

A photograph of the De Nederlandsche Bank building, a modern structure with a curved glass facade on the left and a taller, more rectangular section with horizontal bands of windows on the right. A flag flies from the top of the building. The building is situated next to a canal, with a walkway and some people visible in the foreground.

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market dynamics

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Firms entry, oligopolistic competition and labor market dynamics^{*}

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Abstract

Using U.S. quarterly data we provide VAR evidence showing that a positive productivity shock leads to a persistent decrease in the unemployment rate and in the price markup, together with an increase in aggregate profits. In response to the shock the labor share of income decreases on impact and overshoots its long run trend before reverting to equilibrium. To address these facts, we propose a model where Cournot competition and firms' entry in the goods market interact with search and matching frictions in the labor market. The price markup countercyclicality delivered by our model is a key factor to jointly account for the empirical facts we documented.

Keywords: Firms' Entry, Oligopolistic competition, Unemployment.

JEL classifications: L11, E32.

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The Mortensen-Pissarides (1994) model of search in the labor market is the workhorse framework for the study of unemployment and job flows. In its baseline version each firm has a single job, and the goods market is characterized either by perfect competition or monopolistic competition à la Dixit and Stiglitz (1977).¹ In this environment the extensive margin of job creation and destruction due to firm entry and exit cannot be addressed, the dynamics of the number of jobs cannot be distinguished from the dynamics of the number of firms and price markups are zero or constant. As a result it cannot account for the recent U.S. evidence suggesting that a large fraction of job creation (destruction) is due to the birth (death) of firms, that the number of market competitors is procyclical and that price markups are countercyclical.² To address these facts we provide a general equilibrium model with Mortensen and Pissarides-style search and matching frictions together with endogenous market structures. Market structures are said to be endogenous since the number of producers and price markups are determined in each period. The model features firms' entry à la Bilbiie, Gironi and Melitz (2012) (BGM 2012, henceforth) and oligopolistic competition, in the form of Cournot Competition, between producers as in Jaimovich and Floetotto (2008) and Colciago and Etro (2010 *a* and *b*). Firms are large and workers may separate from a job for two reasons: either because the firm where the job is located exits from the market or because the match is destroyed. As in the bulk of the literature, wages and individual hours are determined according to Nash bargaining.

The interaction between search and matching frictions in the labor market and endogenous market structures improves the performance of the standard labor-search framework along many dimensions. First, the extensive margin of job creation due to firms' entry and exit is addressed. As in the data, new firms account for a relatively small share of overall employment, but they create a large fraction of new jobs. Second, during an economic boom expectations of future profits attract firms into the market. This strengthens competition and, via strategic interactions, reduces price markups. Third, despite markups being countercyclical, aggregate profits remain strongly procyclical as in the data. Finally, thanks to markup countercyclicality, the model reproduces the response of the labor share to a productivity shock, which, as shown by Rios-Rull and Santaella-Llopis (2010) for the U.S., is characterized by coun-

¹See, *inter alia*, Mertz (1995) and Andolfatto (1996).

²Bilbiie, Gironi and Melitz (2012) Jaimovich and Floetotto (2008), Colciago and Etro (2010 *a* and *b*) provide and discuss this evidence. As in Jaimovich and Floetotto (2008) we use the terms new firms and new competitors in a broad sense. They refer to both start ups and to new establishments.

tercyclicalities on impact and overshooting. Conventional search models with Nash bargaining match just the initial drop in the labor share, but fail to address the persistence and the rise above the steady state level. We show that a persistently lower markup acts as a shifter of the standard marginal product of labor and creates a wedge between average labor productivity and the real wage. Specifically, a persistently lower price markup implies that the real wage rises relative to the average productivity of labor for several periods. This leads to the overshooting of the labor share.

To provide additional support to the transmission mechanism featured in our paper we performed a VAR analysis on U.S. data. We constructed a measure of the price markup along the lines suggested by Rotemberg and Woodford (2000) and adopted by Galí et al. (2007). Following Dedola and Neri (2007), we identify technology shocks by adopting an identification scheme based on sign restrictions.³ Our baseline specification considers a VAR(4) containing labor productivity, measured as the ratio between real GDP and total hours worked, the unemployment rate, Barnichon's help wanted index (a measure of vacancies), real aggregate consumption, the price markup, the labor share of income, computed as the real compensation of all employees over real GDP, and real GDP.⁴ The VAR is run on U.S. quarterly data over the period 1951:Q1-2011:Q4 with four lags.⁵ We identify a positive technology shock as one which leads to an increase in labor productivity, real GDP, consumption and vacancies. We do not restrict the response of the price markup, the unemployment rate, the labor share and aggregate profits which are the variables we use to validate the transmission mechanism implied by our model. Figure 1, displays the median (50th percentile) and the 16th and the 84th percentiles of the distribution of impulse response produced by the algorithm discussed in the Appendix for the price markup, the unemployment rate, the labor share of income and labor productivity over ten quarters.⁶ Our estimates sug-

³This identification scheme also allows alternative specifications of the stochastic properties of the process for labor productivity in our model. Namely, the identification procedure is consistent with both a unit root and a stationary process for labor productivity.

⁴Unfortunately we have quarterly time series for the number of new entrants and job creation by new entrants just starting from 1992. Estimating the VAR including one of these time series in turn provides results which are consistent with our transmission mechanism, namely a technology shock leads to positive net entry and to a surge in job creation by new entrants. However, given the shorter sample, estimates are imprecise.

⁵The data source is FRED. The Help Wanted index is available at Régis Barnichon's web page.

⁶The complementary Appendix, available at the web page of the authors, provides

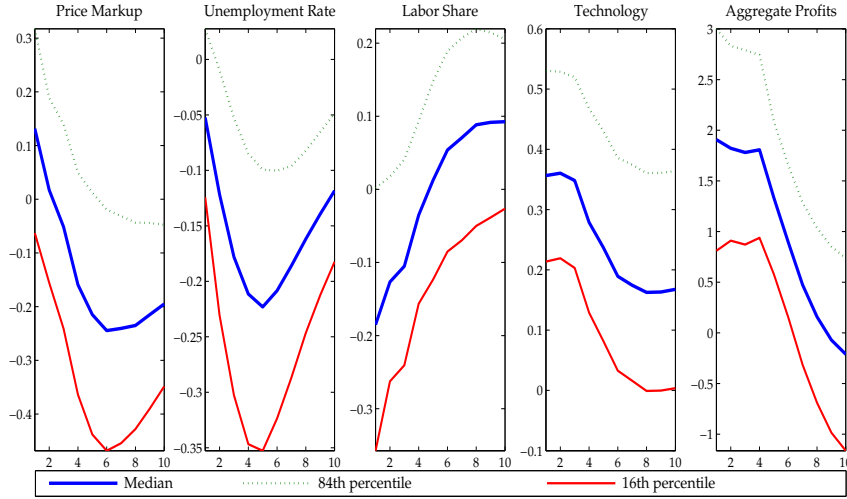


Figure 1: Estimated IRFs to an expansionary technology shock. Response of key variables over ten quarters.

