Labor market imperfections, real wage rigidities and financial shocks*

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Abstract

By using the recent Gertler and Kiyotaki's (2010) setup, this paper explores the interaction between real distortions stemming from the labor market institutions and financial shocks. We find that neither labor market imperfections nor fiscal institutions determining tax wedges have an impact on the volatility of the real economy induced by a financial shock. By contrast, real wage rigidities matter as they amplify the financial shock effects. Thus, economies with larger imperfections will not systematically observe larger or smaller recessions, unless a causality between imperfections and real wage rigidities is introduced.

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1 Introduction

The recent crisis has been considered by most economists to be the worst financial crisis since the Great Depression of the 1930s. Not surprisingly the event has stimulated important debates in policy and academic arenas. One of the specific issues tackled is the interaction between financial shocks and labor market institutions.

Costain *et al.* (2010), Darius *et al.* (2010), Guichard and Rusticelli (2010) and Schulze-Cleven and Farrell (2010) e.g. discuss some mixed evidence concerning the fact that economies characterized by more competitive labor markets

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seem to have suffered more in terms of unemployment after the recent financial crunch. Bentolila *et al.* (2009) point out that the main root of the different performance of France and Spain[1] can be found in the different labor market structures in the two countries.[2] Their argument is simple. Quantitative rigidities (e.g., hiring and firing costs) reduce unemployment volatility, as they prevent adjustments by varying employment. Comparing Spain to France, in the former there is a larger gap between the dismissal costs of workers with permanent and temporary contracts.[3]

OECD data indeed broadly support the idea that economies with imperfect labor markets have been hit less by the crisis. Spain, Ireland and United States are experiencing high increases in their unemployment rates, whereas Germany, France and Italy are suffering less. It seems therefore important to go beyond anecdotal evidence and analyze the potential interactions between labor markets and financial shocks by means of a formal model taking account of the financial transmission mechanism. Understanding phenomena such as the recent financial crisis and the subsequent policy responses in fact "requires the use of a macroeconomic framework in which financial intermediation matters for the allocation of resources." (Woodford, 2010: 21). Our aim is thus to explore the interaction between real distortions stemming from the labor market institutions and financial shocks in a formal setup explicitly designed to model financial disturbances.

An appropriate framework to study the financial shock transmission mechanisms has been recently developed by Gertler and Karadi (2009) and Gertler and Kiyotaki (2010), as an extension of the original modeling of the financial accelerator based on the cyclical variations of the value of collaterals, by Bernanke *et al.* (1996).[4] Gertler and Karadi (2009) and Gertler and Kiyotaki (2010) show that if, due to an agency problem between bankers and depositors, bankers are constrained in the amount of credit they can provide to investing firms, disturbances to the quality of capital induce a credit drop and a significant downturn in economic activity by creating capital losses in the financial sector.

By using a simplified version of the above framework, we analyze the possible interactions between financial shocks and labor market institutions. In particular, our focus is on real factors, in particular we consider the potential role of labor market imperfections and real wage rigidities. The former derive from all those factors having an influence on the size of the "labor wedge" and

[1] Unemployment rate dramatically rose from 8% in 2007 to 20% in 2009 in Spain, whereas it rose only slightly in France.

[2] However, they also stress the role of other factors, e.g. the different housing markets.

[3] Wasmer and Weil (2004) and Hristov (2008) find complementarity between financial shocks and labor maker institutions. See also Acemoglu (2001) and Pagano and Pica (2010) for a more general picture.

[4] Bernanke *et al.* (1996) first introduced a formal model of financial accelerator in a dynamic stochastic general equilibrium model with consumers-lenders and firms-borrowers and no financial intermediation. A "bank channel" was not added until the eruption of the crisis, when a new wave of models of economies with financial frictions emerged (see Goodfriend and Mac Callum, 2007; Angeloni and Faia, 2009; Cùrdia and Woodford, 2009; Dib, 2009; Gertler and Kiyotaki, 2010; Christiano *et al.,* 2010; Gerali *et al.,* 2010; Iacoviello, 2010; Meh and Moran, 2010).

thus impinging on the steady state of the economy. In more detail, we assume monopolistic competition in the labor market and potentially strategic non-atomistic wage-setters, who may coordinate their decisions. The "labor wedge" depends on these institutions and also on the tax wedge.[5] Real wage rigidities instead have to do with factors having an impact on the pattern of adjustment over time of real wages after the economy is hit by stochastic disturbances, e.g. bargaining system regulations, hiring and firing costs, or wage contract duration, rules presiding over the possibility to revise the wage rate in the face of unexpected circumstances.[6]

In a nutshell, we find that only institutions affecting real wage rigidities matter, as only these amplify the reaction of the economy to financial instability. By contrast, unionization, fiscal structure, union coordination and monopoly power have no effect on the financial crisis dynamics. A sort of neutrality of these labor market imperfections as regards the reaction of the economy to financial disturbances thus emerges, but real wage rigidities interact with financial frictions amplifying the effects of financial shocks. Therefore, in the debate on the effect of labor markets on financial shocks, it is important to distinguish between the different institutions and, in particular, to detect their influence on the real wage adjustment mechanism.

The rest of the paper is organized as follows. Section 2 describes our model. Section 3 provides some numerical simulations to describe our main results and provides their intuition. Specifically, we first show our result of neutrality for the labor market imperfections with respect to the financial-shock-driven fluctuations and then we investigate the impact of real wage rigidities. A final section concludes.

2 The model

Our core framework is a real business cycle model with distorted labor and financial markets and real wage rigidities, based on Gertler and Kiyotaki (2010). We consider a simple setup assuming no idiosyncratic uncertainty for producing firms and homogeneous financial intermediaries.[7] Households consist of both workers and bankers and perfect consumption insurance among them is guaran-

[5] The importance of the labor wedge from either a long run or a business cycle perspective has been highlighted by many authors. See, among others, Hall (1997), Cole *et al.* (2002), Mulligan (1998, 2002), Prescott (2004), Galì *et al.* (2007), Chari *et al.* (2007), Acocella *et al.* (2008) and Shimer (2009). Full discussion is beyond the scope of the present paper.

