The Vanishing Procyclicality of Labor Productivity*

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Abstract

We document two changes in postwar US macroeconomic dynamics: the procyclicality of labor productivity vanished, and the relative volatility of employment rose. We propose an explanation for these changes that is based on the decline in labor market turnover, which reduced hiring frictions. We develop a simple model with hiring frictions and variable effort to illustrate the mechanisms underlying our explanation. We show that the decline in turnover can qualitatively and quantitatively match the observed changes in business cycle dynamics.

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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 labor productivity with output or labor input has declined, by some measures dramatically so.[1] Second, the volatility of labor input measures has increased (relative to that of output).[2] We seek to investigate the hypothesis that these changes may be driven by the decline in labor market turnover in the US over this period, which reduced hiring frictions and allowed firms to adjust their labor force more easily in response to various kinds of shocks. In order to illustrate the mechanism behind this explanation, we develop a stylized model of fluctuations with labor market frictions and investigate how its predictions vary with the level of labor market turnover.

The decline in labor market turnover in the US is well documented, among others by Davis, Faberman, and Haltiwanger (2006), Davis (2008), Fallick and Fleischman (2004), Mukoyama and Şahin (2009), Faberman (2008), Davis, Faberman, Haltiwanger, Jarmin, and Miranda (2010), Davis, Faberman, and Haltiwanger (2012), Lazear and Spletzer (2012), Fujita (2011), Cairó and Cajner (2014), Cairó (2013) and Hyatt and Spletzer (2013), see Cairó and Cajner (2014) for an overview of this literature. In this paper, we explore the implications of this decline for business cycle dynamics. Our argument does not depend on the source of the decline in turnover and we leave this interesting question aside.[3] We model the decrease in labor market turnover as a decline in the employment outflow probability or separation rate, which – as in much of the literature – is exogenous in our model. In response to the decline in turnover labor market frictions decrease *endogenously*. This effect arises because adjustment costs in employment in our model are convex, a relatively uncontroversial assumption. We show that the observed decline in turnover is sufficient to quantitatively generate the reduction in frictions needed to explain the changes in labor market dynamics.

The main intuition for our qualitative results is easy to describe. The idea goes back to a literature, starting with Oi (1962) and Solow (1964), which attributes the

[1] As far as we know, Stiroh (2009) was the first to provide evidence of a decline in the labor 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] Recent papers have argued the decline is a result of decreased business volatility (Davis, Faberman, Haltiwanger, Jarmin, and Miranda (2010)), decreased job security (Fujita (2011)) or increased specificity of human capital (Cairó (2013)).

procyclicality of productivity to variations in effort, resulting in seemingly increasing returns to labor.[4] Suppose that firms have two margins for adjusting their effective labor input: (observed) employment and (unobserved) effort, which we respectively denote (in logs) by n_t and e_t.[5] Labor input (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 labor.

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

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

Labor market frictions make it costly to adjust employment n_t. Since these adjustment costs are convex, frictions are higher when the average level of hiring is higher. Effort e_t provides an alternative margin of adjustment of labor 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 labor 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.

The remainder of the paper is organized as follows. Section 2 documents the changes in the patterns of fluctuations in labor 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 Labor Market Dynamics

We document two stylized facts regarding postwar changes in US economic fluctuations. The changes that motivate our investigation pertain to the cyclical behavior of labor productivity and labor input. None of the facts we report are new. However, and to the best of our knowledge, this paper is the first to provide an explanation for these

[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.

changes.

We use quarterly time series for output and labor input over the period 1948:1-2015:4 from the BLS Labor Productivity and Cost (LPC) program, and calculate labor productivity as the ratio between output and labor input. 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-84 (1985:1-2015:4). The break date is chosen to be halfway the decade, in which the decline in labor market turnover started, and roughly halfway between the 1981-82 and 1990-91 recessions.[6] This choice is fairly arbitrary, and we do not make any claims about the specific timing of the various changes in labor 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 smoothing parameter 1600.

2.1 The Vanishing Procyclicality of Labor Productivity

Figure 1 shows the fluctuations at business cycle frequencies in labor 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 formalized in Table 1, which reports the contemporaneous correlation between labor productivity and output and employment, for alternative transformations and time periods. In each case, we report the estimated correlation for the pre and post-84 subsamples, as well as the difference between those estimates. The standard errors, reported in brackets, are computed using the delta method.[7] We now turn to a short discussion of the results in this Table.