gest that after an expansionary technology shock the unemployment rate features a downward hump-shaped pattern. In line with Colciago and Etro (2010) the response of the price markup is countercyclical and remains below its long run level for several periods. As in Rios-Rull and Santaaulàlia-Llopis (2010), the response of the labor share is characterized by countercyclicity on impact and overshooting. Namely, the labor share falls on impact in response to the shock and then shows an hump-shaped response, overshooting its long-run level.⁷ Importantly, despite markups being countercyclical, the response of aggregate profits is procyclical. As shown in Figure 1, profits increase by almost 2 percent on impact and then slightly undershoot their long run trend before reverting to equilibrium.

Also, we consider long-run restrictions a la Galì (1999), and find that the IRFs are qualitatively unchanged.⁸

The estimated IRFs reported in Figure 1 are consistent with those delivered by our model with Cournot competition. Early references on

the details concerning the identification strategy. Notice that the estimated IRFs are essentially unchanged if we identify the technology shock imposing a single sign restriction, namely that it has a positive effect just of labor productivity.

⁷Notice that Rios-Rull and Santaaulàlia-Llopis (2010) consider a VAR of order 1, composed by the labor share and the Solow residual. The identification assumption is that the labor share has no contemporaneous effect on the Solow residual.

⁸In this case the technology shock is identified assuming that it is the only shock with a permanent effect on labor productivity. IRFs are available from the authors.

the procyclicality of firms' entry are Chatterjee and Cooper (1993) for the U.S. and Portier (1995) for France. Bresnahan and Reiss (1987) provide direct support to the fact that stronger competition leads to lower markups. More recent research by Manuszak (2002), Campbell and Hopenhayn (2005), Manuszak and Moul (2008) also provides convincing evidence that markups fall after the entry of new competitors in the market. Reading these results in conjunction with the evidence that net entry of firms is procyclical supports the propagation mechanism purported in our model.

It has to be said that the macroeconomic literature does not speak with a single voice with respect to the cyclicity of price markups. One reason for this controversy is that marginal costs are not observable. Under the assumptions of a competitive labor market coupled with a Cobb-Douglas production function, the labor share of income delivers a measure of real marginal costs. Since the price markup is the inverse of the marginal cost, the inverse of the labor share can be taken as a measure of the price markup. However, in a labor-search framework the inverse labor share is no longer an appropriate proxy for marginal costs and hence for the price markup. As discussed by Krause and Lubik (2007), the presence of labor market frictions reduces the allocative role of current real wages. In this case marginal costs could change even if the wage does not move. Rotemberg and Woodford (2000) suggest a number of corrections to the baseline measure to obtain a more realistic measure of marginal costs. Among them, they propose overhead labor, a CES production function and convex costs of adjusting labor.⁹ Under each of these alternative formulations, marginal cost are more procyclical with respect to the baseline case and imply a countercyclical movement in the price markup, in line with the transmission mechanism supported by this paper. Galì et al. (2007) provide direct evidence of price markups countercyclicality using the alternative measures provided by Rotemberg and Woodford (2000). Their results are challenged by Nekarda and Ramey (2013). Nekarda and Ramey (2013) develop a theoretical framework for measuring markups. Their economy is characterized by many of the frictions featured in policy-oriented New Keynesian (NK) models, such as variable capital utilization. They show that the allowing for variable capital utilization implies that the markup measures introduced by Rotemberg and Woodford (2000) turn procyclical. Our model consists in a minimal departure from the baseline labor search framework, further,

⁹Considering measures of hiring costs or of the asset values of workers could represent alternative ways to measure marginal costs in the presence of labor market frictions. Merz and Yashiv (2007) estimate hiring and investment costs from the asset value of firms.

to isolate our transmission mechanism, we neglect physical capital accumulation and assume all investment is devoted to the creation of new firms. Adopting the same measure of price markup as in Rotemberg and Woodford (2000) and Galí et al. (2007), we find that the price markup is countercyclical conditional on a technology shock. Notice that the Appendix reports details of the markup measure adopted for the empirical analysis.

Papers closely related to ours are Blanchard and Giavazzi (2003), Hebel and Haefke (2009), Shao and Silos (forthcoming) and more recently Acemoglu and Hawkins (2010), Cacciatore and Fiori (2010) and Kaas and Kircher (2011). With respect to Blanchard and Giavazzi (2003) we provide a fully specified DSGE model where the dynamics of the number of firms is explicitly modeled. Hebel and Haefke (2009) consider a labor search model with firms' entry. However, their analysis focuses on the long run effects of deregulation in the goods markets for the level of unemployment and the real wage. Shao and Silos (2008) introduce firms' entry in a Mortensen-Pissarides-style model with monopolistic competition in the goods market. Their framework is characterized by small firms and constant markups. In their framework the overshooting of the labor share is due to the countercyclical value of vacancies. Nevertheless, this condition is difficult to test empirically. The present paper provides empirical support for our transmission mechanism, namely the countercyclicality of price markup in response to technology shocks. Cacciatore and Fiori (2010) consider a model with endogenous entry and imperfect competition, and focus on the macroeconomics effects of structural reforms in goods and labor markets. They show that structural reforms are beneficial in the long run, but are associated to output losses in the short run. Acemoglu and Hawkins (2010) consider a model with large firms, decreasing returns to labor and an extensive margin of job creation due to firms' entry. Decreasing return to labor together with continuous wage bargaining deliver heterogeneity in the size of firms. They find that size heterogeneity implies responses of unemployment and of the job market tightness to a shock to labor productivity which are significantly more persistent than in the Mortensen-Pissarides model.¹⁰ Kaas and Kircher (2011) characterize firms' dynamics in a frictional labor market. They assume large, risk-neutral firms that can commit to long-term wage contracts and study the efficiency of the competitive equilibrium. We consider entry and strategic interactions to identify the role played by job creation of new entrants and variable markups for the dynamics of

¹⁰Hawkins (2011), however, shows that the amplification in Acemoglu and Hawkins (2010) is due to the convex cost schedule that firms face when they adjust their labor force, and not to firms' size heterogeneity.

unemployment and other labor market variables. In Colciago and Rossi (2014) we study the role played by real wage rigidity for the joint dynamics of the labor share of income and labor productivity. We argue that while real wage rigidity implies a wedge between average labor productivity and the real wage, it does not suffice to address the overshooting of the labor share. On the contrary, we show that a countercyclical price markup is key to address the overshooting.

