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PERFORMANCE PAY AND SHIFTS IN MACROECONOMIC CORRELATIONS

by Francesco Nucci* and Marianna Riggi+

Abstract

A coincidence in time between the volatility break associated with the "Great Moderation" and large changes in the pattern of conditional and unconditional correlations between output, hours and labor productivity was detected by Galí and Gambetti (2009). We provide a novel explanation for these findings, based on the major changes that occurred in the U.S. design of labor compensation around the mid-1980s. These include a substantial increase in the incidence of performance pay coupled with a higher responsiveness of real wages to the business cycle. We capture this shift in the structure of labor compensation in a Dynamic New Keynesian (DNK) model and show that, by itself, it generates the disappearance of the procyclical response of labor productivity to non-technology shocks and a reduction of the contractionary effects of technology shocks on hours worked. Moreover, it accounts for a large share of the observed drop in output volatility after 1984 and for most of the observed changes in unconditional correlations.

JEL Classification: E24, E32, J3, J22.
Keywords: procyclical productivity, wage rigidities, performance pay.

Contents

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1 Introduction[1]

Substantial changes in the correlation structure of U.S. macroeconomic series accompanied the downward shift in the volatility of output in the mid-1980s, which has been described as "the Great Moderation".[2] Galí and Gambetti (GG hereafter) (2009) estimate a structural vector autoregression (SVAR) with time-varying coefficients and provide evidence of a significant shift in the patterns of unconditional and conditional comovements among output, hours, and labor productivity as well as in the impulse responses to identified shocks.

Whether the volatility break and the large changes in the pattern of conditional and unconditional second moments experienced by the U.S. economy have a common underlying explanation is an open question. In this paper, we claim that some relevant developments in the design of labor compensation represent the common source of the drop in output volatility and the shift in the structure of conditional and unconditional correlations between output, hours and labor productivity.

The literature documents two major changes in the US wage setting at around mid-80s. The first one is an overall reduction in the degree of real wage rigidities. For instance, Blanchard and Galí (2007b) and Blanchard and Riggi (2009) emphasize the role of increased wage flexibility in accounting for the decrease in the macroeconomic effects of oil shocks. And Galí and van Rens (2010) detect a notable rise in the volatility of the real wage characterizing post-war U.S. dynamics, which contrasts with the parallel decline in output volatility.

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[2]The Great Moderation was first documented by Kim and Nelson (1999) and McConnell and Perez-Quiros (2000), who estimate a break year of 1984 for the volatility of US GDP. An overview of the evidence and its explanations is provided by Blanchard and Simon (2001) and Stock of Watson (2002), who emphasize that the decline in volatility was experienced also in the other G7 countries.

The second striking fact is the substantial increase of firms' reliance on pay-for-performance mechanisms after the early 1980s. Lemieux et al. (2009), for example, using data from the Panel Study of Income Dynamics (PSID), document that the incidence of performance-pay jobs among salaried workers has risen from about 30 percent in the late 1970s to nearly 50 percent in the late 1990s. Moreover, on the basis of an annual survey of Fortune 1000 corporations, they calculate that the fraction of workers with some forms of performance-pay increased from 20.7 percent in 1987 to 44.5 percent in 2002. Mitchell et al. (1990) point to a significant shift towards adoption of incentive pay plans in the 1980s, after a period following the end of World War II to 1979 which was characterized by a decline in their use[3]. Importantly, the growing reliance on these compensation schemes has affected workers in general (Prendergast, 1999) and the increased share of performance-related pay in workers average earnings is associated with an increase in the estimated performance-pay sensitivity.[4]

We argue that the increased flexibility of real wages associated with a higher proportion of performance-related pay in workers average earnings may account for most of the results uncovered by GG (2009). We demonstrate this claim through a Dynamic New Keynesian (DNK) model which includes work effort as an additional dimension of firms' and households' choices. Using stochastic simulations, we find that, on its own, this shift in the design of workers pay yields the following implications:

- A vanishing procyclical response of labor productivity to non-technology shocks.

- A shrinking contractionary effects on hours worked of positive technol-

[3]Similarly, Hall and Liebman (1998) show that the responsiveness of pay to performance for chief executive officers increased after the early 1980s. Jensen and Murphy (1990) estimate low pay-performance sensitivity for top executives in the 1970s to the mid 1980s.

[4]Cuñat and Guadalupe (2005 and 2008) show that the increased responsiveness of pay to performance originates from the trend towards increased product market competition, that induced firms to re-shape the structure of the incentives to reward workers, making performance-related pay schemes more pervasive. Another explanation for the higher incidence of these pay systems is based on the extensive development of performance appraisal systems, due to progress in information and monitoring technologies which provided improved worker performance measures. Lemieux et al. (2009) discuss these advances and point to the extraordinary expansion over the last 30 years of consulting companies specializing in compensation.

ogy shocks.

- A dramatic decline in the procyclicality of labor productivity measured by a notable drop in the unconditional correlation between labor productivity and output as well as by a sign switch in the unconditional correlation with hours, from positive to large negative values.

- A sizeable drop in output volatility, i.e. a great part of the "Great Moderation".

These predictions closely correspond to the empirical findings of GG (2009) on the shift in the structure of conditional and unconditional second moments of U.S. macroeconomic series between the pre-1984 period and the post-1984 period.

By contrast, we show that if the higher wage responsiveness to the business cycle had been associated with a lower relative share of performance pay in workers average earnings, the changes in the patterns of conditional and unconditional correlations would have been exactly the opposite to those reported by GG (2009) in their empirical analysis.

We also investigate whether a structural change in the labor market through a generalized fall in the adjustment costs of labor, rather than through a change in the design of compensation, is conducive in our model to shifts in the pattern of comovements that resemble the empirical ones.[5] We show that while it may explain the lower procyclicality of labor productivity, it yields predictions that are at odds with the observed changes in the hours response to technology shocks. Of course, we do not rule out the potential relevance of this and other alternative explanations of the Great Moderation. However, our paper emphasizes that the developments occurred in the design of labor compensation, leading to a higher relevance of performance-related pay in the cyclical fluctuations of wages, have played a key role in explaining the enhanced macroeconomic stability and the parallel shift in the structure of macroeconomic correlations.

The paper is organized as follows. Section 1 provides evidence on the large changes in the structure of the correlations among output, hours and productivity associated with the Great Moderation. Section 2 presents the theoretical model. Section 3 discusses the implications of the change in the structure

[5] This interpretation is suggested by Barnichon (2007), Galí and van Rens (2010) and GG (2009).

of labor compensation for the impulse responses to identified shocks, for the comovements among output, hours and labor productivity and for output volatility. Section 4 analyzes the macroeconomic consequences of a drop in labor adjustment costs and Section 5 concludes.

2 The Anatomy of the Great Moderation

GG (2008) analyze the correlation structure of U.S. output, labor productivity and hours over the Post-WWII period, and document a dramatic shift in the patterns of conditional and unconditional second moments of these macroeconomic series with the onset of the Great Moderation. Most of their evidence is obtained by estimating a SVAR with time-varying coefficients and stochastic volatility. The model is bivariate and includes (first differences of the logarithm of) labor productivity and (the log level of) hours per capita. Technology shocks are identified using long-run restrictions as in Galí (1999): the unit root in labor productivity originates uniquely in technology innovations so that only the latter have permanent effects on productivity. A number of empirical findings arise from their analysis and the major ones are the following.

Changes in conditional correlations The correlation of labor productivity with both output and hours *conditional* on technology and non - technology shocks shows large changes since the mid-1980s which are reflected in the impulse responses to identified shocks and can be summarized in two empirical results.