[6] See Layard *et al.* (1991) and Belot and Van Ours (2001) for a more detailed discussion about imperfections, real rigidities and labor market institutions. Regarding their relevance, in particular for Europe, see ECB (2009) and references therein. Among others, Du Caju *et al.* (2008), Christoffel *et al.* (2009), Rumler and Scharler (2009), Abbritti and Weber (2010), Knell (2010), Guichard and Rusticelli (2010).

[7] This setup developed by Gertler and Karadi (2009) mimics a frictionless interbank market with idiosyncratic shocks, as in the Lucas island model (see Gertler and Kiyotaki, 2010). Results can be easily extended to the case of interbank frictions. However, Gertler and Kiyotaki (2010) shows that this extension will only have quantitative effects with respect to the frictionless case (or homogeneous case).

teed. We consider a non-competitive labor market with strategic wage setters and real wage rigidities. In this market, workers supply hours to non-financial firms and return wages to the household. Similarly, bankers transfer profits earned from the financial activity back to their family. Homogeneous banks intermediate funds between households and non-financial firms in the financial market,[8] facing endogenously determined balance sheet constraints due to an agency problem. Banks provide funds against future profits of the firms which are able to offer perfect state contingent debt. Thus we can think of the banks' claims as equities.[9] Competitive non-financial firms produce output by means of capital and labor. Finally, competitive capital producing firms owned by the households are also introduced.

2.1 Households

In the economy there is a continuum of infinitely lived households indexed by i on the unit interval $(0,1)$; each of them supplies a differentiated labor type. Preferences of households are defined over consumption ($C_{t,i}$) and hours worked ($L_{t,i}$):

$$E_0 \sum_{t=0}^{\infty} \beta^t U\left(C_{t,i}, L_{t,i}\right) = E_0 \sum_{t=0}^{\infty} \beta^t [\ln(C_{t,i} - hC_{t-1,i}) - \frac{\chi}{1+\varepsilon} L_{t,i}^{1+\varepsilon}] \tag{1}$$

with $\beta \in (0,1)$. h is the habits in consumption parameter, χ measures the relative weight of the labor argument and ε is the inverse Frisch elasticity of labor supply.

The household budget constraint at time t is:

$$C_{t,i} = (1-\tau_L)\, W_{t,i} L_{t,i} + \Pi_{t,i} + R_t D_{t-1,i} - D_{t,i} - T_t \tag{2}$$

where $D_{t-1,i}$ is the total quantity of short term debt the household acquires from banks or government in the form of real bonds that pay the gross real return R_t over the period from $t-1$ to t; $W_{t,i}$ is the real wage, $\Pi_{t,i}$ is the net payout to the household from ownership of both non-financial and financial firms;[10] T_t is a lump sum tax; τ_L indicates the labor income tax rate.

Households first order conditions imply a standard Euler condition:[11]

$$1 = \beta E_t \frac{U_{Ct+1}}{U_{Ct}} R_{t+1} \tag{3}$$

where U_C is the marginal utility of consumption which is defined as follows:

$$U_{Ct} \equiv \frac{1}{C_t - hC_{t-1}} - \frac{\beta h}{C_{t+1} - hC_t}$$

[8] Households can lend money to the banks or fund the government debt. Both deposits and government debts are one period riskless financial activities, i.e. perfect substitutes. This implies that credit rationing only affects banks in collecting deposits, as household can lend to them or the government.

[9] In other words bank loans have the same value as firms' equities.

[10] Note that $\Pi_{t,i}$ is net of the transfer the household gives to its members that enter banking at time t.

[11] Index i is dropped for simplicity.

Thus, $\Lambda_{t,t+1} = \beta \frac{U_{Ct+1}}{U_{Ct}}$ is the household's discount factor. The condition about the optimal labor supply will be introduced at a later stage, when we consider the labor market.

2.2 The Real Sector

2.2.1 Final good producing firms

The economy is populated by a continuum of symmetric competitive good producing firms indexed by f on the unit interval $(0,1)$; they employ both capital (K_{t-1}) and labor (L_t) as inputs. Each firm produces perfectly substitutable goods given a Cobb-Douglas production function:

$$Y_{t,f} = A_t K_{t-1,f}^{\alpha} {L_{t,f}}^{1-\alpha} \tag{4}$$

where $A_t = exp\,(a_t)$ is an aggregate productivity shock, with $a_t = \rho_a\, a_{t-1} + u_t$, and u_t a *i.i.d.* normal variable and $L_{t,f}$ denotes a labor bundle of imperfect substitutable labor types distributed over a unit interval, represented by:

$$L_{t,f} = \left[\int_0^1 L\,(i)_{t,f}^{\frac{\eta-1}{\eta}}\, di \right]^{\frac{\eta}{\eta-1}} \tag{5}$$

where η is a measure of the wage setters' monopoly power (i.e., the intratemporal elasticity of substitution across different labor inputs).

For any given level of its labor demand, $L_{t,f}$, each firm must decide the optimal allocation across labor inputs, subject to the aggregation technology (5). From the minimization cost problem solution, demand for labor type i by firm f is then:

$$L(i)_{t,f} = \left(\frac{(1+\tau_S)\, W_t\,(i)}{W_t} \right)^{-\eta} L_{t,f} \tag{6}$$

where τ_S is the payroll tax rate and

$$W_t = \left[\int_0^1 W_t\,(i)^{1-\eta}\, di \right]^{\frac{1}{1-\eta}} \tag{7}$$

is the average real wage index.