This paper differs from Colciago and Rossi (2014) in various respects. To the best of our knowledge we are the first to provide empirical evidence concerning the joint dynamics of the unemployment rate, price markups, aggregate profits and the labor share of income in response to a productivity shock. Our model with Cournot competition outperforms the standard search model in replicating these dynamics, both qualitatively and quantitatively. The Cournot model delivers standard deviations of the price markup and the labor share of income very close to their empirical counterparts. In line with the evidence, the correlation between the labor share of income and output is positive conditional on a productivity shock. Importantly, this is not the case in the standard search model, where the sign of this correlation is negative.

The remainder of the paper is organized as follows. Section 2 spells out the model economy. Section 3 contains the main results and Section 4 concludes. In the Appendix we provide analytical details and the procedure used to identify productivity shocks.

1 The model

The economy features a continuum of atomistics sectors, or industries, on the unit interval. Each sector is characterized by different firms producing a good in different varieties, using labor as the only input. In turn, the sectoral goods are imperfect substitutes for each other and are aggregated into a final good. Households use the final good for consumption and investment purposes. Price competition and endogenous firms' entry is modeled at the sectoral level, where firms also face search and matching frictions in hiring workers.

1.1 Labor and Goods Markets

At the beginning of each period N_{jt}^e new firms enter into sector $j \in (0, 1)$, while at the end of the period a fraction $\delta \in (0, 1)$ of market participants exits from the market for exogenous reasons.¹¹ As a result, the number

¹¹As discussed in BGM (2012), if macroeconomic shocks are small enough $N_{j,t}^e$ is positive in every period. New entrants finance entry on the stock market.

of firms in a sector N_{jt} , follows the equation of motion:

$$N_{jt+1} = (1 - \delta)(N_{jt} + N_{jt}^e) \quad (1)$$

where N_{jt}^e is the number of new entrants in sector j at time t . Following BGM (2012) we assume that new entrants at time t will only start producing at time $t+1$ and that the probability of exit from the market, δ , is independent of the period of entry and identical across sectors. The assumption of an exogenous constant exit rate is adopted for tractability, but it also has empirical support. Using U.S. annual data on manufacturing, Lee and Mukoyama (2007) find that, while the entry rate is procyclical, annual exit rates are similar across booms and recessions. Below we describe the entry process and the mode of competition within in each sector in detail. For simplicity, we assume that entry requires a fixed cost ψ in units of the final good, which is common across sectors.¹² The labor market is characterized by search and matching frictions, as in Andolfatto (1996) and Merz (1995). Firms producing in t need to post vacancies in order to hire new workers. Unemployed workers and vacancies combine according to a CRS matching function and deliver m_t new hires, or matches, in each period. The matching function reads as $m_t = \gamma_m (v_t^{tot})^{1-\gamma} u_t^\gamma$, where γ_m reflects the efficiency of the matching process, v_t^{tot} is the total number of vacancies created at time t and u_t is the unemployment rate. The probability that a firm fills a vacancy is given by $q_t = \frac{m_t}{v_t^{tot}}$, while the probability to find a job for an unemployed worker reads as $z_t = \frac{m_t}{u_t}$. Firms and individuals take both probabilities as given. Matches become productive in the same period in which they are formed. Each firm separates exogenously from a fraction $1 - \varrho$ of existing workers each period, where ϱ is the probability that a worker stays with a firm until the next period. As a result a worker may separate from a job for two reasons: either because the firm where the job is located exits from the market or because the match is destroyed. Since these sources of separation are independent, the evolution of aggregate employment, L_t , is given by

$$L_t = (1 - \delta) \varrho L_{t-1} + m_t \quad (2)$$

Notice that $u_t = 1 - L_{t-1}$ also represents the fraction of agents searching for a job.¹³

¹²Our results are unchanged, both qualitatively and quantitatively, if we assume that new entrants do not exit from the market.

¹³Given that population is normalized to one, the number of unemployed workers and the unemployment rate are identical.

1.2 Households

Using the family construct of Merz (1995) we can refer to a representative household consisting of a continuum of individuals of mass one. Members of the household insure each other against the risk of being unemployed. The representative family has lifetime utility:

$$U = E_0 \sum_{t=0}^{\infty} \beta^t \left\{ \log C_t - \chi L_t \frac{h_t^{1+1/\varphi}}{1+1/\varphi} \right\} \quad \chi, \varphi \geq 0 \quad (3)$$

where $\beta \in (0, 1)$ is the discount factor, the variable h_t represents individual hours worked and C_t is the consumption of the final good. The family receives real labor income $w_t h_t L_t$, where w_t is the real wage, and profits Π_t from the ownership of firms. Unemployed individuals receive a real unemployment benefit b , hence the overall benefit for the household is $b(1 - L_t)$. This is financed through lump sum taxation by the government. Notice that the household recognizes that employment is determined by the flows of its members into and out of employment according to

$$L_t = (1 - \delta) \varrho L_{t-1} + z_t u_t \quad (4)$$

The household chooses how much to save in riskless bonds and in the creation of new firms through the stock market according to standard Euler and asset pricing equations. The first order condition (FOC) with respect to employment, L_t , is

$$\Gamma_t = \frac{1}{C_t} w_t h_t - \chi \frac{h_t^{1+1/\varphi}}{1+1/\varphi} - \frac{b}{C_t} + \beta E_t [(1 - \delta) \varrho - z_{t+1}] \Gamma_{t+1} \quad (5)$$

where Γ_t is the marginal value to the household of having one member employed rather than unemployed and $1/C_t$ is the marginal utility of consumption. Equation (5) indicates that the household's shadow value of one additional employed member (the left hand side) has four components: first, the increase in utility generated by having an additional member employed, given by the real wage expressed in utils; second, the decrease in utility due to more hours dedicated to work, given by the marginal disutility of employment; third the foregone utility value of the unemployment benefit b/C_t ; fourth, the continuation utility value, given by the contribution of a current match to next period household's employment.¹⁴

¹⁴In the Appendix the details of the derivations.