First, while in the pre-Great Moderation period labor productivity responds positively and significantly to non-technological innovations, displaying a pro-cyclical profile, in the more recent sub-period the response of labor productivity is negative and labor productivity becomes countercyclical conditional on non - technology shocks. Second, in the pre-Great Moderation period the effect of a technology shock on hours is negative and significant, while in the post-1984 period the effect, albeit still negative, is smaller (in absolute value) and almost reaching zero[6]. Figures 1a and 1b summarize

[6] The effect on impact of technology shocks on labor input is a rather controversial issue in the literature. On empirical ground, Galí (1999) and Basu et al. (2006), among many others, document a negative correlation between labor productivity and hours conditional on technology shocks. They use different identification methods: long run restrictions

the bulk of this evidence. The first panel deals with the average responses of labor productivity to a non-technology shock in the pre-1984 and post-1984 periods. The second panel documents the average responses of hours to technology shocks in the two periods.

Changes in unconditional correlations As for the changes in unconditional correlations, GG (2009) use Band-Pass (BP) filtered data and report a dramatic fall in the cyclical behavior of labor productivity. The unconditional correlation between labor productivity and output becomes close to zero in the post-84 sample period while it was 0.61 in the pre-84 period. By using hours worked as the cyclical indicator, labor productivity becomes a countercyclical variable as the unconditional correlation between labor productivity and hours changes from 0.18 to -0.46. Consistently with GG, Barnichon (2007) finds that the sign of the correlation between cyclical unemployment and the cyclical component of labor productivity switched in the mid-80s: from negative it became positive. Stiroh (2009) confirms that the increased output stability in the US reflects a significant decline in the correlation between labor productivity growth and hours growth.

Changes in volatility As for the changes in unconditional volatilities, GG document that the standard deviation of output drops from 2.59 in the pre-84 period to 1.23 in the post-84 period and that the decline in the standard deviation of hours and labor productivity is not as large as that experienced by output. On the other hand, Galí and van Rens (2010) find

in the former case, a direct measure of technology change derived through a growth accounting approach in the latter case. The finding of a contractionary effect of technology improvements has been questioned along several dimensions. Christiano et al. (2003) argue that it originates from a specification error due to over-differencing of hours worked: if hours (per capita) are assumed to be a stationary variable and their level is used in the VAR analysis, then hours worked would rise, rather than fall, in the aftermath of a technology improvement. Chari et. al (2008) take the stand that Galí's (1999) result is potentially flawed by small-sample bias. In response to these criticisms, Fernald (2007) shows that once one allows for (statistically and economically plausible) trend breaks in productivity, the treatment of hours is relatively unimportant and hours fall sharply on impact following a technology improvement. Francis and Ramey (2005) provide arguments supporting the unit root hypothesis for per capita hours. Indeed, the impulse response functions from the model with stationary hours indicate that non-technology shocks have long-lived significant effects on labor productivity contrary to the fundamental identifying assumption.

that the standard deviation of both the product and consumption wages has increased by, respectively, 40 and 10 percent in the post-84 sample compared to the previous sub-period.

The complex picture that emerges from these findings challenges the "good luck" view of the Great Moderation and suggests that the US economy has witnessed more than a mere scaling down of the size of shocks. In what follows, we argue that the increased output stability and the shifts in the pattern of macroeconomic correlations have a common source which is related to the important changes occurred in the structure of labor pay.

3 Theoretical Framework

In this section we develop a DNK model with variable labor effort. Model features can be summarized as follows:

- Given our objectives, we assume that there are two sources of fluctuations in the economy: a technology and a non-technology shock. We characterize the nature of the shocks in accordance with the empirical analysis by GG, whose findings we seek to explain. In particular, we assume that the exogenous productivity factor has a unit root and is thus non-stationary in levels so that a technology shock affects productivity in the long-run. On the contrary, we assume a stationary process for what we call the non-technology shock and characterize it as a preference shock, as in Galí and Van Rens (2010).

- Effective labor input used by firms is a function of hours worked and effort exerted.

- Following Galí (1999), we split labor compensation in two components: the one rewarding hours and the one rewarding performance. Moreover, along the line of Blanchard and Galí (2007a and 2010), we introduce *ad hoc* rigidities in the labor compensation.

- We introduce hours adjustment costs, which, while not needed for the intuition behind our argument, allow us to shed light on how far we can go by assuming a more flexible labor market, which implies a decrease in "labor hoarding", without any changes in the structure of labor compensation.[7]

3.1 Households

We consider a continuum of households uniformly distributed on the unit interval. Household j maximizes

$$\underset{0}{E}\sum_{t=0}^{\infty}\beta^{t}\xi_{t}\left\{U[C_{t}\left(j\right),C_{t-1}]-g[H_{t}\left(j\right),E_{t}\left(j\right)]\right\}, \tag{1}$$

where $C_t(j)$ is household j's consumption in period t of the usual Dixit-Stiglitz aggregate of goods with elasticity of substitution ϵ, C_{t-1} is the aggregate consumption level in period $t-1$, the function $g(.)$ measures the disutility from work, which depends on hours H_t and effort exerted E_t and β is the discount factor; ξ_t is a preference disturbance term with mean unity which follows the stationary first order autoregressive process

$$\log\xi_{t}=\rho_{\xi}\log\xi_{t-1}+\varepsilon_{t}^{\xi}, \tag{2}$$

where ε_t^{ξ} are zero-mean, i.i.d. innovations. We assume a specification of the period utility consistent with the balanced growth path:

$$U[C_{t}\left(j\right),C_{t-1}]\equiv\log[C_{t}\left(j\right)-hC_{t-1}], \tag{3}$$

where $h\in[0,1)$ denotes the degree of external habit formation. Following Bils and Cho (1994) and Barnichon (2007), we assume that the period disutility of labor takes the form:

$$g\left(H_{t}\left(j\right),E_{t}\left(j\right)\right)=\frac{\lambda_{h}}{1+\sigma_{h}}H_{t}^{1+\sigma_{h}}\left(j\right)+H_{t}\left(j\right)\frac{\lambda_{e}}{1+\sigma_{e}}E_{t}^{1+\sigma_{e}}\left(j\right), \tag{4}$$

where λ_h, λ_e, σ_h, and σ_e are positive constants.

The period budget constraint, conditional on the optimal allocation of expenditures among different goods, is given by:

$$P_{t}C_{t}+Q_{t}B_{t}=W_{t}H_{t}+V_{t}E_{t}+B_{t-1}+\Pi_{t}, \tag{5}$$

[7] The presence of labor hoarding is a common explanation for the procyclicality of labor productivity and the ensuing short run increasing returns to labor (SRIRL) puzzle.

where P_t is the price level, Q_t is the price of a one-period nominally riskless bond, paying one unit of money and B_t is the amount of that bond purchased in period t. As in Galí (1999), W_t and V_t represent the nominal prices of one hour's work (nominal hourly wage hereafter) and of a unit of effort, respectively, where the latter represents our measure of performance pay. Π_t denotes the households' profits from ownership of firms.

The optimal consumption/savings and labor supply decisions are described by

$$Q_t = \beta E_t \frac{\xi_{t+1}}{\xi_t} \left(\frac{C_t - hC_{t-1}}{C_{t+1} - hC_t} \right) \frac{P_t}{P_{t+1}} \tag{6}$$

$$W_t^r \equiv \frac{W_t}{P_t} = (C_t - hC_{t-1}) \left(\lambda_h H_t^{\sigma_h} + \frac{\lambda_e}{1+\sigma_e} E_t^{1+\sigma_e} \right) \tag{7}$$

$$V_t^r \equiv \frac{V_t}{P_t} = (C_t - hC_{t-1}) \lambda_e H_t E_t^{\sigma_e}. \tag{8}$$

Equations (7) and (8) are the perfectly competitive hour and effort supply schedules, respectively. We relax the assumption of perfect competition in the labor market along the lines suggested by Blanchard and Galí (2007a, 2007b and 2010), by introducing ad hoc rigidities into the compensation structure, which prevent the cyclical components of both W_t^r and V_t^r from fully adjusting to their competitive counterparts. In particular, let us detrend W_t^r and V_t^r with the non-stationary level of technology, A_t, so that $\widetilde{W}_t^r \equiv \frac{W_t^r}{A_t}$ and $\widetilde{V}_t^r \equiv \frac{V_t^r}{A_t}$ denote the cyclical components of the hourly real wage and the real price of effort, respectively. We then replace equations (7) and (8) with the following hourly wage and performance pay curves, which, together, characterize the structure of labor compensation:

$$\widetilde{W}_t^r = \left[\frac{(C_t - hC_{t-1}) \left(\lambda_h H_t^{\sigma_h} + \frac{\lambda_e}{1+\sigma_e} E_t^{1+\sigma_e} \right)}{A_t} \right]^{1-\gamma_h}, \tag{9}$$

$$\widetilde{V}_t^r = \left[\frac{(C_t - hC_{t-1}) \lambda_e H_t E_t^{\sigma_e}}{A_t} \right]^{1-\gamma_e}, \tag{10}$$

where the parameters γ_e and γ_h measure the sensitivity of worker's pay to the business cycle. The lower are γ_e and γ_h the higher is the responsiveness of labor compensation to economic conditions.