Firms equate the marginal productivity of labor to the wage. As firms are symmetric we can just drop the index f and obtain aggregate labor demand:

$$L_t = \left(\frac{(1+\tau_S)\, W_t}{A_t K_{t-1}^{\alpha}\,(1-\alpha)} \right)^{-\frac{1}{\alpha}} \tag{8}$$

or

$$W_t = \frac{1-\alpha}{1+\tau_S} \frac{Y_t}{L_t} \tag{9}$$

As far as capital services demand is concerned, we observe that the gross profit per unit of capital Z_t is given by:

$$Z_t = \frac{Y_t - (1 + \tau_S) W_t L_t}{K_t} = \alpha A_t \left(\frac{L_t}{K_t}\right)^{1-\alpha}. \tag{10}$$

Firms are financed by banks, who collect the savings of households. Firms buy new capital goods from capital producers by issuing state-contingent equities at price Q_t and committing to pay the flow of future gross capital profits to the banks.

2.2.2 Capital producing firms

There is a continuum of length one of competitive capital producing firms.[12] They transform one unit of final good into one unit of capital good (priced Q_t) subject to a flow adjustment cost. Thus, the representative capital producing firm maximizes the following expected present discounted value of future profits:[13]

$$E_t \sum_{t=0}^{\infty} \Lambda_{t,t+1} \left((Q_t - 1) I_t - f\left(\frac{I_t}{I_{t-1}}\right) I_t \right)$$

where I_t is the production (i.e., investment) and $f(.)$ is the adjustment cost function. We assume that $f(1) = f'(1) = 0$ and $f''(I_t/I_{t-1}) > 0$; $f(I_t/I_{t-1}) I_t$ is physical adjustment costs.

Profit maximization implies:

$$Q_t = 1 + f\left(\frac{I_t}{I_{t-1}}\right) + \frac{I_t}{I_{t-1}} f'\left(\frac{I_t}{I_{t-1}}\right) - E_t \Lambda_{t,t+1} f'\left(\frac{I_{t+1}}{I_t}\right)\left(\frac{I_{t+1}}{I_t}\right)^2 \tag{11}$$

The law of motion for capital is given by:

$$K_{t+1} = \Psi_{t+1} \left(I_t + K_t \, (1 - \delta) \right) \tag{12}$$

where δ is the capital depreciation rate and $\Psi_t = exp(\psi_t)$ is a capital quality shock, i.e., an exogenous source of variation in the value of capital; $\psi_t = \rho_\psi \psi_{t-1} + \varepsilon_t$ and ε_t is a *i.i.d.* normal variable with zero mean and finite variance, σ^2.[14]

2.2.3 Labor markets

Differently from Gertler and Kiyotaki (2010), the labor market is not competitive as each worker sells a different kind of labor. Each wage-setter bargains over the real wage, taking other workers' decisions as given. However, wage setting

[12] Firms' indices are dropped for simplicity.

[13] Capital producing firms earn no profits in steady state; when fluctuations occur they redistribute profits directly to the households who own capital producing firms.

[14] See Gertler and Karadi (2009), Brunnermeier and Sannikov (2009) and Gourio (2009) for this kind of shock.

might be coordinated to various degrees.[15] The coordination degree is captured by the parameter n^{-1} in the following way. Each wage-setter (indexed by j, with $j = 1, ...n$) acts on behalf of a length n^{-1} of workers. More specifically, each union j set the wage $W_{t,j}$ of the agent $i \in j$, (i.e., $W_{t,i} = W_{t,j}$ if $i \in j$) so as to maximize his utility in (1), subject to the budget constraint (2), (6) and (8).

In fact, by (7), in the decentralized equilibrium each union j anticipates that

$$\frac{\partial W_t}{\partial W_{t,j}} = \frac{\partial}{\partial W_{t,j}} \left[\int_{i \in j} W_t(i)^{1-\eta} di + \int_{i \notin j} W_t(i)^{1-\eta} di \right]^{\frac{1}{1-\eta}} = \frac{1}{n} \left(\frac{W_{t,j}}{W_t} \right)^{-\eta} \tag{13}$$

At the symmetric equilibrium,[16] the wage-setters' first order conditions yield:

$$0 = E_t \left[\frac{1}{C_{t,i} - hC_{t-1,i}} - \frac{\beta h}{C_{t+1,i} - hC_{t,i}} \right] \left[(\eta - 1)(n-1) + \frac{1-\alpha}{\alpha} \right] + - \chi \frac{(1-\tau_L) L_t^{\varepsilon}}{W_t} \left[\eta (n-1) + \frac{1}{\alpha} \right] \tag{14}$$

This implies that labor supply is

$$W_t^* = -\upsilon E_t \frac{U_{Lt}}{U_{Ct}} \frac{1}{1-\tau_L} \tag{15}$$

where $\upsilon = \frac{1+\alpha\eta(n-1)}{1-\alpha[1-\alpha(\eta-1)(n-1)]}$ denotes the gross wage markup. Observe that our formulation nests alternative labor market regimes, ranging from perfect competition (n, $\eta \to \infty$, $\upsilon = 1$) to monopolistic competition ($n \to \infty$, $1 < \eta < \infty$, $\upsilon = \eta (\eta - 1)^{-1}$), to strategic wage setting ($1 \leq n < \infty, 1 < \eta < \infty$).

Following Blanchard and Galì (2007) and Christoffel and Linzert (2010), we assume that real wages respond sluggishly to labor market conditions in a parsimonious way. Specifically, we assume the following partial adjustment model[17]:

$$W_t = (W_{t-1})^{\kappa} (W_t^*)^{\kappa - 1} \tag{16}$$

where κ is an index of real rigidities.

[15] See, e.g., Gnocchi (2009) for a similar framework. See also Lippi (2003).

[16] We restrict attention to symmetric equilibria where all wage-setters claim the same real wage.