1.3 Firms and Technology

The final good is produced aggregating a continuum of measure one of sectoral goods according to the function

$$Y_t = \left[\int_0^1 \ln Y_{jt}^{\frac{\omega-1}{\omega}} dj \right]^{\frac{\omega}{\omega-1}} \quad (6)$$

where Y_{jt} denotes output of sector j and ω is the elasticity of substitution between any two different sectoral goods. The final good producer behave competitively. In each sector j , there are $N_{jt} > 1$ firms producing differentiated goods that are aggregated into a sectoral good by a CES aggregating function defined as:

$$Y_{jt} = N_{jt}^{-\frac{1}{\varepsilon-1}} \left[\sum_{i=1}^{N_{jt}} y_{jt}(i)^{\frac{\varepsilon-1}{\varepsilon}} \right]^{\frac{\varepsilon}{\varepsilon-1}} \quad (7)$$

where $y_{jt}(i)$ is the production of good i in sector j , $\varepsilon > 1$ is the elasticity of substitution between sectoral goods.¹⁵ As in Colciago and Etro (2010 a), we assume a unit elasticity of substitution between goods belonging to different sectors. This allows to realistically separate limited substitutability at the aggregated level, and high substitutability at the disaggregated level. Each firm i in sector j produces a differentiated good with the following production function

$$y_{jt}(i) = A_t n_{jt}(i) h_{jt}(i) \quad (8)$$

where A_t represents technology which is common across sectors and evolves exogenously over time. Variable $n_{jt}(i)$ is firm i 's time- t workforce and $h_{jt}(i)$ represents hours per employee. Period- t real profits of a firm are defined as

$$\pi_{jt}(i) = y_{jt}(i) - w_{jt} n_{jt}(i) h_{jt}(i) - \kappa v_{jt}(i) \quad (9)$$

where $w_{jt}(i)$ is the real wage paid by firm i , $v_{jt}(i)$ represents the number of vacancies posted at time t and κ is the output cost of keeping a vacancy open. The value of a firm is the expected discounted value of its future profits

$$V_{jt}(i) = E_t \sum_{s=t+1}^{\infty} \Lambda_{t,s} \pi_{js}(i) \quad (10)$$

where $\Lambda_{t,t+1} = (1 - \delta) \beta \left(\frac{C_{t+1}}{C_t} \right)^{-1}$ is the households' stochastic discount factor which takes into account that firms' survival probability is $1 -$

¹⁵The term $N_{jt}^{-\frac{1}{\varepsilon-1}}$ implies that there is no variety effect in the model.

δ . Firms which do not exit from the market have a time- t individual workforce given by

$$n_{jt}(i) = \varrho n_{jt-1}(i) + v_{jt}(i) q_t \quad (11)$$

The unit intersectoral elasticity of substitution implies that the nominal expenditure, EXP_t , is identical across sectors. Thus, the final producer's demand for each sectoral good is

$$P_{jt}Y_{jt} = P_tY_t = EXP_t. \quad (12)$$

where P_{jt} is the price index of sector j and P_t is the price of the final good at period t . Denoting with $p_{jt}(i)$ the price of good i in sector j , the demand faced by the producer of each variant is

$$y_{jt}(i) = \left(\frac{p_{jt}(i)}{P_{jt}} \right)^{-\varepsilon} Y_{jt} \quad (13)$$

where P_{jt} is defined as

$$P_{jt} = N_{jt}^{-\frac{1}{1-\varepsilon}} \left[\sum_{i=1}^{N_{jt}} (p_{jt}(i))^{1-\varepsilon} \right]^{\frac{1}{1-\varepsilon}} \quad (14)$$

Using (13) and (12) the individual demand of good i can be written as a function of aggregate expenditure,

$$y_{jt}(i) = \frac{p_{jt}^{-\varepsilon}(i)}{P_{jt}^{1-\varepsilon}} EXP_t \quad (15)$$

As technology, the entry cost and the exit probability are identical across sectors, in what follows we drop the index j and refer to a representative sector. As a result

$$N_{jt} = N_t, \quad P_{jt} = P_t, \quad n_{jt}(i) = n_t(i), \quad h_{jt}(i) = h_t(i), \quad v_{jt}(i) = v_t(i)$$

and

$$p_{jt}(i) = p_t(i), \quad \pi_{jt}(i) = \pi_t(i), \quad V_{jt} = V_t(i)$$

1.4 Cournot Competition

Let us consider competition in quantities. Contrary to the traditional Dixit-Stiglitz approach which neglects strategic interactions between firms, we take these into consideration and derive the exact Cournot equilibrium. Each firm i chooses $y_t(i)$, $n_t(i)$ and $v_t(i)$ to maximize $\pi_t(i) + V_t(i)$,

taking as given the quantity of the other firms in the sector. The firm problem is to maximize profits subject to the inverse demand function, given by:

$$p_t(i) = \frac{y_t(i)^{-\frac{1}{\varepsilon}} EXP_t}{\sum_{i=1}^{N_t} y_t(i)^{\frac{\varepsilon-1}{\varepsilon}}} \quad (16)$$

which implies that period profits can be written as

$$\pi_t = \frac{y_t(i)^{1-\frac{1}{\varepsilon}}}{\sum_{i=1}^{N_t} y_t(i)^{\frac{\varepsilon-1}{\varepsilon}}} \frac{EXP_t}{P_t} - w_t(i) n_t(i) h_t(i) - kv_t(i) \quad (17)$$

and the constraint (15) is replaced by $A_t n_t(i) h_t(i) = y_t(i)$.

In what follows we distinguish between producers according to their period of entry. We define as new firms those producing units which entered the market in period $t - 1$ and at time t produce for the first time.¹⁶ The term incumbent firms refers, instead, to producers which entered the market in period $t - 2$ or prior. The distinction is relevant because new firms have no beginning of period workforce. Nevertheless, in a separate appendix we show that all producing firms in the Cournot equilibrium, independently of the period of entry, have the same size, impose the same markup over a common marginal cost and have the same individual level of production. For this reason in what follows we drop the index i denoting variables relative to the individual firm. Optimal pricing implies that the relative price chosen by firms is

$$p_t = \mu_t MC_t \quad (18)$$

where are nominal marginal costs, and μ_t the endogenous markup,

$$\mu_t = \frac{\varepsilon}{(\varepsilon - 1)} \frac{N_t}{(N_t - 1)} \quad (19)$$

Notice that the markup is decreasing in the degree of substitutability between products θ , with an elasticity $\epsilon_\theta = 1/(\theta - 1)$. The markup remains positive for any degree of substitutability, since even in the case of homogenous goods, we have $\lim_{\theta \rightarrow \infty} \mu(\theta, N_t) = N_t/(N_t - 1)$.

