	0.68	0.72	−0.22	0.71	0.93	1.00
$\delta = 0.15$	0.62	0.69	0.71	−0.25	0.72	0.93	1.00
$\delta = 0$	0.00	**0.70**	0.70	−0.28	0.74	0.91	1.00

Chetty, Guren, Manoli, and Weber (2012) argue based on estimates from micro-data that the Frisch elasticity of labour supply along the extensive margin is around 0.25. In our baseline specification, we use a utility function that is linear in labour supply, which amounts to a Frisch elasticity of infinity. To explore the robustness of our results, we change utility function (1),

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

where $\theta = 0$ corresponds to our baseline specification and $\theta = 4$ to a Frisch elasticity of 0.25. This change affects the efficiency condition for effort (11) and the Bellman equation for worker surplus (17) and therefore the expression for the lower bound of the bargaining set (20). In both cases, the change amounts to replacing the MRS between consumption and leisure from $\frac{Z_t}{\gamma C_t^{\eta}}$ to $\frac{Z_t}{\gamma C_t^{\eta} L_t^{\theta}}$, where $L_t = \frac{1+\zeta \mathcal{E}_t^{1+\phi}}{1+\zeta} N_t$ is total effective labour supply. The results below are for $\theta = 4$ (and the other parameters recalibrated as appropriate). Results are very similar to the baseline calibration.