[6] The decline in the separation rate seems to start immediately after the 1981-82 recession, see e.g. Figure 1 in Cairó and Cajner (2014). However, we are reluctant to split the sample right at the end of a recession.

[7] 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.

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 0.60. In other words, in the early part of the sample labor productivity was clearly procyclical.

In the post-84 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 significant. Thus, on the basis of those estimates labor productivity has become an acyclical variable (with respect to output) over the past two decades.

When we use an employment-based measure of labor productivity, output per worker, the estimated correlations also drop substantially but remain significantly greater than zero in the post-84 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 labor productivity has increased considerably.[8]

2.1.2 Correlation with Labor Input

The right-hand side panels in Table 1 display several estimates of the correlation between labor productivity and labor input. The estimates for the pre-84 period are low, but still significantly greater than zero. Thus, labor productivity was procyclical with respect to labor input in that subperiod, but much less so that 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.[9]

As was the case when using output as the cyclical indicator, the estimated correlations between labor productivity and employment decline dramatically in the post-84 period. In fact these correlations become significantly negative, with a point estimate ranging from -0.60 to -0.77 for output per hour and from -0.40 to -0.53 for output per worker, depending on the filter. The change with respect to the pre-84 period is highly significant. In other words, labor productivity in the past two decades has become strongly countercyclical with respect to labor input.

[8] 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 labor 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. $\rho(h-n,y) > 0$.

[9] 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 labor productivity and hours were -0.20 when using household data and 0.16 using establishment data.

2.2 The Rising Relative Volatility of Labor Input

The left-hand panel of Table 2 displays the standard deviation of several measures of labor input in the pre and post-84 periods, as well as the ratio between the two. The variables considered include employment in the private sector, hours in the private sector (employment times hours per worker) and economy-wide hours. 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 35% and 49% and always significantly so.

A more interesting piece of evidence is the change in the *relative* volatility of labor input, measured as the ratio of the standard deviation of labor input to the standard deviation of output. These estimates are presented in the right-hand panel of Table 2. Without exception, all labor input measures have experienced an increase in their relative volatility in the post versus pre-84 period. In other words, the decline in the variability of labor input has been less pronounced than that of output. The increase in the relative volatility of hours worked ranges from 30% to 48% in the private sector and from 7% to 30% in the total economy. The corresponding increase for employment is slightly smaller, ranging from 23% to 43% in the private sector, but is still statistically significant.

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

2.3 Conclusions

Summarizing, we showed that labor productivity in the US became less procyclical or acyclical with respect to output, and 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 labor productivity increased, and the correlation between employment and output decreased slightly, see appendix A.[10]

These changes in business cycle dynamics, roughly coincided with the decline in labor market turnover. The strong decline in labor market turnover appears to be specific to the US, and there is no evidence for a similar reversal of the cyclicality of labor productivity in other countries, see appendix B.

From the vantage point of the early 80s – the period when the seminal contributions to RBC theory were written – the procyclicality of labor 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 labor input in these models was lower than in the data, which posed one

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

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 labor input increased even further and productivity is barely procyclical anymore. A possible reason is that over time non-technology shocks became more important drivers of business cycles, as Barnichon (2010) argues. However, this does not explain why similar changes in dynamics are observed also when conditioning on particular shocks, as in Galí and Gambetti (2009).

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 labor market. We show that the vanishing procyclicality of labor productivity and the increasing relative volatility of employment can be explained by the decline in labor market turnover, which resulted in a reduction in hiring costs.

3 A Model of Fluctuations with Labor Market Frictions and Endogenous Effort

Having documented in some detail the changing patterns of labor productivity and labor 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 the decline in labor market turnover.

To formalize this explanation, we develop a model of fluctuations with labor 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 labor 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 emphasized 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 recognize 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.[11]

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 labor supply. Each household member's utility function is additively separable in consumption and leisure, and the household assigns equal consumption C_t

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

to all members in order to share consumption risk within the household. Thus, the household's objective function is given by,[12]

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

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 labor 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 labor input adjustment to changes in effort.

The household maximizes 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.

3.2 Firms

Firms produce a homogenous consumption good using a production technology that uses labor and effort as inputs,

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

[12] We assume utility is linear in effective labor for simplicity. The implication that the Frisch elasticity of labor 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).

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 labor 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 normalize 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 maximize the expected discounted value of profits,

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

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

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

where δ is the gross separation rate (employment exit probability) and $Q_{0,t}$ is the stochastic discount factor for future profits. 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.[13] 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 labor supply and

[13] 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.