¹⁶Recall that just a fraction $(1 - \delta)$ of time $t-1$ entrants start producing in period t .

1.4.1 Job Creation Condition

The first order condition (FOC) with respect to vacancies reads as

$$\phi_t = \frac{\kappa}{q_t} \quad (20)$$

Thus, the firm sets the value of the marginal worker, ϕ_t , equal to the expected cost of hiring the worker, $\frac{\kappa}{q_t}$. The FOC with respect to employment reads as

$$\phi_t = (mc_t A_t h_t - w_t h_t) + \varrho E_t \Lambda_{t,t+1} \phi_{t+1} \quad (21)$$

Condition (21) implies that the value of the marginal worker is represented by the profits associated to the additional worker, the term in brackets, plus the continuation value. Next period, with probability ϱ the match is not severed. In this event the firm obtains the future expected value of a job. Combining the latter two equations delivers the Job Creation Condition (JCC)

$$\frac{\kappa}{q_t} = \left(\frac{1}{\mu_t} A_t h_t - w_t h_t \right) + \varrho E_t \Lambda_{t,t+1} \frac{\kappa}{q_{t+1}} \quad (22)$$

where we used the pricing condition to substitute for $mc_t = \frac{1}{\mu_t}$. Since the ratio $\frac{1}{\mu_t}$ increases in the number of firms, it follows that competition leads to a rise in the marginal cost and hence in the equilibrium marginal revenue. For this reason the marginal revenue product of labor (MRP), given by $\frac{1}{\mu_t} A_t h_t$, also rises with competition. Thus, stronger competition promotes the creation of vacancies and employment due to its positive effect on the MRP of labor.

1.4.2 Hiring policy

Let π_t^{new} and v_t^{new} be, respectively, the real profits and the number of vacancies posted by a new firm. Symmetrically, π_t and v_t define, respectively, the individual profits and vacancies posted by an incumbent producer. New firms and incumbent firms are characterized by the same size, n_t . Thus, the optimal hiring policy of new firms, which have no initial workforce, consists in posting at time t as many vacancies as required to hire n_t workers. As a result $v_t^{new} = \frac{n_t}{q_t}$. Since $n_t = \varrho n_{t-1} + v_t q_t$, it has to be the case that

$$v_t^{new} = v_t + \varrho \frac{n_{t-1}}{q_t} \quad (23)$$

Hence, a new firm posts more vacancies than an incumbent producer. For this reason, and given vacancy posting is costly, the profits of new firms are lower than those of incumbent firms. To see this, notice that

$$\pi_t^{new} = y_t - w_t h_t n_t - k v_t^{new} \quad (24)$$

Substituting equation (23) in the latter delivers

$$\pi_t^{new} = (y_t - w_t h_t n_t - \kappa v_t) - k \frac{\varrho n_{t-1}}{q_t} = \pi_t - k \frac{\varrho n_{t-1}}{q_t} \quad (25)$$

The last equality follows from the fact that the term in the round bracket represents the profits of an incumbent producer, π_t . Consistently with the U.S. empirical evidence in Haltiwanger et al. (2010) and Cooley and Quadrini (2001), a young firm creates on average more new jobs than a mature firm and distributes lower dividends.

1.4.3 Endogenous Entry

In each period the level of entry is determined endogenously to equate the value of a new entrant, V_t^e , to the entry cost

$$V_t^e = \psi \quad (26)$$

Notice that perspective new entrants have lower value than producing firms because they will have, in case they do not exit from the market before starting production, to set up a workforce in their first period of activity. The difference in the value between a firm which is already producing and a perspective entrant is, in fact, the discounted value of the higher vacancy posting cost that the latter will suffer, with respect to the former, in the first period of activity. Formally

$$V_t = V_t^e + \kappa \varrho E_t \Lambda_{t,t+1} \frac{n_t}{q_{t+1}} \quad (27)$$

where V_t is the value of a producing firm (both new firms and incumbent firms) at time t .

1.5 Bargaining over Wages and Hours

As in Trigari (2009), individual bargaining takes place along two dimensions: the real wage and the hours of work. We assume Nash bargaining. That is, the firm and the worker choose the wage w_t and the hours of work h_t to maximize the Nash product

$$(\phi_t)^{1-\eta} (\Gamma_t C_t)^\eta \quad (28)$$

where ϕ_t is firm value of having an additional worker, while $\Gamma_t C_t$ is the household's surplus expressed in units of consumption. The parameter η reflects the parties' relative bargaining power. The FOC with respect to the real wage is

$$\eta \phi_t = (1 - \eta) \Gamma_t C_t \quad (29)$$

Using the definition of ϕ_t in equation (21) and that of Γ_t given by equation (5), after some manipulations, yields the wage equation

$$w_t h_t = \eta \left(\frac{1}{\mu_t} A_t h_t + \frac{\kappa}{(1-\delta)} E_t \Lambda_{t,t+1} \theta_{t+1} \right) + (1-\eta) \left(b + \chi C_t \frac{h_t^{1+1/\varphi}}{1+1/\varphi} \right) \quad (30)$$

where we used $\frac{z_t}{q_t} = \theta_t$, $\Lambda_{t,t+1} = (1-\delta) \beta \left(\frac{C_{t+1}}{C_t} \right)^{-1}$ and $mc_t = \frac{1}{\mu_t}$. The wage shares costs and benefits associated to the match according to the parameter η . The worker is rewarded for a fraction η of the firm's revenues and savings of hiring costs and compensated for a fraction $1-\eta$ of the disutility he suffers from supplying labor and the foregone unemployment benefits. A distinguishing feature of our approach is that the wage depends on the degree of competition in the goods market. The direct effect of competition on the real wage is captured through the term $\eta \frac{1}{\mu_t} A_t h_t$, which represents the share of the MRP which goes to workers. As discussed above, entry leads to an increase in the ratio $\frac{1}{\mu_t}$ and hence in the MRP. Thus, everything else equal, stronger competition shifts the wage curve up. This result is similar to that in Blanchard and Giavazzi (2003), who find a positive effect of competition on the real wage. The FOC with respect to h_t yields

$$\chi C_t h_t^{1/\varphi} = \frac{1}{\mu_t} A_t \quad (31)$$

Because the firm and the worker bargain simultaneously about wages and hours, the outcome is (privately) efficient and the wage does not play an allocational role for hours. Stronger competition leads to an increase in hours bargained between the workers and firms for the same reasons for which competition positively affects the wage schedule.¹⁷

1.6 Aggregation and Market Clearing

Considering that sectors are symmetric and have a unit mass, the sectoral number of firms and new entrants also represents their aggregate counterpart. Thus, the dynamics of the aggregate number of firms is

$$N_t = (1-\delta) (N_t + N_t^e) \quad (32)$$

The firms' individual workforce, n_t , is identical across producers, hence $L_t = N_t n_t$. The aggregate production function is:

$$Y_t = N_t y_t = A_t L_t h_t \quad (33)$$

¹⁷Notice that we ruled out the possibility of a hiring externality. This simplifies the derivation of the wage equation. Further, Ebell and Haefke (2009) show that the quantitative effect of overhiring is minor.