Changing γ_h and γ_e, however, changes both the degree of cyclicality of labor compensation as well as the stationarized steady state values of its two components: $\overline{\widetilde{W^r}}$ and $\overline{\widetilde{V^r}}$. In general, an increase in the flexibility of labor compensation may leave unchanged the shares of performance pay and hourly pay in workers average earnings or, conversely, it may be associated with a change in the relative importance of the two compensation margins in workers average earnings. Indeed, for a given value of γ_h, a decrease in γ_e captures a higher flexibility of labor compensation associated with a higher relevance of performance pay in the cyclical fluctuations of labor compensation, i.e., with a higher share of effort-related pay in worker's average earnings, $\left(\frac{\overline{\widetilde{V^r}}}{\overline{\widetilde{W^r}}+\overline{\widetilde{V^r}}}\right)$. Conversely, for a given value of γ_e, a decrease in γ_h reflects a higher flexibility of labor compensation associated with a higher relevance of hourly pay in the cyclical fluctuations of labor compensation, i.e., with a higher share of hourly pay in worker's average earnings, $\left(\frac{\overline{\widetilde{W^r}}}{\overline{\widetilde{W^r}}+\overline{\widetilde{V^r}}}\right)$. Thus, the parameters γ_e and γ_h affect the degree of responsiveness to economic conditions of the cyclical components of the two remuneration margins as well as their relative shares in workers average earnings.

3.2 Firms

We distinguish between two sectors: retail and wholesale firms. Households are employed by wholesale firms which face convex costs of varying their hours input and operate in a competitive market in relation to the goods they produce. Wholesale firms sell their output to retailers, which are monopolistically competitive and set prices in a staggered fashion, as in Calvo (1983). The separation of the two sectors is a modelling strategy which aims at providing a convenient separation of the two frictions (hours adjustment costs and price stickiness) in the model.

3.2.1 Wholesale firms

Production by wholesale firm j is

$$Y_{jt}^{w} = A_t L_{jt}^{\alpha}, \tag{11}$$

where $\alpha \in (0,1]$ and L_{jt} denotes the *effective* labor input defined as a function of hours and effort:[8]

$$L_{jt} = H_{jt}E_{jt}, \tag{12}$$

and A_t was defined earlier as the productivity factor common across firms. We assume a trending nonstationary process for the technology level, A_t, to be consistent with the identification approach in GG which assumes that only technology shocks have a permanent effect on the level of productivity. Following Altig et al. (2005) and Gertler et al.(2008), we assume that $Z_t \equiv \frac{A_t}{A_{t-1}}$ obeys the following exogenous stochastic process:

$$\log Z_t = (1-\rho_a)\log\gamma_a + \rho_a \log Z_{t-1} + \varepsilon_t^a, \tag{13}$$

where γ_a defines the constant growth rate and ε_t^a is the i.i.d. technology shock.

Each firm j varies its hours input by facing convex costs, which are increasing with the speed of the desired adjustment and are measured in terms of the final good, according to the following adjustment cost function:

$$G_{jt} = \frac{\phi_h}{2}\left(\frac{H_{jt}}{H_{jt-1}} - 1\right)^2 Y_t, \tag{14}$$

where $\phi_h \geq 0$ is the hours' adjustment cost parameter. The adjustment cost function implies that firms have an incentive to make gradual changes to hours which result in an intertemporal smoothing of their demand for hours.

Let Π_{jt} denote firm j' s period t profit. The wholesale firm maximizes

$$E_t \sum_{k=0}^{\infty} \beta^k \frac{\xi_{t+k}}{\xi_t}\left(\frac{C_t - hC_{t-1}}{C_{t+k} - hC_{t+k-1}}\right)\Pi_{jt+k} \tag{15}$$

subject to (11), where $\Pi_{jt} = \frac{1}{\mu_t}Y_{jt}^w - \frac{W_t}{P_t}H_{jt} - \frac{V_t}{P_t}E_{jt} - \frac{\phi_h}{2}(\frac{H_{jt}}{Hjt-1} - 1)^2 Y_t$ and $\mu_t = \frac{P_t}{P_t^w}$ is the markup of retail over wholesale prices. The first order conditions for this problem imply

$$V_t^r \equiv \frac{V_t}{P_t} = \frac{MPE_{jt}}{\mu_t} \tag{16}$$

[8] See Galí (1999); as in the standard literature, we assume that effort is perfectly observable.

and

$$\begin{array}{l} W_t^r \equiv \frac{W_t}{P_t} = \frac{MPH_{jt}}{\mu_t} - \phi_h \left(\frac{H_{jt}}{H_{it-1}} - 1 \right) \frac{Y_t}{H_{jt-1}} + \\ +\beta E_t \frac{\xi_{t+1}}{\xi_t} \frac{C_t - hC_{t-1}}{C_{t+1} - hC_t} \phi_h \left(\frac{H_{jt+1}}{H_{jt}} - 1 \right) \frac{H_{jt+1}}{H_{jt}^2} Y_{t+1} \end{array} \tag{17}$$

where $MPH_{j,t}$ is the marginal product of hours ($MPH_{j,t} \equiv \alpha A_t H_{jt}^{\alpha-1} E_{jt}^{\alpha}$) and $MPE_{j,t}$ is the marginal product of effort ($MPE_{j,t} \equiv \alpha A_t H_{jt}^{\alpha} E_{jt}^{\alpha-1}$). In symmetric equilibrium $H_{j,t} = H_t$ and $E_{j,t} = E_t$ for all j, since all wholesale firms are identical and make the same decisions.

3.2.2 Retailers

We assume a continuum of monopolistically competitive retailers, indexed by i on the unit interval. The retail firm purchases the wholesale output and converts it into a differentiated final good, according to the following technology:

$$Y_t(i) = Y_t^w(i), \tag{18}$$

where $Y_t^w(i)$ is the quantity of the (single) wholesale good.