[17] Note that equation (16) is compatible with different theoretical specifications of the labor market. Thus, it permits us to consider the effects real wage rigidities from a general perspective, i.e., abstracting from their roots. On the different sources of real wage rigidities (including right-to-manage, social norms, matching models) see, among others, Blanchard and Katz (1999), Christoffell *et al.* (2006, 2009), Hall (2005), Hall and Milgrom (2008), Christoffel and Linzert (2010).

The labor market clearing condition comes from the labor demand (9) and supply (16), which is subject to a partial adjustment process, unless $\kappa = 0$. Because of the labor market imperfections, in the steady state the ratio between the marginal rate of substitution $(-U_L/U_C)$ and the marginal product of labor (MPL) will be different from one, i.e. a *labor wedge* ϑ will arise:

$$MPL = -\vartheta E_t \frac{U_L}{U_C} \tag{17}$$

where $\vartheta \equiv \upsilon \frac{1+\tau_S}{1-\tau_L}$. This wedge is an increasing function of η and n[18] (i.e., the elasticity of substitution of wage-setters' coordination) and of the tax rates (τ_S and τ_L). In other words, the labor wedge reflects, on the one hand, technology, labor market institutions and the productive structure of a country and, on the other hand, the taxation and social security system. In our setup, an increase in the gross wage markup or in the tax wedge raises the cost of labor (and real wages) and, *coeteris paribus*, lowers employment.[19]

The parameter ϑ is thus a measure of the (permanent) labor market imperfections, whereas κ measures the (temporary) rigidities in the wage adjustment process.

2.2.4 Aggregate resource constraint

The economy-wide resource constraint is:

$$C_t = Y_t - I_t \left[1 + \frac{\gamma}{2} \left(\frac{I_t}{I_{t-1}} - 1 \right)^2 \right] - Y_t \, \bar{g} \tag{18}$$

where $\bar{g}$ is a fixed fraction of income which the government spends financing the expenditure by taxation without any recourse to debt.

2.3 The financial sector

As mentioned above, the representation of the financial sector is borrowed from Gertler and Karadi (2009) and Gertler and Kiyotaki (2010). Banks are owned by households. Each period a fraction σ of bankers survives while a fraction $1-\sigma$ exits and is replaced.[20] Each banker's objective is then to maximize the expected discounted present value of its future flows of net worth n_t, that is:

$$V_t = E_t \sum_{i=1}^{\infty} (1-\sigma)\sigma^{i-1} \Lambda_{t,t+i} n_{t+i} \tag{19}$$

[18] For reasonable values of α and η.

[19] Of course, our simplified model does not capture all relevant channels. For instance, the ultimate effects of tax wedges on employment cannot be unambiguously inferred without considering that the labor taxes might be used to finance policies that foster labor supply.

[20] New bankers are endowed with a fraction $\zeta/(1-\sigma)$ of the value of the assets intermediated by the existing bankers. Indeed, there are different ways to model bankers turnover. See Gertler and Kiyotaki (2010: 10) for a discussion.

Bankers can loan the sum of the bank net worth n_t and deposits d_t to firms or can divert a fraction θ of this sum to their family. Diverting assets can be profitable for the banker who, afterwards, would default on his debt and shut down, and correspondingly represents a loss for creditors who, at most, could reclaim the fraction $1-\theta$ of assets. As a consequence, depositors would restrict their credit to the banks as they realize that the following incentive constraint must hold for the banks in order to prevent them from diverting funds:

$$V_t(s_t, d_t) \geqslant \theta\,(n_t + d_t) \tag{20}$$

i.e., the value of the bank must always be greater than the amount the banks can divert.

Each period, the value of loans funded, $Q_t\, s_t$, must equal the sum of the bank net worth n_t and deposits d_t:

$$Q_t\, s_t = n_t + d_t \tag{21}$$

where s_t is the volume of loans funded. Recall that the bank's loans can be interpreted as firms' equities owned by the bank.

The net worth for the single bank evolves according to:

$$n_t = \Psi_t[Z_t + (1-\delta)\ Q_t]s_{t-1} - R_t d_{t-1} \tag{22}$$

where Z_t is the dividend payment at t on the loans the bank funded at time $t-1$. It is worth noticing that Ψ_t affects the value of the capital of the non financial firms and, in turn, the value of the equities held by the bank.

The solution of the above dynamic optimization problem implies[21]

$$Q_t\, s_t = \phi_t n_t \tag{23}$$

as

$$\mu_t \equiv \frac{v_{st}}{Q_t} - v_t > 0 \tag{24}$$

$$\phi_t = \frac{v_t}{\theta - \mu_t} \tag{25}$$

where ϕ_t is the leverage ratio of the bank; v_{st} is the marginal value of assets for the banks; and v_t is the marginal value of deposits to the bank at time t.

As banks are constrained on the retail deposit market, there will be a positive difference between the marginal value and cost of loans for the banks. Moreover, the marginal value of net worth Ω_t and the gross rate of return on bank assets R_{kt} must obey the following conditions:

$$v_t = E_t\, \Lambda_{t,t+1}\Omega_{t+1}R_{t+1} \tag{26}$$

$$\mu_t = E_t\, \Lambda_{t,t+1}\Omega_{t+1}(R_{kt+1} - R_{t+1}) \tag{27}$$

[21] See Appendix A for details on the derivation.

with[22]

$$\begin{aligned}\Omega_{t+1} &= 1-\sigma+\sigma(v_{t+1}+\phi_{t+1}\mu_{t+1}) &(28)\\ R_{kt+1} &= \Psi_{t+1}\frac{Z_{t+1}+(1-\delta)Q_{t+1}}{Q_t} &(29)\end{aligned}$$

It follows that there will always be an excess return of assets over deposits:

$$E_t\,\Lambda_{t,t+1}\Omega_{t+1}R_{kt+1} > E_t\,\Lambda_{t,t+1}\Omega_{t+1}R_{t+1} \quad (30)$$

Aggregating (23) over all banks,[23] we obtain the sector balance sheet and the demand for assets from the banks:

$$\begin{aligned}Q_t\,S_t &= N_t+D_t &(31)\\ Q_t\,S_t &= \phi_t N_t &(32)\end{aligned}$$

The overall bank lending capacity depends on the aggregate bank capital which, in turn, may be affected by the changing value of the funded assets.