Total vacancies posted at period t are $v_t^{tot} = (1 - \delta) N_{t-1} v_t + (1 - \delta) N_{t-1}^e v_{t-1}^{new}$, where $(1 - \delta) N_{t-1}$ is the number of incumbent producers and $(1 - \delta) N_{t-1}^e$ is the number of new firms. Aggregating the budget constraints of households we obtain the aggregate resource constraint of the economy

$$C_t + \psi N_t^e + \kappa v_t^{tot} = w_t h_t L_t + \Pi_t \quad (34)$$

which states that the sum of consumption and investment in new entrants must equal the sum between labor income and aggregate profits, Π_t , distributed to households at time t . Aggregate profits are defined as

$$\Pi_t = (1 - \delta) N_{t-1} \pi_t + (1 - \delta) N_{t-1}^e \pi_t^{new} \quad (35)$$

Goods' market clearing requires

$$Y_t = C_t + N_t^e \psi + \kappa v_t^{tot} \quad (36)$$

Finally, the dynamics of aggregate employment reads as

$$L_t = (1 - \delta) \varrho L_{t-1} + q_t v_t^{tot} \quad (37)$$

which shows that workers employed into a firm which exits the market join the mass of unemployed. The Appendix lists the full set of equilibrium conditions for the economy.

1.7 Calibration

Calibration is conducted on a quarterly basis as in Shimer (2005) and Blanchard and Galí (2010) among others.¹⁸ The discount factor, β , is set to the standard value of 0.99, while the rate of business destruction, δ , equals 0.025 to match the U.S. empirical level of 10 percent business destruction a year reported by BGM (2012). The baseline value for the entry cost is set to one, which leads to a ratio of investment to output close to 15 per cent, as in BGM (2012). With no loss of generality, the value of χ is such that steady state labor supply equals one. In this case the Frisch elasticity of labor supply reduces to φ , to which we assign a value of 1/2 in line with the evidence. We take as the baseline value for the intersectoral elasticity of substitution $\varepsilon = 20$. This leads to a steady state markup equal to 28 percent. This value is within the range estimated by Oliveira Martins and Scarpetta (1999) for a large number of U.S. manufacturing sectors. Technology is assumed to follow a first order autoregressive process given by $\hat{A}_t = \rho_A \hat{A}_{t-1} + \varepsilon_{At}$, where $\hat{A}_t = \ln(A_t/A)$ and $\rho_A \in (0, 1)$ and ε_{At} is a white noise disturbance, with zero expected value and standard deviation σ_A . As

¹⁸The computation of the steady state is in the Appendix.

standard in the literature we set the steady state marginal productivity of labor, A , to 1. We calibrate the productivity process in order to mimic the dynamic of labor productivity obtained from our VAR estimates. This requires setting $\rho_A = 0.9$ and standard deviation $\sigma_A = 0.0035$. Next we turn to parameters that are specific to the search and matching framework. The aggregate separation rate is $1 - (1 - \delta) \varrho$. We set ϱ such that the latter equals 0.1, as suggested by estimates provided by Hall (1995) and Davis et al. (1996). The elasticity of matches to unemployment is $\gamma = \frac{1}{2}$, within the range of the plausible values of 0.5 to 0.7 reported by Petrongolo and Pissarides (2001) in their survey of the literature on the estimation of the matching function. In the baseline parameterization we impose symmetry in bargaining and set $\eta = \frac{1}{2}$, as in the bulk of the literature. We then set the efficiency parameter in matching, γ_m , and the steady state job market tightness to target an average job finding rate, z , equal to 0.7 and a vacancy filling rate, q , equal to 0.9. We draw the latter value from Andolfatto (1996) and De Haan et al. (2000), while the former from Blanchard and Galì (2010). Notice that a job finding rate equal to 0.7 corresponds, approximately, to a monthly rate of 0.3, consistent with the U.S. evidence. Since we consider a labor-leisure choice, the overall replacement rate is given by the sum between the unemployment insurance benefit and the disutility cost of working. We calibrate the latter to 0.75. The cost of posting a vacancy κ is obtained by equating the steady state version of the JCC and the steady state wage setting equation. The steady state rate of unemployment is equal to $u = \frac{1 - (1 - \delta) \varrho}{q\theta + (1 - (1 - \delta) \varrho)} = 0.125$, which is increasing in the rate, δ , of business destruction and in the exogenous, firm-level job separation rate, ϱ . As expected the unemployment rate is decreasing in the job filling probability q . The endogenous steady state rate of unemployment is higher than the observed U.S. rate. However it can be justified by interpreting the unmatched workers in the model as being both unemployed and partly out of the labor force. As argued by Trigari (2009), this interpretation is consistent with the abstraction in the model from labor force participation choices.¹⁹

Importantly, notice in our model the steady state ratio between jobs

¹⁹Krause and Lubik (2007) calibrate their model to deliver an unemployment rate of 12 per cent on the basis of this motivation. Many studies in the search and matching literature feature much higher unemployment rates. For example Andolfatto's (1996) model features a steady state unemployment rate of 58 per cent, while Trigari (2009) is characterized by an unemployment rate equal to 25 per cent.

created by new firms (JC^{new}) and total job creation (JC) is given by

$$\frac{JC^{new}}{JC} = \frac{(1 - \delta) N^e v^{new} q}{v^{tot} q} = \frac{\delta}{\theta q} \frac{(1 - u)}{u}$$

for the calibration used this implies that job creation by new producers account for about 25 per cent of total (gross) job creation, close to the quarterly U.S. average of 20 per cent reported by Jaimovich and Floetotto (2008). Finally, notice that the ratio between workers employed by first period incumbent firms (L^{new}) and total employment (L) is

$$\frac{L^{new}}{L} = \frac{(1 - \delta) N^e \frac{L}{N}}{L} = \delta$$

Thus, since we set $\delta = 0.025$ this implies that new firms account for about 2.5 percent of total employment, slightly lower than the 3 percent reported by Haltiwanger et al. (2010) as the average value for the U.S. between 1976 and 2005. To sum up, in our model new entrants create on average a relevant fractions of new jobs while accounting just for a small share of overall employment, thus being in accordance with US data.