Following Calvo (1983), retailers can reset their price at random dates: in each period only a randomly chosen fraction $(1-\theta)$ of retailers adjusts their prices. The remaining retailers keep their prices unchanged. Let P_t^* denote the new price set by a retailer at time t; then the aggregate price index satisfies

$$P_t = \left[\theta \left(P_{t-1} \right)^{1-\epsilon} + (1-\theta) \left(P_t^* \right)^{1-\epsilon} \right]^{\frac{1}{1-\epsilon}}. \tag{19}$$

The pricing decision of a retail firm obeys the following equilibrium condition:

$$\underset{t}{E} \sum_{k=0}^{\infty} \theta^k Q_{t,t+k} Y_{t+k/t} \left(\frac{P_t^*}{P_{t-1}} - \frac{\epsilon}{\epsilon - 1} MC_{t+k/t} \frac{P_{t+k}}{P_{t-1}} \right) = 0 \tag{20}$$

where $MC_{t+k/t}$ denotes the real marginal cost in $t+k$ for a firm that last reset its prices in t and $Q_{t,t+k}$ is the stochastic discount factor for nominal payoffs, $Q_{t,t+k} \equiv \beta^k \frac{\xi_{t+k}}{\xi_t} \left(\frac{C_t - hC_{t-1}}{C_{t+k} - hC_{t+k-1}} \right) \frac{P_t}{P_{t+k}}$. Assuming that hours' adjustment costs are distributed to the aggregate households, market clearing requires[9]

$$A_t L_t^{\alpha} = C_t \int_0^1 \left[\frac{P_t(i)}{P_t} \right]^{-\epsilon} di. \tag{21}$$

3.3 Monetary Policy

The model is closed by a monetary policy rule. We assume that monetary policy obeys a simple Taylor rule, in which the nominal interest rate reacts to the current level of inflation and to the cyclical behavior of output:

$$\frac{1+i_t}{\overline{R}} = \pi_t^{\phi_\pi} \left(\frac{Y_t}{A_t} \right)^{\phi_y}$$

where $\overline{R}$ is the steady state nominal gross rate and ϕ_π and ϕ_y are parameters.

3.4 The stationary representation of the model

The non-stationary technology process induces a stochastic trend in C_t, Y_t, W_t^r and V_t^r. To obtain the stationary representation of the model, the non-stationary variables are rescaled by the level of technology: $\widetilde{X}_t = \frac{X_t}{A_t}$, where X_t is a generic variable and $\widetilde{X}_t$ its corresponding stationary ratio (see e.g. Gertler *et al.*, 2008, Juillard *et al.,* 2008 and Smets and Wouters, 2007). The detrended model is then log-linearized around the balanced growth steady state. The complete system of log-linear equations in stationary form is the following:

1. Technology

$\widetilde{y}_t = \alpha \left(h_t + e_t \right)$

2. Euler Equation

$$\widetilde{c}_t = \frac{\frac{h}{\gamma_a}}{1+\frac{h}{\gamma_a}} \left(\widetilde{c}_{t-1} - z_t \right) + \frac{1}{1+\frac{h}{\gamma_a}} E_t \left(\widetilde{c}_{t+1} + z_{t+1} \right) + \\ - \frac{1-\frac{h}{\gamma_a}}{1+\frac{h}{\gamma_a}} \left(i_t - E_t \pi_{t+1} + E_t \Delta \log \xi_{t+1} \right)$$

[9] Market clearing for good i requires $A_t L_{i,t}^{\alpha} = C_t(i)$. Integrating over i yields $A_t L_t^{\alpha} = \int_0^1 C_t(i) di = C_t \int_0^1 \frac{C_t(i)}{C_t} di = C_t \int_0^1 \left[\frac{P_t(i)}{P_t} \right]^{-\epsilon} di$.

3. Performance Compensation

$$\widetilde{v}_t^r = (1-\gamma_e)\left[\frac{1}{1-\frac{h}{\gamma_a}}\left(\widetilde{c}_t - \frac{h}{\gamma_a}\widetilde{c}_{t-1} + \frac{h}{\gamma_a}z_t\right) + h_t + \sigma_e e_t\right]$$

4. Hour Compensation

$$\widetilde{w}_t^r = (1-\gamma_h)\left[\frac{1}{1-\frac{h}{\gamma_a}}\left(\widetilde{c}_t - \frac{h}{\gamma_a}\widetilde{c}_{t-1} + \frac{h}{\gamma_a}z_t\right) + \frac{\lambda_h\sigma_h}{\lambda_h + \frac{\lambda_e}{1+\sigma_e}\overline{E}^{1+\sigma_e}}h_t + \frac{\lambda_e\overline{E}^{1+\sigma_e}}{\lambda_h + \frac{\lambda_e}{1+\sigma_e}\overline{E}^{1+\sigma_e}}e_t\right]$$

5. Phillips Curve

$$\pi_t = \beta E_t\pi_{t+1} +$$
$$+\frac{(1-\beta\theta)(1-\theta)}{\theta}\frac{\alpha}{\alpha+\epsilon(1-\alpha)}\left[\widetilde{w}_t^r - \widetilde{y}_t + h_t + \frac{\epsilon}{\epsilon-1}\frac{\phi_h}{\alpha}\left(h_t - h_{t-1}\right) - \beta\frac{\epsilon}{\epsilon-1}\frac{\phi_h}{\alpha}\left(E_t h_{t+1} - h_t\right)\right]$$

6. Aggregate Resource Constraint

$$\widetilde{y}_t = \widetilde{c}_t$$

7. Efficient Price Frontier

$$\widetilde{v}_t^r = \widetilde{w}_t^r - e_t + h_t + \frac{\epsilon}{\epsilon-1}\frac{\phi_h}{\alpha}\left(h_t - h_{t-1}\right) - \beta\frac{\epsilon}{\epsilon-1}\frac{\phi_h}{\alpha}\left(E_t h_{t+1} - h_t\right)$$

8. Monetary policy rule

$$i_t = \phi_\pi\pi_t + \phi_y\widetilde{y}_t$$

In the following section, we conduct stochastic simulations in order to investigate the implications for macroeconomic correlations of a structural change in the design of labor compensation.

4 The role of Performance-related Pay

This section establishes that the higher flexibility of labor compensation, coupled with a higher share of performance-related pay in workers average earnings, does explain most of the empirical evidence summarized in section 2. In order to pin down the role of changes in the US design of labor compensation, we fix all the model's parameters except γ_e and investigate if an increasing relevance of performance-related pay in the cyclical fluctuations of labor compensation can account for the observed shifts associated with the Great Moderation. It is important to emphasize that, in doing so, we do not maintain that the US economy has not undergone relevant structural changes other than those occurred in the structure of labor pay. By keeping all the parameters but γ_e fixed across periods, we try to ascertain the specific ability of changes in labor pay in accounting for the shifting patterns of macroeconomic correlations and volatilities.

In line with what is widely accepted in the literature, we calibrate the discount factor, β, to a value of 0.99 and the elasticity of substitution among differentiated goods, ϵ, to a value of 6, which is consistent with a gross steady state markup of 20 percent. The sticky price parameter, θ, is calibrated equal to 0.6, which implies an average price duration of three quarters, a value consistent with the empirical evidence (see Sbordone, 2006). The degree of external habit formation h is set equal to 0.6. As for the monetary policy rule, we set $\phi_\pi = 1.2$, in the range of values $(1, 5]$ that cover the empirically plausible set conditional on having a unique equilibrium, and $\phi_y = 0.1$. We calibrate the elasticity of output with respect to effective labor input, α, to a value of 2/3, and the labor adjustment cost parameter, ϕ_h, is set equal to 1. We assume that the elasticity of the marginal disutility of effort with respect to effort is equal to 1 ($\sigma_e = 1$) and we calibrate σ_h to 1, in accordance with Schor's (1987) estimate of 0.5 for the elasticity of effort with respect to hours, $\frac{\sigma_h}{1+\sigma_e}$. The steady state balanced growth term γ_a is calibrated equal to 1.004, consistent with the average quarterly output growth of 0.4 per cent recorded in the U.S. data. Following Altig et al. (2005), Gertler et al. (2008) and Juillard et al. (2008) we assume a trending nonstationary $AR(2)$ process for the level of technology, A_t, by setting $\rho_a = 0.5$. The non-technology disturbance term is assumed to follow a stationary $AR(1)$ process characterized by a first order autocorrelation parameter, ρ_ξ, equal to 0.9.

4.1 Performance related pay and Changes in the Structure of Conditional Correlations

The response of labor productivity to non-technology shocks

Figure 2a highlights that the response at impact (i.e. in the first period) of labor productivity to a non-technology shock is monotonically strictly increasing in γ_e and this holds true for any given value of γ_h. Hence, an increase in the responsiveness of the real wage to economic conditions associated with a higher relevance of the performance-related component in the cyclical fluctuations of labor compensation lowers the procyclicality of labor productivity conditional on non-technology shocks. When the share of performance-related pay is sufficiently large, labor productivity becomes countercyclical.