The aggregate net worth (N_t) evolves according to

$$N_t = (\sigma+\zeta)\,\Psi_t[Z_t+(1-\delta)\;Q_t]S_{t-1}-\sigma R_t D_{t-1} \quad (33)$$

The above expression is determined by a double aggregation. We compute the aggregate net worth of new and old bankers using (22) twice and then we sum them up. In detail, we know that the new individual bankers are endowed with a fraction $\zeta/(1-\sigma)$ of the value of the asset intermediated by the exiting bankers (i.e., $(1-\sigma)\,[Z_t+(1-\delta)\;Q_t]S_{t-1}$) while the surviving bankers' net worth is equal to $\sigma[Z_t+(1-\delta)\;Q_t]S_{t-1}$.

Finally, the securities markets clear when ($S_t=K_{t+1}$):

$$S_t = I_t+(1-\delta)K_t \quad (34)$$

This completes the description of the set-up of the model.

[22] The term $\Lambda_{t,t+1}\Omega_{t+1}$ can be thought of as the *augmented stochastic* discount factor since it accounts for the stochastic marginal value of the net worth (Ω_{t+1}).

[23] Aggregate values for financial assets are indicated by capital letters.

2.4 Equilibrium

A competitive equilibrium is a set of plans $\{C_t, L_t, I_t, K_t, Q_t, Z_t, R_{kt}, R_t, N_t, W_t, D_t, S_t, v_t, \Omega_t, \phi_t, \mu_t\}$ satisfying the following conditions derived above:[24]

$$
\begin{aligned}
1 &= \beta E_t \frac{U_{Ct+1}}{U_{Ct}} R_{t+1} && (35)\\
L_t &= \left(\frac{(1+\tau_S) W_t}{A_t K_{t-1}^{\alpha} (1-\alpha)} \right)^{-\frac{1}{\alpha}} && (36)\\
Z_t &= \alpha A_t \left(\frac{L_t}{K_t} \right)^{1-\alpha} && (37)\\
Q_t - 1 &= f\left(\frac{I_t}{I_{t-1}} \right) + \frac{I_t}{I_{t-1}} f'\left(\frac{I_t}{I_{t-1}} \right) - E_t \Lambda_{t,t+1} f'\left(\frac{I_{t+1}}{I_t} \right) \left(\frac{I_{t+1}}{I_t} \right)^2 && (38)\\
K_{t+1} &= \Psi_{t+1} \left(I_t + K_t \, (1-\delta) \right) && (39)\\
W_t &= (W_{t-1})^{\kappa} \left(-v E_t \frac{U_{Lt}}{U_{Ct}} \frac{1}{1-\tau_L} \right)^{\kappa-1} && (40)\\
C_t &= A_t K_{t-1}^{\alpha} L_t^{1-\alpha} (1-\bar{g}) - I_t \left[1 + \frac{\gamma}{2} \left(\frac{I_t}{I_{t-1}} - 1 \right)^2 \right] && (41)\\
\phi_t &= \frac{v_t}{\theta - \mu_t} && (42)\\
v_t &= E_t \, \Lambda_{t,t+1} \Omega_{t+1} R_{t+1} && (43)\\
\mu_t &= E_t \, \Lambda_{t,t+1} \Omega_{t+1} (R_{kt+1} - R_{t+1}) && (44)\\
\Omega_{t+1} &= 1 - \sigma + \sigma (v_{t+1} + \phi_{t+1} \mu_{t+1}) && (45)\\
R_{kt+1} &= \Psi_{t+1} \frac{Z_{t+1} + (1-\delta) Q_{t+1}}{Q_t} && (46)\\
Q_t \, S_t &= N_t + D_t && (47)\\
\phi_t &= \frac{Q_t \, S_t}{N_t} && (48)\\
N_t &= (\sigma + \zeta) \, \Psi_t [Z_t + (1-\delta) \; Q_t] S_{t-1} - \sigma R_t D_{t-1} && (49)\\
S_t &= I_t + (1-\delta) K_t && (50)
\end{aligned}
$$

given the exogenous process $\{\Psi_t\}$ and the economy initial conditions for the endogenous state variables.

[24] Note that (41) is obtained aggregating (4) and substituting it into (18); equation derives from (9) and (16); v_{st} can be obtained from (24); U_{Ct} and $\Lambda_{t,t+1}$ have been already defined and $f\,(.)$ will be specified in the next section.

3 Financial shocks and labor rigidities

3.1 Calibration

We calibrate the model at a quarterly frequency. The discount factor is set at a value consistent with a real interest rate of 4% per year. We set the inverse Frisch labor supply elasticity (ε) to 2 and the parameter χ of the utility function so that households devote about one third of their time to paid work in the deterministic steady state, normalizing to one the total time. The habits parameter is 0.5.[25] The depreciation rate (δ) is 0.025 and the capital share (α) is 0.33. We assume that the adjustment cost is

$$f\left(\frac{I_t}{I_{t-1}}\right) = \frac{\gamma}{2}\left(\frac{I_t}{I_{t-1}} - 1\right)^2$$

and use a calibration in line with Altig *et al.* (2011).[26]

In the labor market, as benchmark we set the intra-temporal elasticity of substitution across labor inputs to 6, corresponding to a wage markup of 20%. In the baseline case, we consider a small degree of workers' coordination in setting their actions (i.e., they behave closely to atomistic wage-setters) by setting $1/n = 0.33$. The corresponding wage markup is 1.25. We also consider a small tax wedge by setting it to 1.20.[27] We do not report the index of real wage rigidities (κ) as different calibrations will be considered. Specifically, in the next subsection, we only focus on labor market imperfections and assume real wages adjust immediately ($\kappa = 0$). In the next subsection instead we focus on real rigidities by using the baseline calibration under different assumption about κ, ranging 0 from to 0.7.