2 Business Cycle Analysis

In what follows we will study the impulse response functions (IRFs) to a productivity shock, and then we will evaluate the second order moments. We compare the performance of the Cournot model to two alternative models: i) the "Standard Search" model. This is a version of our model with no entry costs, where each firm has a single worker and where goods market are characterized by monopolistic competition. In this case the dynamics of the number of firms is the same as the dynamics of aggregate employment and the price markups is constant; ii) the "Entry-Only" model. This is a version of our model characterized by monopolistic competition. The Entry-Only model isolates the role played by strategic interaction, i.e. by markup variability, for the dynamics of the variables in which we are interested.

Importantly, the calibration strategy is identical across the models. In particular, the replacement rate, which is known to be relevant for the propagation of technology shocks on labor market variables, is held constant across models.

2.1 IRFs to a Technology Shock

Figure 2 is the model counterpart of Figure 1. It depicts the IRFs of the same variables considered in Figure 1 in response to a one standard

deviation productivity shock in the alternative frameworks we consider. Time on the horizontal axis is in quarters.²⁰

Solid lines represent percentage deviations from the steady state of variables in response to a one standard deviation productivity shock in the Cournot model, dashed lines show the same responses in the Entry Only model and dotted lines represent the IRFs of the Standard Search model. The response of labor productivity is common across models.

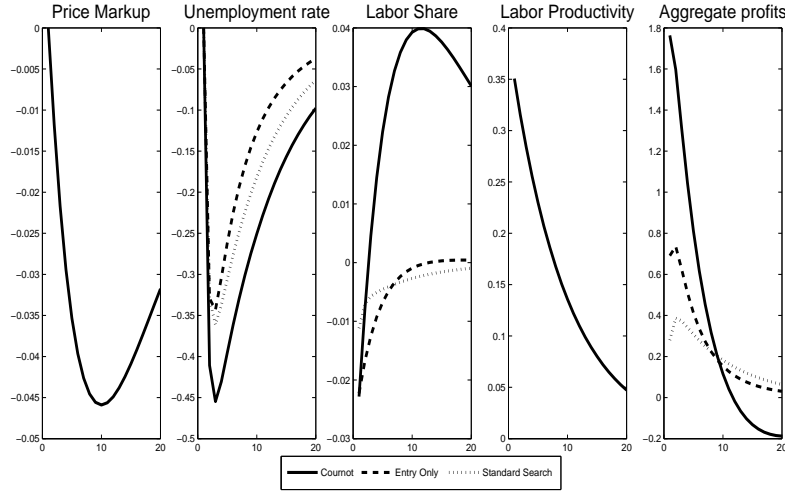


Figure 2: Responses of price markup, unemployment rate, labor share of income, labor productivity and aggregate profits to a one standard deviation technology shock under alternative models.

The Cournot model reproduces the estimated dynamics of the price markup, aggregate profits, the unemployment rate and the labor share of income. In particular, unemployment and price markups are countercyclical, while aggregate profits are procyclical. The response of aggregate profits is consistent with the evidence reported in Figure 1. Indeed, as in the structural VAR, profits increase by about 2 percent on impact and then revert inertially to their initial level slightly undershooting their long run value. The response of aggregate profits is instead moderate in the two alternative models. Further, in line with our VAR, and

²⁰The empirical response of real GDP, real consumption and vacancies display a positive response on impact and revert in a hump-shaped fashion to the baseline afterwards. Our models, as well as the benchmark Search model, do not capture the hump shaped response pattern. Incorporating habits in consumption would presumably help resolving the problem for GDP and consumption, while sunk costs for vacancy creation could help matching the response of vacancies, as argued by Fujita and Ramey (2007).

also with the empirical evidence reported by Rios-Rull and Santaaulàlia-Llopis (2010), the Cournot model replicates the dynamics of labor share of income, which is countercyclical on impact and overshoots its long run value for several periods. The response of unemployment is countercyclical in the three models, but amplified in the Cournot framework. Recall that the Cournot framework and the "Entry Only" model differ just because of the price markup variability, which is thus the source of the amplification.

Figure 3, where lines have the same meaning as in Figure 2, helps understanding the transmission mechanism of technology shock in our models.

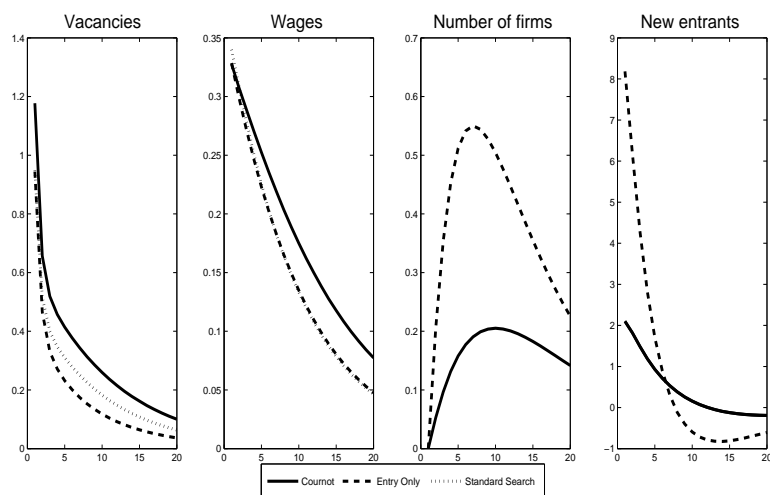


Figure 3: Responses of Aggregate Profits, Real Vacancies, Wage, New Entrants and the Number of Firms to a one standard deviation technology shock under alternative models.

A positive technology shock creates expectations of future profits which lead to the entry of firms. New firms post a large amount of vacancies to reach their desired size. This results in a stronger and more persistent response of unemployment with respect to that delivered by the Standard Search model, as displayed in Figure 2. Given entry is subject to a one period time-to-build lag the total number of firms, N_t , does not change on impact, but builds up gradually.²¹ Figure 2 shows that in the Cournot framework, stronger competition translates into a lower markup, which reaches its negative peak after few periods and then gradually reverts

²¹In the Standard Search model there is no meaningful distinction between firms and workers. For this reason we do not report the dynamics of N_t , N_t^e and individual employment for the Standard Search model.

to the steady state. This leads to the countercyclical and overshooting dynamics of the labor share.