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,

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

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,[14]

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

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,

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

[14] 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).

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

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

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

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

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 labor market.[15] 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

[15] Specifically, the within-period timing we assume is the following. First, aggregate shocks realize 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 realized.

of effort. This marginal disutility of employment, expressed in terms of consumption, is given by,[16]

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

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.

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

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

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

Nash bargaining assumes that the wage is set such that the total surplus from the match is split in equal proportions between household and firm.[17] It is straightforward to see that in our framework, $S_t^H = \frac{1}{2}\left(S_t^H + S_t^F\right) = \frac{1}{2}\left(W_t^{UB} - W_t^{LB}\right)$, so that

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

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

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

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

3.5 Equilibrium

We conclude the description of the model by listing the conditions that characterize the equilibrium. The equilibrium level of effort is determined by efficiency condition (11). Vacancy posting decisions by firms are summarized 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.

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

Output is defined as in production function (4), the stochastic discount factor as the marginal rate of intertemporal substitution (7), and the parameters $\Psi_F = \frac{\alpha\psi}{1+\phi-(1-\alpha)\psi}$ and $\Psi_H = \frac{\psi}{1+\phi}\frac{(1-\eta)(1+\phi)-\psi}{1+\phi-\psi}$ are functions of the structural parameters. In total, we have 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 labor market frictions. However, unlike in the standard model, fluctuations in our model are driven by technology shocks as well as non-technology shocks or preference shocks. The two driving forces of fluctuations, log total factor productivity $a_t \equiv \log A_t$ and log preferences over consumption $z_t \equiv \log Z_t$ follow stationary $AR(1)$ processes,

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

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

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

4 Implications of the Decline in Labor Market Turnover

We now proceed to use this model to analyze the possible role of the decline in labor market turnover in generating the observed changes in the cyclical patterns of labor productivity and labor input. Since employment adjustment costs are quadratic, labor market frictions increase with labor market turnover. We therefore start by looking at a version of the model with a frictionless labor 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 for different values of the parameters.

4.1 Frictionless Labor Market

Consider the limiting case of an economy without labor 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

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

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 labor productivity. Using lower-case letters to denote the natural logarithms of the original variables, ignoring constant terms and normalizing the variance of the shocks,[18] 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.[19]

From the previous equations, it is straightforward to calculate the model's implica-

[18] 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 $\Omega = 1/[1-(1-\alpha)(1-\eta)]$.

[19] 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

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

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

In the absence of labor market frictions, labor 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 labor 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:

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

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

4.2 Preview of the Results

We can contrast the predictions of the frictionless model above, with the opposite extreme case of infinitely large labor market frictions, i.e. $g\,(H) = \infty$ if $H > 0$. In this case, no new workers will be hired, so that by the aggregate resource constraint (22) $C_t = Y_t$, as in the frictionless case. For simplicity, also assume that the separation rate equals zero, $\delta = 0$, so that employment is fixed. In this case, combining the production function (4) with the equilibrium condition for effort (11), and taking logarithms, ignoring constant terms and normalizing the variance of the shocks,[20] 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 labor input occurs on the intensive margin. With an infinitely large separation rate, labor 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.

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

Comparing the predictions of the model with very high turnover and therefore very large labor 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 sufficienly large decline in labor market turnover:

1. Labor productivity becomes less procyclical with respect to output.
2. Labor 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 labor market turnover fell so much that labor market frictions went from infinity to zero. Rather, the argument so far is meant to illustrate that if the decline in labor market turnover was large enough, it can qualitatively explain the patterns we observe in the data. To answer the question whether we can also quantitatively match those patterns for reasonable parameter values, we now turn to a numerical analysis of the full model.

4.3 Calibration

We simulate data at quarterly frequency and calibrate accordingly. The calibration is summarized 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 labor 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 labor 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.[21] We calibrate κ such that 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 (2011), Cairó and Cajner (2014)).[22] 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-84 period.[23] 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

[21] Despite the estimates in Merz and Yashiv (2007), in later work Yashiv (2012) and Faccini, Millard, and Yashiv (2012) favor a less convex specification closer to our benchmark specification. Two important points should be noted here. First, a crucial insight from Merz and Yashiv (2007) and Yashiv (2012) is that it is important to allow for an interaction in adjustment costs in capital and labor in order to get correct estimates for these adjustment costs. We ignore this interaction because our model does not have capital. This should not cause any problems because we are not estimating the model. Second, by assuming adjustment costs are convex, we are ruling out a large class of adjustment cost functions. This assumption is justified by various studies that find that, while non-convexities are important at the plant level, convex adjustment costs provide a good approximation for the aggregate dynamics for capital (Cooper and Haltiwanger (2006), Khan and Thomas (2008)) and employment (Cooper and Willis (2004)).