Conversely, figure 2b shows that high values of γ_h are associated with countercyclical responses of labor productivity conditional on non-technology shocks and labor productivity becomes procyclical as γ_h approaches to zero. The response at impact of labor productivity to non-technology shocks is therefore monotonically strictly decreasing with γ_h, regardless of the values assigned to γ_e. In other words, an increase in the flexibility of labor compensation associated with a lower relative share of performance pay would imply an increase in the degree of procyclicality of labor productivity conditional on non-technology shocks.

The economic intuition behind this result is as follows. The apparent feature of short run increasing returns to labor (SRIRL) derives from the fact that firms vary the intensity of their labor utilization over the cycle. The extent to which this happens depends on the short run profitability of substituting increases in effort for increases in hours of work. Profitability depends on the structure of labor compensation and in particular on the shares of the two compensation margins: following an increase in demand, the smaller the increase in the compensation for effort, the more profitable it will be to react to current and expected changes in the economy by varying labor effort and the higher will be the degree of procyclicality of labor productivity.

To see this, consider the efficient price frontier:

$$\widetilde{v}_t^r - \widetilde{w}_t^r = h_t - e_t + \frac{\epsilon}{\epsilon - 1}\frac{\phi_h}{\alpha}\left(h_t - h_{t-1}\right) - \beta\frac{\epsilon}{\epsilon - 1}\frac{\phi_h}{\alpha}\left(E_t h_{t+1} - h_t\right) \tag{22}$$

Combining the efficient price frontier with the aggregate production function yields the following expression for the cyclical component of labor productivity:

$$\widetilde{mph}_t = \alpha\left(\widetilde{w}_t^r - \widetilde{v}_t^r\right) + (2\alpha - 1)\left(h_t\right) + \frac{\epsilon}{\epsilon - 1}\phi_h\left(h_t - h_{t-1}\right) - \beta\frac{\epsilon}{\epsilon - 1}\phi_h\left(E_t h_{t+1} - h_t\right) \tag{23}$$

In the aftermath of a positive non-technology shock, both effort and hours compensation tend to increase and, of course, so do hours. The previous equation therefore highlights that the sign of the response of labor productivity, $\widetilde{mph}_t$, to a non-technology shock depends on the relative movements of the two compensation margins, $\widetilde{w}_t^r$ and $\widetilde{v}_t^r$. Labor productivity can indeed show a positive response to an expansionary non-technology shock if hours wages rise by more than the performance compensation. In other words, the sign and the magnitude of labor productivity response depends crucially on the interplay between the variations of the hourly wage and the performance pay. Thus, the increase in the relevance of performance pay in the cyclical fluctuations of labor compensation (i.e. a drop in γ_e) can indeed account for the disappearance of the positive correlation between labor productivity and hours conditional on non-technology shocks, that occurred in the early 1980s.

The response of hours to technology shocks

Figure 3a shows that (the absolute value of) the response at impact of hours worked to technology improvements is monotonically strictly increasing in γ_e, irrespective of the value assigned to the parameter γ_h. Conversely, Figure 3b highlights that (the absolute value of) the response at impact of hours worked to technology improvements is monotonically strictly decreasing in γ_h, regardless of the value taken by the parameter γ_e.

The economic intuition is straightforward. The model predicts a negative response of firms' use of labor input. Indeed, the negative response of labor input to a technology expansion is theoretically consistent with a sticky price economy in which monetary policy is not fully accommodative (Galì 1999, Basu et al. 2006, Dotsey, 2002 and Galí and Rabanal, 2004).[10] Following a technology shock, both effort and hours compensation tend to rise. The efficient price frontier (22) implies that hours contraction will be larger the higher is the increase in hourly wages (i.e. the lower is γ_h; see Riggi, 2010 and Riggi and Tancioni, 2010) and the smaller is the increase in performance compensation (i.e. the higher is γ_e). Thus, for a given value of γ_h, an increase in the flexibility of labor compensation associated with an increase in the relevance of performance pay (i.e. a lower γ_e) drives down the (absolute value of the) negative correlation between hours and productivity conditional to a technology shock, because it induces firms to reduce labor input by adjusting on the performance side more than on the hours side.

[10] Following a technology improvement aggregate demand does not grow as much as it would under price flexibility and therefore the more productive firms are able to satisfy demand with fewer hours worked by employees.

A calibration exercise

A natural question emerges about the required variation in γ_e necessary to account for the changes in the structure of conditional correlations documented by GG (2009). The literature does not provide much guidance about setting a value for γ_e and even less so for calibrating a value to the pre-1984 period and another one for the post-1984 period. We therefore perform a calibration exercise to find the values of γ_e that minimize the distance between the theoretical, model-based IRFs and the empirical SVAR-based average IRFs of labor productivity and hours to non-technology and technology shocks, respectively. The empirical IRFs are those estimated by GG (2009) and depicted in Figures 1a and 1b. We set $\gamma_h = 0.7$ in order to capture the high degree of labor compensation rigidities documented for the pre-1984 period (Blanchard and Riggi, 2009), and we maintain the calibration discussed above for the remaining parameters. The values of γ_e that provide the best approximation of the empirical SVAR-based average IRFs are $\gamma_e = 0.719$ in the pre-1984 sample and $\gamma_e = 0.274$ in the post-1984 sample[11]. Given the calibration for the other parameters this implies an increased relevance of performance pay in workers average earnings of more than 16 percent.[12] Figures 4a and 4b report the theoretical IRFs.

This exercise highlights that the developments occurred in the design of labor compensation, leading to a higher relevance of performance related pay in the cyclical fluctuations of wages, go a long way in accounting for the changes in the pattern of conditional comovements among output, hours, and labor productivity. Consistent with the empirical findings, our model predicts that an increase in the performance pay sensitivity implies a change from positive to negative of the sign of labor productivity response to non-technology innovations and a drop in absolute value of the negative response of hours to technology shocks.

[11] The standard deviation of the estimated value of γ_e in the pre-1984 is 0.0212. The standard deviation of the estimated value of γ_e in the post-1984 is 0.0196.

[12] Indeed, given the calibration of the other parameters, the two values of γ_e imply an increase in $\frac{\overline{\widetilde{V^r}}}{\overline{\widetilde{W^r}}+\overline{\widetilde{V^r}}}$ from to 0.432 to 0.503. See the Appendix on steady state calculations.

4.2 Performance pay and Changes in the Structure of Unconditional Second Moments

Stiroh (2009) and GG argue that a substantial fraction of the decline in output volatility characterizing the Great Moderation period can be explained by the relevant decline in the correlation between labor productivity and hours. In order to analyze the implications of the changes in the structure of labor compensation for macroeconomic unconditional correlations and volatilities, we use artificial data generated from our model economy in which both technology and non-technology shocks are present. In particular, we consider the two values of γ_e obtained in the previous calibration exercise: 0.719 and 0.274. For each parameterization, we extract randomly 1,000 samples of 100 observations each from the artificial dataset, compute second moments and average them across the 1,000 samples.[13] To appraise the ability of the increased performance pay sensitivity to account for the observed changes in macroeconomic correlations and volatilities, we keep the remaining parameters fixed at the calibrated values previously described in this section.

The first panel of table 1 shows the evidence by GG (2009) on the observed shift in macroeconomic correlations between output, labor productivity and hours. The second panel of table 1 reports the variations in the cyclical comovements between output and hours, hours and productivity, and output and productivity computed on the artificial data generated within our model by assuming that the change in γ_e had been the sole structural change occurred in the economy. The comparison between the model-based changes in cross correlations and the corresponding observed changes reported in the first panel reveals that the structural change on which we are focusing can account for the shifts in the comovements among macroeconomic variables. The correlation between output and hours is stable across the two subsamples, as documented by GG. Conversely, the procyclical behaviour of labor productivity seems to vanish when we turn to the post-1984 sample. Indeed, when we take output as a cyclical indicator, in the second sub-sample labor productivity becomes an essentially acyclical variable. In particular, GG document that the unconditional correlation between labor productivity and business output drops to 0.03 from a value of 0.61. In our analysis we document that, when γ_e takes a lower value, such correlation drops to 0.03

[13] The sample length of 100 quarters is empirically reasonable since it broadly resembles the period associated with the Great Moderation (from 1984:1 onwards) and the pre-Great Moderation period (from 1948:1 to 1983:4).