Notice that markup countercyclicality is essential to obtain the overshooting of the labor share. To see this, consider the definition of the labor share of income $ls_t = w_t \frac{L_t h_t}{Y_t}$, which in log deviations amounts to $\hat{ls}_t = \hat{w}_t - (\hat{Y}_t - \hat{L}_t - \hat{h}_t) = \hat{w}_t - \hat{A}_t$. In log-linear terms, the labor share equals the difference between the real wage and productivity. Bargaining over wages implies that only a fraction η of the increase in productivity goes to workers. As a result $\hat{w}_t < \hat{A}_t$ on impact, and the labor share is countercyclical on impact. This is common across the models we consider, as shown in Figure 2. However, just in the oligopolistic framework the labor share overshoots its long run value, consistently with the VAR evidence. The overshooting is strictly related to the shape of the response of the price markup. Equation (30) shows that a persistently lower markup acts as a shifter of the standard marginal product of labor allowing the real wage to rise relative to the average productivity of labor for several periods. Since $\hat{ls}_t = \hat{w}_t - \hat{A}_t$, this explains the overshooting of the labor share.

2.2 Second Moments

To further assess the implications of endogenous market structures for the business cycle, we compute second moments of some relevant macroeconomic variables in response to a one standard deviation technology shock. Table 1 reports the standard deviation, autocorrelation and correlation with output for four key variables: the unemployment rate, aggregate profits, the price markup and the labor share of income. The standard deviations are normalized relative to that of output.

Panel A of Table 1 reports estimates of conditional correlation between variables. Conditional cross correlations are obtained from our baseline VAR model. Notice that the dynamic pairwise cross correlation conditional on shock i , $\rho_{xy/i}$, between variables x and y is computed as follows. Let $\Psi_T^{x/i}$ be the vector containing the median of the distribution of impulse response of variable x to shock i over a time horizon of T periods, then

$$\rho_{xy/i} = \frac{\sum_{j=1}^T \Psi_T^{x/i}(j) \Psi_T^{y/i}(j)}{\sqrt{\text{var}(x/i) \text{var}(y/i)}} \quad (38)$$

where $\text{var}(x/i) = \sum_{j=1}^T \left(\Psi_T^{x/i}(j) \right)^2$ and $\text{var}(y/i) = \sum_{j=1}^T \left(\Psi_T^{y/i}(j) \right)^2$.²² In the same Table we report the moments produced by the models con-

²²We set T=100 in our computations.

sidered in the previous section, namely the Standard Search model, the Entry-Only model and the Cournot model.

In terms of quantitative performance, we find no relevant difference between the Standard Search model and the Entry-Only model. By construction both cannot address markup countercyclicality, and thus cannot capture the dynamic correlation between output and the labor share of income, as well as the relative standard deviation of the latter. On the contrary, the Cournot model matches fairly well the relative variability of the price markup and that of the labor share of income. Further, as argued above, markup countercyclicality allows the Cournot framework to match the sign of the dynamics correlation between the labor share of income and output. This is not the case in the standard search model and in the Entry-Only model, where the sign of the correlation is the opposite of the empirical one.²³ Further, the Cournot model does slightly better than the standard search model at addressing the relative variability of unemployment and the negative dynamic correlation with output. All models underestimate the relative variability of profits. However, the Cournot model offers a better performance with respect to other models also in this respect, suggesting that the market structure matters to explain the variability of aggregate profits. Explaining the variability of aggregate profits is notoriously difficult, as argued by Lewis and Poilly (2012).

We see the performance of our Cournot model as a relative success. First, our model can explain stylized facts about which the benchmark search model is silent. Second to the best of our knowledge, our model is the first that can account for the joint dynamics of profits, the price markup and the labor share of income in response to a technology shock. Third, in response to the shock, it delivers the same performance of the standard search model at addressing the relative variability and contemporaneous correlation of the unemployment rate with output, while it outperforms it at explaining the variability of the other variables considered. For these reasons we claim that endogenous market structures are a relevant transmission channel of technology shocks in an otherwise standard model of search in the labor market.

3 Conclusions

We provide VAR evidence for the US economy suggesting that an expansionary technology shock leads to a decrease in the unemployment rate and in the price markup, together with an increase in aggregate prof-

²³Notice that the contemporaneous correlation between the labor share of income and real GDP is negative, in the data as well as in all the models we consider. As already mentioned, the labor share is countercyclical on impact.

	u	π	μ	ls
A: Empirical Conditional Moments				
Std(x)/Std(Y)	0.23	1.92	0.28	0.15
Corr. with Y	-0.60	0.66	-0.42	0.12
B: Standard Search				
Std(x)/Std(Y)	0.15	0.06	–	0.02
Corr. with Y	-0.90	0.99	-	-0.98
C: Entry Only				
Std(x)/Std(Y)	0.11	0.08	–	0.03
Corr. with Y	-0.85	0.99	-	-0.93
D: Cournot				
Std(x)/Std(Y)	0.16	0.19	0.25	0.13
Corr. with Y	-0.87	0.85	-0.64	0.44

Table 1: Standard deviations of the main macroeconomic variables. All standard deviations are relative to that of output

its. In response to the shock, the labor share of income falls on impact, overshoots its long-run level and returns to its initial level after several periods.

To match these facts, we develop a DSGE model where endogenous market structures and matching frictions in the labor market interact endogenously. We account for strategic interactions among producers and for the extensive margin of job creation due to entry and exit of firms from the market. Strategic interactions in the form of Cournot competition imply that the price markup depends negatively on the number of competitors in the market. Since the latter is procyclical in the model, as in the data, the price markup is countercyclical. Thanks to this mechanism our model delivers IRFs to a technology shock which are qualitatively consistent with the empirical ones. Further, we show that the Cournot model quantitatively outperforms both the standard labor search model and a model characterized by constant markups in replicating business cycle moments of the main macroeconomics variables in response to a productivity shock. For these reasons we argue that the price markup countercyclicality delivered by our model with Cournot competition in the goods market is a key factor to jointly account for the empirical facts we have documented.

Our analysis could be extended in various dimensions. One aspect we neglect is the asymmetry between market competitors in terms of both size and the probability of exit from the market. Davis et al. (2009)

document that the distribution of vacancy creation is strongly biased in favor of small firms; Haltiwanger et al. (2010) show that younger firms are more likely to exit from the market than more mature firms. Implementing these features in the model is left for future research.

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