[22] The estimates in Fujita (2011) differ from those in Davis, Faberman, Haltiwanger, Jarmin, and Miranda (2010) and Cairó and Cajner (2014) because Fujita calculates worker flows from matching the labor 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.

[23] 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 $\delta = s / (1 - f) = 0.35$.

result in the unemployment volatility puzzle. The second target is arbitrarily chosen to emphasize that we consider this model mostly illustrative and not able to generate realistic predictions for the overall level of volatility in the economy.

For the parameters related to effort, we have very little guidance from previous literature. We normalize $\phi = 0$ 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 separation rate.

4.4 Simulation 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 labor market turnover of the same size as observed in the US, roughly matches the change in the cyclicality of labor productivity and the relative volatility of labor 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.

Labor productivity is strongly procyclical in terms of its correlation with output in the model and its procyclicality falls substantially as we reduce labor market turnover. The correlation of productivity with employment also falls, from around zero in the labor 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 D.

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 labor market turnover. Second, the effort choice provides an intensive margin of adjustment for labor input. As frictions fall, it becomes optimal to adjust labor more through employment and less through effort. Thus, the volatility of employment increases more than that of output. Note that the model also predicts that the volatility of effort falls, but this predictions is not testable without observable measures of effort.[24]

[24] Some authors have used hours per worker as an observable proxy for effort, see e.g. Basu, Fernald,

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 labor supply shocks. In a one-shock model, the correlations between all variables would be close to either 1 or -1.[25] 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 labor 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.

5 Conclusions

In this paper, we documented two changes in labor market dynamics over the postwar period in the US: the strong procyclicality of labor productivity has vanished, and the volatility of employment has increased with respect to output. We presented a model to argue that the decline in labor market turnover, modelled as a reduction in the employment exit probability, can explain these changes.

The intuition for why a decline in labor market turnover increases the relative volatility of employment and reduces the procyclicality of labor 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 labor, 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 labor and output – and therefore labor productivity – has changed almost unavoidably leads to the conclusion that there must be another input into the production process.

and Kimball (2006). However, the crucial characteristic of the effort margin in our model is that it is not subject to adjustment costs, or at least that adjusting this margin is less costly than adjusting along the extensive margin. It is not clear that adjusting work hours is costless. In fact, van Rens (2012) argues that adjustment costs in hours per worker may be larger rather than smaller than adjustment costs in employment in OECD countries.

[25] 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.

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Table 1. The Vanishing Procyclicality of Labor Productivity

	Corr with output			Corr with labor input		
	Pre-84	Post-84	Change	Pre-84	Post-84	Change
Output per hour						
BP	0.63	0.07	−0.55	0.23	−0.41	−0.64
	[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	−0.72	0.21	−0.55	−0.77
	[0.05]	[0.09]	[0.10]	[0.07]	[0.07]	[0.10]
Output per worker						
BP	0.78	0.51	−0.27	0.29	−0.11	−0.39
	[0.03]	[0.07]	[0.07]	[0.08]	[0.09]	[0.12]
4D	0.77	0.44	−0.33	0.19	−0.20	−0.40
	[0.03]	[0.08]	[0.08]	[0.07]	[0.12]	[0.14]
HP	0.77	0.32	−0.45	0.24	−0.29	−0.53
	[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 labor productivity and cost program (LPC) and refer to the private sector (non-farm business sector). Labor input is total hours worked in the first panel and employment in the second panel, consistent with the definition of labor productivity. The sample period is 1948-2015.

Table 2. The Rising Volatility of Labor Input

	Std. Dev.			Relative Std. Dev.		
	Pre-84	Post-84	Ratio	Pre-84	Post-84	Ratio
Hours (private sector)						
BP	2.02	1.52	0.75	0.80	1.09	1.37
	[0.10]	[0.09]	[0.06]	[0.03]	[0.04]	[0.07]
4D	3.05	2.43	0.80	0.77	1.08	1.40
	[0.16]	[0.27]	[0.10]	[0.03]	[0.06]	[0.10]
HP	2.04	1.76	0.86	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	1.32
	[0.08]	[0.07]	[0.06]	[0.03]	[0.05]	[0.09]
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	0.99	1.50
	[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 labor 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