(from a value of 0.95). By taking hours worked as a cyclical indicator labor productivity becomes a coutercyclical variable. Indeed, GG report that the actual correlation shifts from 0.18 to -0.46 and our model predicts a shift from 0.90 to -0.38.

In table 2 we compare the evidence provided by GG and Galí and van Rens (2010) on the changes in the volatility of output and other variables with our results from artificial data when we vary the parameter γ_e. On its own, the increased performance sensitivity of pay accounts for a sizeable part of the drop in output volatility documented in the literature on the Great Moderation. GG report that the standard deviation of B-P filtered output declines by about 53 per cent in the post-1984 period and our model predicts a reduction of 22 percent when γ_e is set at the lower value.[14] GG also report a decline in the volatility of labor productivity and hours but they emphasize that it is less pronounced than that of output. Our model-based data, on the contrary, indicate that the standard deviation of labor productivity and hours has increased, rather than decreased (although to a small extent in the case of hours).[15]

The increase in the volatility of labor compensation in real terms, driven by the higher performance sensitivity of pay and measured by a shift in the standard deviation from 1.82 to 2.63, is consistent with the empirical evidence reported in Galí and Van Rens (2010) for the US economy, which shows a sizeable increase in the volatility of actual (real) wages over the post-1984 period. When they consider compensation per hour deflated using the compensation deflator from the BLS Labor Productivity and Cost (LPC) program and transformed using the B-P filter on the (log of) variable, the

[14] In our model economy, we calibrate the standard deviation of the two shocks so as to obtain - in the high γ_e case - a standard deviation of output that is exactly equal to the actual standard deviation of output in the pre-1984 sample.

[15] The increase in the unconditional volatility of hours worked is explained by the contribution of non-technology shocks. If the compensation for effort becomes less rigid (i.e. γ_e shrinks), while the compensation for hours is as rigid as before (i.e. γ_e stays unchanged), then following a demand shock it is profitable for firms to react by adjusting on the hours margin to a larger extent than before. This of course implies that the volatility of hours is expected to rise. By contrast, the increase in the unconditional volatility of labor productivity is mainly driven by the contribution of technology shocks. If the compensation for effort becomes less rigid, in the aftermath of a technology shock the variation (in absolute value) of performance pay relatively to the variation of hourly wage tends to be higher than before and this induces a smaller adjustment of hours worked and a larger variation of worker's performance. This implies an increase in the volatility of labor productivity.

standard deviation shifts from 0.71 to 0.99 for the pre- and post-1984 periods. We believe that this finding ought to be emphasized as it stands in contrast with the overall, parallel decline of macroeconomic volatility.[16]

5 The role of hours adjustment costs

A common explanation for the procyclical behavior of labor productivity is labor hoarding, which is caused by a variety of costs involved in adjusting the labor force. Since the latter cannot be costlessly adjusted in the short run, firms react to changes in demand by varying the intensity of labor utilization. Thus, the labor force is smoothed over the cycle, and the cyclical variations in labor effort, which increases in booms and decreases in recessions, generate a perception of SRIRL (Sbordone, 1996). It follows that a straightforward interpretation of the decline in the correlation between labor productivity and hours, conditional on non-technology shocks, would be based on the decrease of labor adjustment costs over the recent decades, due to higher competition, a more flexible labor market and tougher corporate governance. By developing a theoretical model, Galí and van Rens (2010) point to the decline in labor market frictions as the major source of the vanishing procyclicality of labor productivity.

In our model economy, this interpretation is captured by a decrease in the value of the parameter ϕ_h. The role of ϕ_h in shaping the procyclicality of labor productivity is highlighted by equation (23) which establishes that higher labor adjustment costs renders the SRIRL outcome more likely. Accordingly, Figure 5a shows that a downward shift of ϕ_h, taking up different values ranging from 2 to zero, yields a gradual disappearance of the procyclical response of labor productivity to non-technology shocks. Indeed, the response at impact of labor productivity to a non-technology shock is monotonically strictly increasing in ϕ_h, regardless of the parameterization used for γ_e.

However, the drop in labor hoarding driven by lower adjustment costs

[16]As a robustness inspection of the results documented in Tables 1 and 2, we have verified whether the values of the unconditional moments computed on the artificial data may depend on initial conditions. To tackle this issue we have eliminated the first 100 observations from the overall sample of 10000 observations and extracted randomly, as before, 1,000 samples of 100 observations each from this revised artificial dataset. The results remain virtually unchanged.

would lead to an even larger initial drop in hours following a technology innovation, in contrast with the evidence in GG and the results of our SVAR-based IRFs. Figure 5b shows that the response at impact of hours worked to technology improvements is, in general, monotonically strictly declining (in absolute value) in the adjustment cost parameter, ϕ_h. Intuitively, hours response to a technology shock would be lower the higher are the hours adjustment costs.

Of course the inability of the decrease in labor adjustment costs to account on its own for both changes in the dynamic responses to shocks does not rule out the potential relevance that decreasing labor market frictions may have had for the Great Moderation. For example, the drop in labor adjustment costs combined with a stronger anti-inflationary stance of the monetary policy could make a good job in explaning the Great Moderation and the parallel shifts in macroeconomic correlations.

6 Conclusions

Galí and Gambetti (2009) show that large changes in the patterns of conditional and unconditional correlations among output, hours and labor productivity have accompanied the substantial decline in macroeconomic volatility experienced by the US economy since the mid-1980s.

In this paper we have proposed a novel explanation for these observed patterns based on extensive evidence showing that the U.S. design of labor compensation has changed around the mid-1980s, towards an increased flexibility of workers' pay combined with a greater relevance of the performance-pay component in the cyclical fluctuations of labor compensation.

Using stochastic simulations, we have showed that a structural change towards an increased flexibility in real wages associated with a higher share of the performance-related component in workers compensation can account for the following empirical patterns: a) the disappearance of the procyclical productivity puzzle; b) the smaller contractionary effects on hours of a technology improvement; c) the decline in the unconditional correlation between labor productivity and both output and hours; d) the decline in output volatility and e) the parallel increase in the volatility of real wage.

We have also showed that if the higher wage flexibility had been accompanied by a *lower* share of the performance-related component in workers compensation we would have implications for the patterns of comovements which go in the opposite direction to those that emerge from empirical analysis.

The evidence by GG and Galí and van Rens (2010) is useful to shed light on the merits of different explanations for the Great Moderation. We do not claim that the shift in the design of labor compensation is the sole structural change behind the complex picture associated with the Great Moderation. However, our goal is to emphasize that the developments occurred in the design of labor compensation, leading to a higher relevance of performance-related pay in the cyclical fluctuations of wages, have played a key role in explaining the enhanced macroeconomic stability and the parallel shift in the structure of macroeconomic correlations.

On the other hand, the explanation of shifts in macroeconomic correlations based on modifications to pay settings is particularly appealing as it can be reconciled with an empirical puzzle highlighted by Davis and Kahn (2008), namely that the substantial slump in the volatility of aggregate real activity has been coincident with an increase in *individual* income volatility and earnings uncertainty (see also Comin and Mulani, 2006). Arguably, these opposite trends in micro and macro volatility are potentially consistent with a higher incidence of the performance-related component of labor compensation, that rewards idiosyncratic effort and individual worker characteristics.