Regarding the financial sector, we calibrate σ to obtain an average banks survival period of ten years; θ and ζ to meet an economy-wide leverage ratio of about four and an average credit spread of one hundred basis points per year.[28] We finally assume that in the steady state government consumption represents 20% of value added. Besides, our baseline model allows for perfectly flexible real wages; we analyze the effect of different levels of rigidities in a separate section.

The values we assign to the structural parameters in the baseline calibration of the model are summarized in Table 1.

[25] As in Gertler and Kiyotaki (2010), Christiano *et al.* (2005) consider 0.65.

[26] Results are robust with respect to different calibrations. Elasticity of investment to the price of capital ($1/\gamma$) usually ranges between 0.1-0.6. Further simulations are available upon request.

[27] Alternative choices will be later discussed.

[28] See Gertler and Kiyotaki (2010) for a discussion.

β	0.99	Discount rate
ε	0.5	Inverse Frisch labor supply elasticity
χ	5.584	Relative utility weight of labor
h	0.5	Habits parameter
α	0.33	Effective Capital share
δ	0.025	Depreciation rate
$1/\gamma$	0.4	Elasticity of investment to the price of capital
η	6	Elasticity of substitution across labor inputs
$1/n$	0.33	Union density
$\frac{1+\tau_S}{1-\tau_L}$	1.2	Tax wedge
θ	0.39	Fraction of divertable assets
σ	0.972	Survival rate of bankers
$\frac{\zeta}{1-\sigma}$	0.107	Transfer to new entering bankers
$\bar{g}$	0.2	Steady state government consumption
ρ_ψ	0.66	Persistence of the capital quality shock

Table 1 – Baseline parameter values

3.2 Labor market imperfections

In order to isolate real wage rigidities from labor market imperfections in this section we set $\kappa = 0$, i.e. we assume no partial adjustment for real wages.

Equilibrium in the labor market is then given by the following equation:

$$(1-\alpha)\ A_t K_{t-1}^{\alpha} L_t{}^{-\alpha} = \vartheta \chi L_t^{\varepsilon} E_t \left[\frac{1}{C_t - hC_{t-1}} - \frac{\beta h}{C_{t+1} - hC_t} \right] \tag{51}$$

By using (51) we consider three different scenarios: the competitive wages case; our baseline calibration; an economy with larger imperfections where we set $\eta = 4.4$ (the resulting markup is 1.35).[29] It is worth noticing that in all scenarios we consider tax distortions as the tax wedge is set according to our baseline calibration.

Figure 1 displays the impulse response functions[30] to a negative capital quality shock in the three scenarios.

[29] Recall that the markup is also influenced by the wage-setter coordination.

[30] The figure displays per cent deviations from the steady state. Output response is computed from the production function, after aggregation.

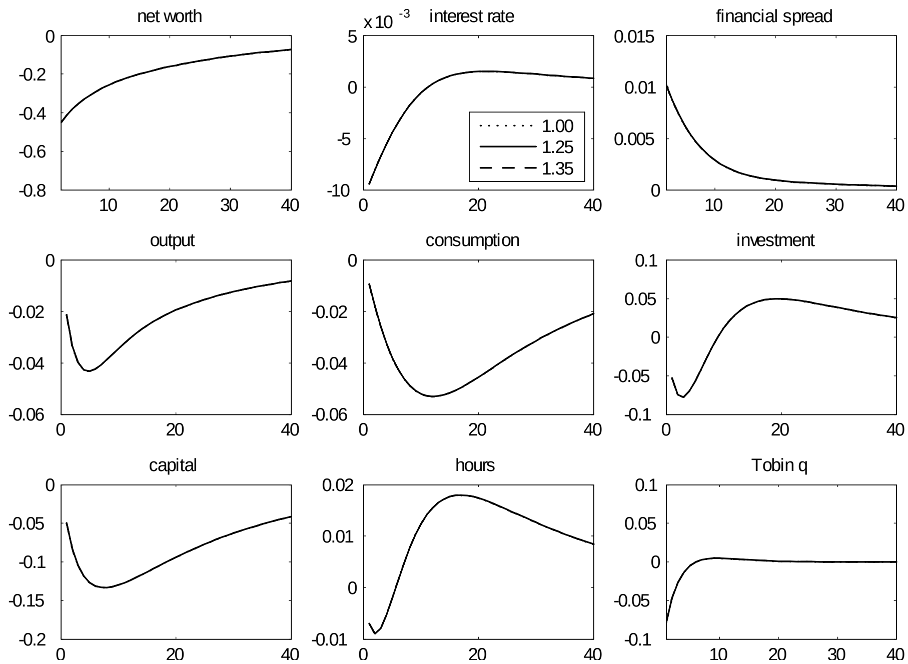

Figure 1 - Financial shock and labor market imperfections

The dynamics is of the kind described by Gertler and Kiyotaki (2010). The financial shock triggers a financial accelerator[31] that implies a fall in the investment activity as well as in the other real variables because of the reduction in the value of the net worth of banks (which entails a rise in the external finance premium) and thus in their capacity of collecting deposits. The fall in investment and the disruption of financial intermediation lead to a fall in labor demand and a consequent fall in output and consumption.

Concerning the labor market imperfections the result is clear. The dynamics of the model is independent of the degree of imperfections in the labor market.[32] A sort of neutrality of the labor market institutions with respect to the propagation in the economy of financial disturbances arises.