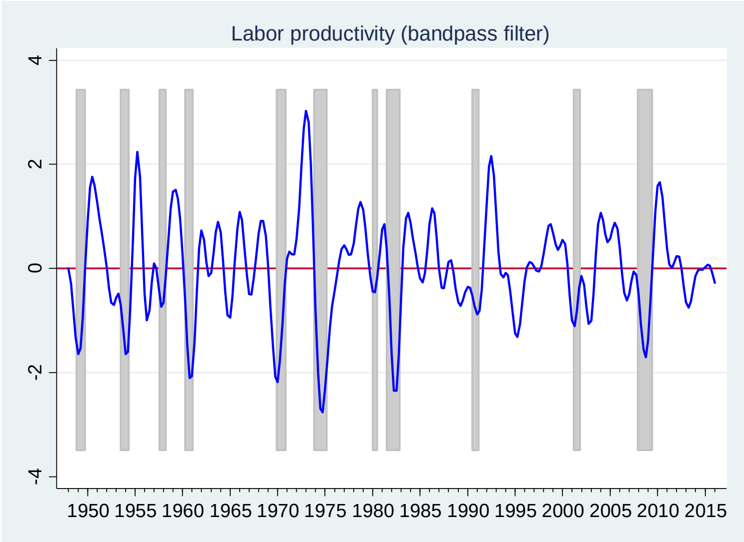
	Parameter	Target
Utility:	$\beta = 0.99$	quarterly data
	$\eta = 1$	log utility over consumption
	$\gamma = 1.24$	frictionless employment population ratio $\bar{N} = 0.7$
Production:	$f(N) = N^{1-\alpha}$, $\alpha = 1/3$	capital share
Effort:	$\zeta = 0.299$	normalization: frictionless $\overline{\mathcal{E}} = 1$
	$\phi = 0$	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: $\text{sd}(y) = 1\%$
	$\rho_z = 0.97$, $\sigma_z = 0.173$	$\text{sd}(n)/\text{sd}(y) = 0.66$

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	0.31	0.66	0.30	
Post-84			0.60	−0.15	0.81	0.88	
Model							
$\delta = 0.40$	3.69	0.52	0.79	0.12	0.62	0.86	1.00
$\delta = 0.35$ (Pre)	**3.00**	0.57	0.75	0.03	**0.66**	0.86	**1.00**
$\delta = 0.30$	2.30	0.59	0.71	−0.07	0.71	0.86	1.00
$\delta = 0.25$	1.63	0.62	0.66	−0.15	0.76	0.86	1.00
$\delta = 0.20$ (Post)	1.02	0.65	0.61	−0.22	0.81	0.86	1.01
$\delta = 0.15$	0.53	0.67	0.57	−0.28	0.86	0.85	1.02
$\delta = 0$	0.00	**0.70**	0.48	−0.37	0.94	0.83	1.04

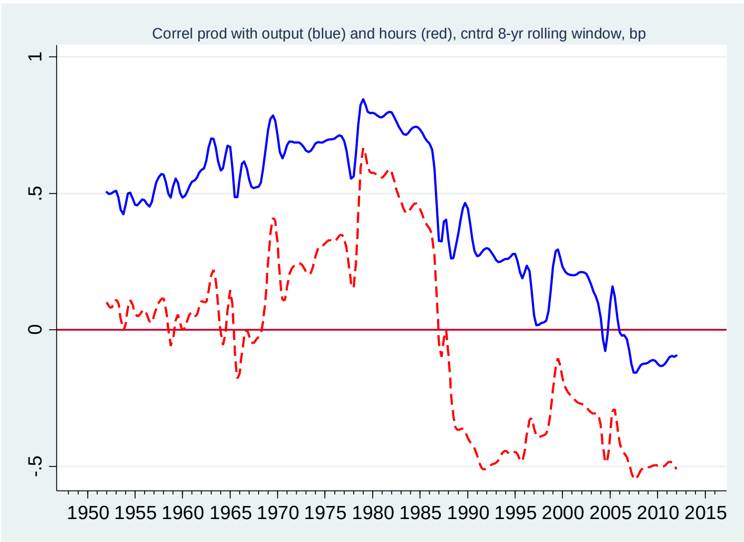
Moments for the model are based on simulated time series of 200,000 quarters. We simulate the model for 201,000 quarters but ignore the first 1,000 quarters to eliminate the effect of the initial conditions. Numbers in bold are calibration targets.

Figure 1. The Vanishing Procyclicality of Labor Productivity



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

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



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