We therefore see two natural directions for future research. First, an extension to the model by allowing for heterogeneous consumers to investigate the coincidence between changes in the structure of macroeconomic correlations and the increased volatility of earnings at the individual level; and second, a structural estimation of the model.

Appendix

Steady state calculation

As it is standard in the literature, we normalize $\overline{H}$ to be equal to one (see, e.g., Smets and Wouters, 2007). In order to compute the performance pay share on workers labor compensation, we need to recover the steady state value of $\overline{E}$. To this aim, we combine the cost minimization condition with (9) and (10) in the main text:

$$\overline{E} = \frac{\overline{\widetilde{W}^r}}{\overline{\widetilde{V}^r}} = \frac{\left[\left(\overline{\widetilde{C}} - \frac{h}{\gamma_a}\overline{\widetilde{C}}\right)\left(\lambda_h + \frac{\lambda_e}{1+\sigma_e}\overline{E}^{1+\sigma_e}\right)\right]^{1-\gamma_h}}{\left[\left(\overline{\widetilde{C}} - \frac{h}{\gamma_a}\overline{\widetilde{C}}\right)\lambda_e\overline{E}^{\sigma_e}\right]^{1-\gamma_e}} \tag{1A}$$

Using $\overline{\widetilde{C}} = \overline{E}^{\alpha}$, (1A) can be rewritten as follows:

$$\frac{\left[\lambda_h + \frac{\lambda_e}{1+\sigma_e}\overline{E}^{1+\sigma_e}\right]^{1-\gamma_h}\overline{E}^{\alpha(1-\gamma_h)}}{\left(\lambda_e\overline{E}^{\sigma_e}\right)^{1-\gamma_e}\overline{E}^{\alpha(1-\gamma_e)}}\left(1 - \frac{h}{\gamma_a}\right)^{\gamma_e-\gamma_h} = \overline{E} \tag{2A}$$

Rearranging yields:

$$\frac{\left(\lambda_h + \frac{\lambda_e}{1+\sigma_e}\overline{E}^{1+\sigma_e}\right)^{1-\gamma_h}}{\lambda_e^{1-\gamma_e}}\left(1 - \frac{h}{\gamma_a}\right)^{\gamma_e-\gamma_h} = \overline{E}^{1-\alpha(\gamma_e-\gamma_h)+\sigma_e(1-\gamma_e)} \tag{3A}$$

By solving the polinomial equation, we recover the steady state value of $\overline{E}$, which depends on γ_e (among the other parameters) and we are able to study how the performance pay share in workers labor compensation varies with γ_e. Indeed, the relative share of performance pay is equal to

$$\frac{\overline{\widetilde{V}^r}}{\overline{\widetilde{W}^r} + \overline{\widetilde{V}^r}} = \frac{1}{\overline{E}+1} \tag{4A}$$

or, equivalently, looking at the share from the supply side:

$$\begin{aligned}\frac{\overline{\widetilde{V}^r}}{\overline{\widetilde{W}^r}+\overline{\widetilde{V}^r}} &= \frac{\left(\widetilde{C}-\frac{h}{\gamma}\widetilde{C}\right)^{1-\gamma_e}\lambda_e^{1-\gamma_e}E^{\sigma_e(1-\gamma_e)}}{\left(\widetilde{C}-\frac{h}{\gamma}\widetilde{C}\right)^{1-\gamma_e}\lambda_e^{1-\gamma_e}E^{\sigma_e(1-\gamma_e)}+\left(\widetilde{C}-\frac{h}{\gamma}\widetilde{C}\right)^{1-\gamma_h}\left(\lambda_h+\frac{\lambda_e}{1+\sigma_e}E^{1+\sigma_e}\right)^{1-\gamma_h}} = \\ &= \frac{1}{1+\frac{E^{\alpha(\gamma_e-\gamma_h)-\sigma_e(1-\gamma_e)}\left(1-\frac{h}{\gamma}\right)^{\gamma_e-\gamma_h}\left(\lambda_h+\frac{\lambda_e}{1+\sigma_e}E^{1+\sigma_e}\right)^{1-\gamma_h}}{\lambda_e^{1-\gamma_e}}}\end{aligned} \tag{5A}$$

The value of the share obtained by plugging the model-consistent value of $\overline{E}$ into(4A) coincides with the value obtained by plugging $\overline{E}$ into (5A). We are thus able to recover the change in the ratio of performance pay to workers labor compensation which is consistent with the variation in γ_e, suggested by the minimum distance exercise presented in section 3.1 (main text).

Figure 1a
The average responses of labor productivity to non-technology shocks

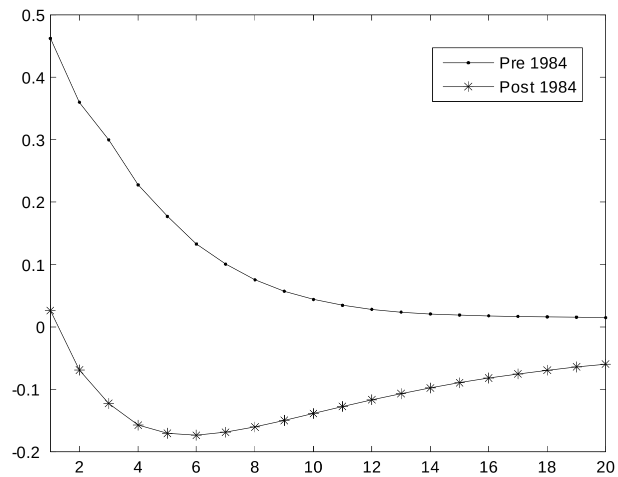
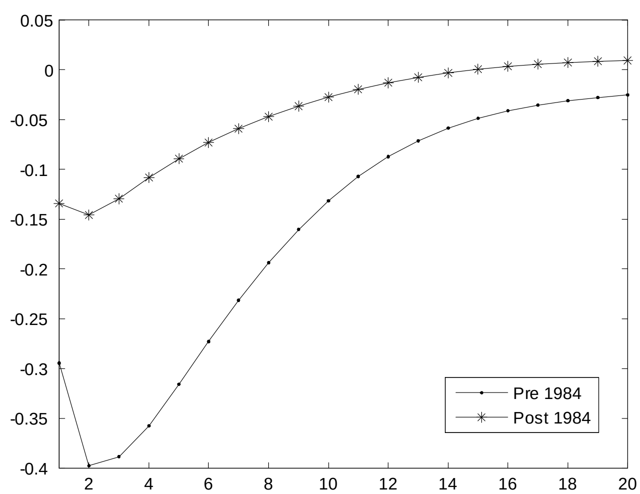


Figure 1b
The average responses of hours to technology shocks



Source: our replication of Galì and Gambetti (2009)'results (see figures 6.B and 7.B on pages 47-48 of their paper).