What emerges is that the effect of the financial shock is robust to changes in the degree of labor market imperfections, i.e. in the level of the labor wedge. Since the labor wedge results from the combination of various factors like the elasticity of substitution among labor kinds (η), the degree of interaction among

[31] Differently from the frictionless case that is not reported. See Gertler and Kiyotaki (2010).

[32] Although the three scenarios exhibit the same dynamics, the effects at the levels are different. Specifically, the economy with more imperfections will be characterized by lower levels of capital and labor at the steady state and thus will suffer less the financial shock at the levels.

wage setters (n) and the tax rates (τ_S and τ_L), we can meaningfully point out that the effects of a financial shock are robust to the variations of these institutional factors and labor market features.

The *neutrality* result concerning the role played by different degrees of labor market imperfections in shaping the consequences of a financial shock in our economy may have relevant policy implications. In fact, contrary to some anecdotal evidence, according to our simulations, the institutional factors affecting the labor wedge do not alter the channels of transmission of financial frictions to the real economy.

3.3 Real wage rigidities

The above neutrality results is robust with respect to wage rigidities: if we set κ between zero and one, different degrees of labor market imperfections (either in the markup or the tax wedge) do not affect financial-shock-driven fluctuations.[33] On the other hand, different degrees of wage rigidities clearly lead to different dynamics of real variables, as a change in κ affects the dynamics, but independently of the degree of labor market imperfections.

Figure 2 describes the impulse responses triggered by a negative financial shock in our economy under different degrees of real wage rigidities. In simulations, we use our baseline calibration[34] and consider: perfectly flexible wages ($\kappa = 0$); an intermediate level of real wage rigidity ($\kappa = 0.4$); and an economy with a very slow adjustment process for real wages ($\kappa = 0.7$).

[33] Further simulations are available upon request.

[34] However, the figure is robust with respect to a change in the wage markup or in the tax wedge, because, as already said, labor market imperfections are neutral with respect to financial shock dynamics.

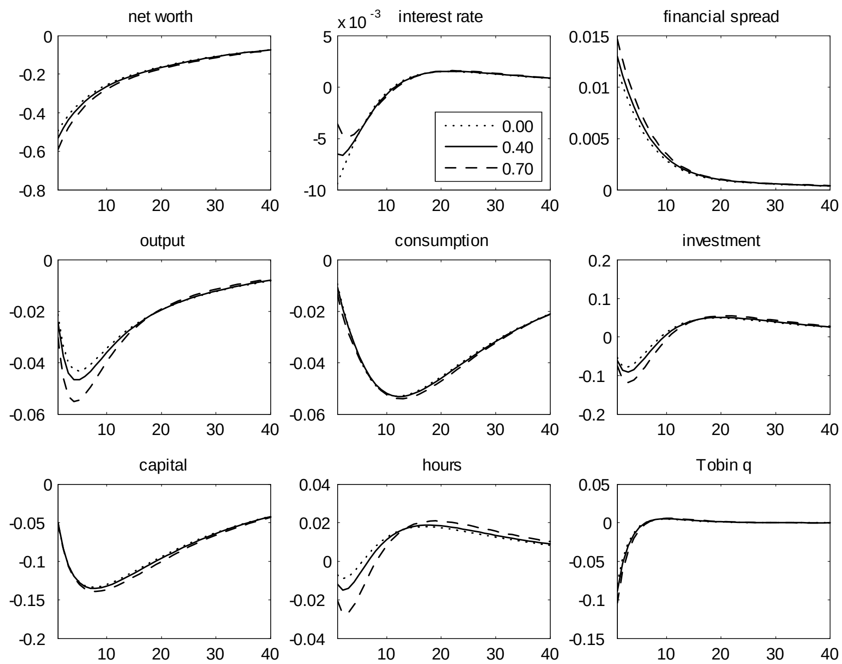

Figure 2 - Financial shock and real wage rigidities

From a qualitative point of view, all the variables react to the shock exactly as described in the previous section, but the clear-cut result reported in Figure 2 is that, differently from other labor market imperfections, real wage rigidities amplify the effects of the financial crisis.

Larger real wage rigidities are associated with both deeper fluctuations and slower recoveries of the variables with respect to their steady state path.[35] In fact, these rigidities interact with financial frictions by affecting the net worth of the banks, thus worsening the reaction of the economy to a negative financial shock. The result can be intuitively explained as follows: when the quality of capital worsens, the marginal productivity of labour decreases, if the real wage is not free to fall in parallel to this, employment and, therefore, the productivity of capital fall more than when the real wage is flexible. The effect is a marked reduction in the rate of return of capital, which further worsens the banks' balance sheets, leading to a deepening of the credit contraction.

[35] It is worth noticing that larger welfare losses are associated to larger fluctuations (see, for a discussion, Gertler and Karadi, 2009; Gertler and Kiyotaki, 2010).

4 Conclusions

By using the recent Gertler and Kiyotaki's (2010) setup, this paper has explored the interaction between distortions in labor market institutions and in the financial sector. We found that labor market imperfections such as workers' monopoly power and /or strategic interactions among wage setters or fiscal institutions determining tax wedges have no impact on the volatility of the real economy induced by a financial shock. Instead, real wage rigidities matter, as they amplify the effects of financial imperfections.

Our results have serious implications for the policy debate about the role of labor markets in amplifying or dampening the current financial crisis. Amplifications of financial shocks are related only to those features of the institutional setting that affect the dynamic adjustment process of wages. Economies with larger imperfections in labour markets will not systematically observe larger or smaller recessions, unless a positive correlation between those imperfections and real wage rigidities is introduced.[36]

This implies that one should carefully detect the different features of labour markets in order to predict the likely effects of financial frictions on volatility.