Figure 2. Nontechnology Shocks: Response at impact of labor productivity

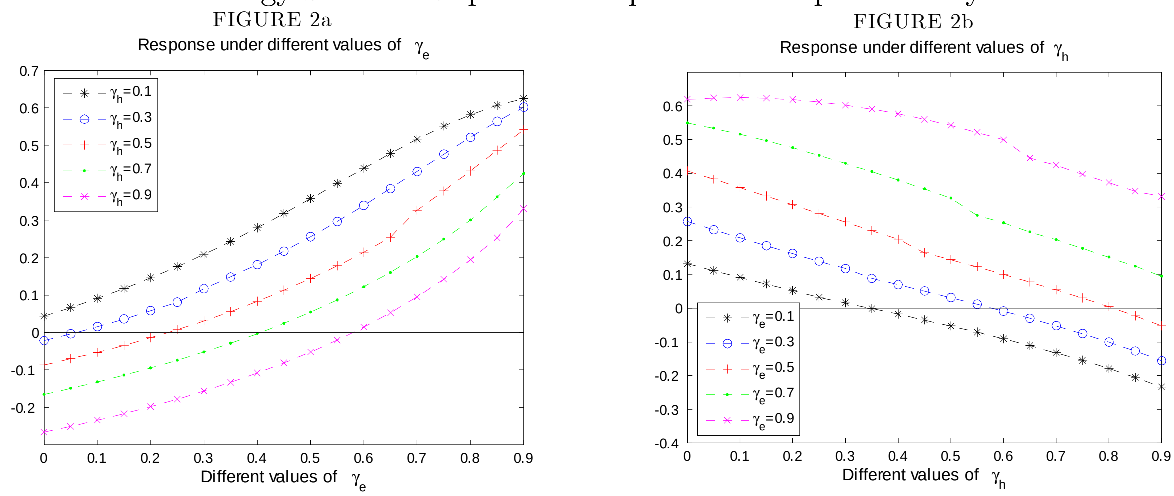


Figure 3. Technology Shocks: Response at impact of hours

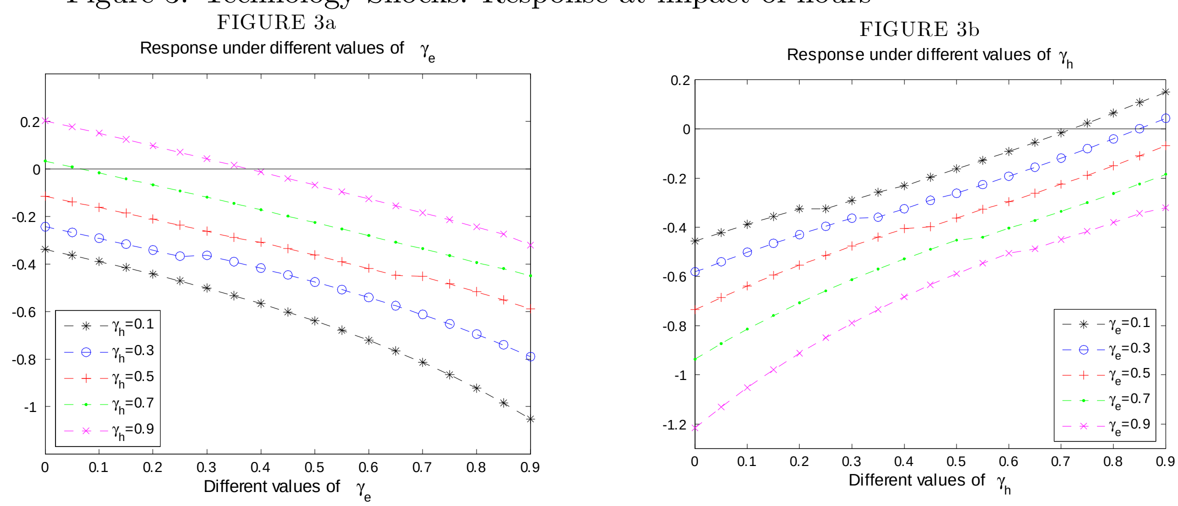


Figure 4a. Nontechnology Shocks: Labor Productivity response

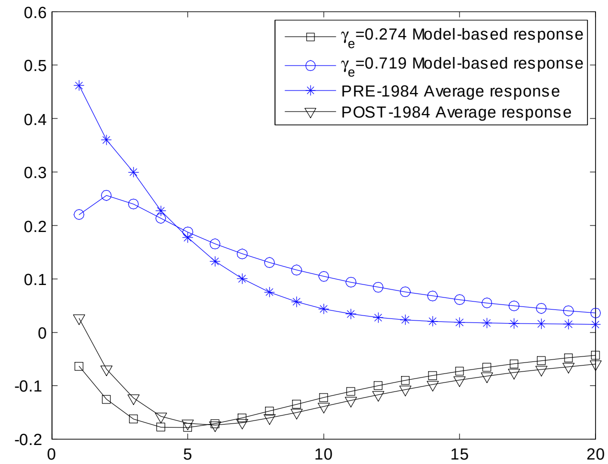


Figure 4b. Technology Shocks: Hours response

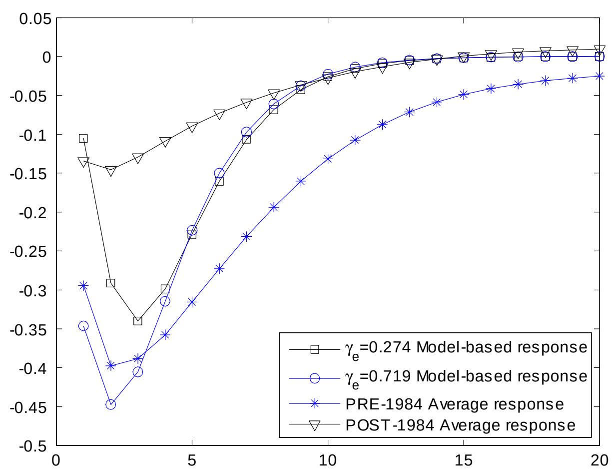


Table 1 Changes in Cross Correlations

	Evidence from GG (2009) (table 3, pp. 31) (BP-filter)			Second moments of artificial model-based data (cyclical components)		
	Pre-1984	Post-1984	Change	$\gamma_e = 0.719$	$\gamma_e = 0.274$	Change
Output, hours	0.89	0.86	-0.02	0.99	0.91	-0.08
Hours, productivity	0.18	-0.46	-0.65	0.90	-0.38	-1.28
Output, productivity	0.61	0.03	-0.58	0.95	0.03	-0.92

Table 2 Changes in Volatility

	Evidence from GG and Galí-Van Rens (2010) Standard Deviation (BP-filter)			Second moments of artificial model-based data (cyclical components)		
	Pre-1984	Post-1984	$\frac{\text{Post-1984}}{\text{Pre-1984}}$	$\gamma_e = 0.719$	$\gamma_e = 0.274$	$\frac{\text{Post-1984}}{\text{Pre-1984}}$
Output	2.59	1.23	0.47	2.59	2.02	0.78
Hours	2.08	1.39	0.67	1.94	2.19	1.12
Productivity	1.18	0.68	0.57	0.69	0.87	1.26
Wage	0.71	0.99	1.38	1.82	2.63	1.44

Figure 5. The role of hours adjustment costs

FIGURE 5a. Non technology shocks
Response at impact of labor productivity

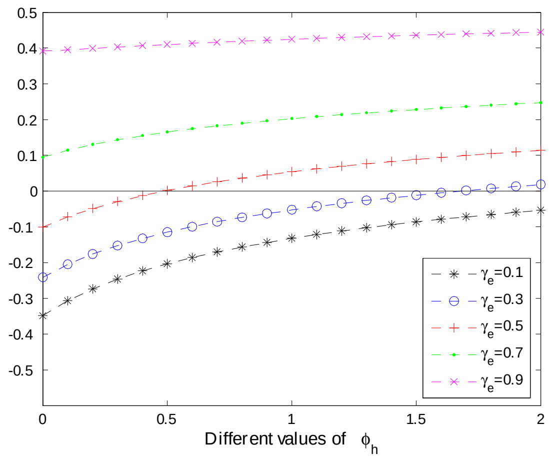
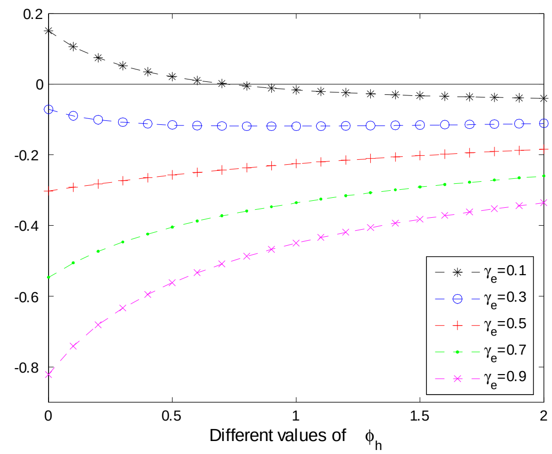


FIGURE 5b. Technology shocks
Response at impact of hours



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