Appendix A – Financial sector appendix

A1 – Banker's maximization problem

The objective of the bank at the end of period $t-1$ is the expected present value of future dividends, as follows:

$$V_{t-1}(s_{t-1}, d_{t-1}) = E_{t-1} \sum_{i=1}^{\infty} (1-\sigma)\sigma^{i-1} \Lambda_{t,t-1+i} n_{t-1+i} \tag{52}$$

Given the (sequence of) balance sheets constraints:

$$Q_{t-1}s_{t-1} - n_{t-1} = d_{t-1}. \tag{53}$$

we can formulate the following Bellman equation:

$$V_{t-1}(s_{t-1}, d_{t-1}) = E_{t-1}\Lambda_{t-1,t}\{(1-\sigma)n_t + \sigma[\underset{s_t,d_t}{Max} V_t(s_t, d_t)]\} \tag{54}$$

The net worth at t, n_t, i.e. the gross payoff from assets funded at $t-1$, net of borrowing costs, evolves according to

$$n_t = \psi_t[Z_t + (1-\delta)\ Q_t]s_{t-1} - R_t d_{t-1}. \tag{55}$$

[36] However, this does not seem empirically to be the case. For instance, Belgium, Germany and Italy are characterized by high degrees of union density and coverage as well of tax wedges, but Germany and Italy, in contrast to Belgium, have a very low wage indexation, which is one of the factors influencing real wage flexibility (see Du Caju *et al.*, 2008).

By combining (53) and (55), we can then write:

$$Q_t s_t - d_t = d_{t-1} = \psi_t[Z_t + (1-\delta)\ Q_t]s_{t-1} - R_t d_{t-1}. \tag{56}$$

Given the incentive constraint stemming from the agency problem:

$$V_{t-1}(s_{t-1}, d_{t-1}) \geqslant \theta Q_{t-1} s_{t-1}, \tag{57}$$

to solve the maximization problem of the banker we define the Lagrangian L:

$$\begin{aligned} L = E_{t-1}\Lambda_{t-1,t}[((1-\sigma)\psi_t[Z_t + (1-\delta)\ Q_t]s_{t-1} - R_t d_{t-1}) + \\ + \sigma\{V_t(s_t, d_t) + \lambda_t[V_t(s_t, d_t) - \theta Q_t s_t]\}]. \end{aligned} \tag{58}$$

This has to be maximized given the constraint (56).To do so we formulate the following guess for the value function:

$$V_t(s_t, d_t) = v_{st} s_t - v_t d_t. \tag{59}$$

The derivative of (58) with respect to d_t (of which s_t is a function, given (56)) must equal zero, for an interior solution. This gives us, by using (56) to calculate the derivative of s_t with respect to d_t, the following condition:

$$E_{t-1}\Lambda_{t-1,t}\left(-\lambda_t\theta - \frac{\partial V_t(s_t, d_t)}{\partial d_t}(1+\lambda_t)\right) = 0 \tag{60}$$

or, assuming (59):

$$-\theta\lambda_t + v_t\,(1+\lambda_t) = 0 \tag{61}$$

The constraint (57) can be written, using (59), as $v_{st}s_t - v_t d_t \geq \theta Q_t s_t$ and, by (by using (53)):

$$v_t n_t \geq Q_t s_t \left(\theta + v_t - \frac{v_{st}}{Q_t}\right) \tag{62}$$

so assuming this constraint holds as an equality we deduce: $V_t(s_t, d_t) = v_{st}s_t - v_t\,(Q_t s_t - n_t) = \frac{(v_{st} - v_t Q_t) v_t n_t}{Q_t\left(\theta + v_t - \frac{v_{st}}{Q_t}\right)} + v_t n_t$. Hence:

$$V_t(s_t, d_t) = v_t n_t \left(\frac{\mu_t}{\theta - \mu_t} + 1\right) \tag{63}$$

where $\mu_t = \frac{v_{s_t}}{Q_t} - v_t > 0$.

If we define:

$$\phi_t \equiv \frac{v_t}{\theta - \mu_t} \tag{64}$$

it follows that

$$V_t(s_t, d_t) = n_t\,(\mu_t\phi_t + v_t) \tag{65}$$

By substituting the above expression (65) for $V_t(s_t, d_t)$ in (54), we have:

$$V_t(s_t, d_t) = E_t\Lambda_{t+1,t}\left[(1-\sigma)n_{t+1} + \sigma n_{t+1}\left(\mu_{t+1}\phi_{t+1} + v_{t+1}\right)\right]$$

or

$$V_t(s_t, d_t) = E_t \Lambda_{t,t+1} \Omega_{t+1} n_{t+1} \tag{66}$$

where

$$\Omega_{t+1} = (1-\sigma) + \sigma \left(\mu_{t+1} \phi_{t+1} + v_{t+1} \right) \tag{67}$$

and using (55):

$$V_t(s_t, d_t) = E_t \Lambda_{t,t+1} \Omega_{t+1} \left(\psi_{t+1} [Z_{t+1} + (1-\delta)\ Q_{t+1}] s_t - R_{t+1} d_t \right) \tag{68}$$

So by the method of undetermined coefficients it follows that:

$$v_t = E_t \Lambda_{t,t+1} \Omega_{t+1} R_{t+1} \tag{69}$$

and

$$v_{st} = E_t \Lambda_{t,t+1} \Omega_{t+1} \left\{ \psi_{t+1} [Z_{t+1} + (1-\delta)\ Q_{t+1}] \right\}. \tag{70}$$

A2 – Assets demand

We can rewrite (62), given (24), as:

$$(\theta - \mu_t)\, Q_t s_t = v_t n_t \tag{71}$$

The individual bank total demand for assets $Q_t\, s_t$ can then be written, using (24) as:

$$Q_t\, s_t = \phi_t n_t \tag{72}$$

which, at the aggregate level, turns out to be:

$$Q_t\, S_t = \phi_t N_t \tag{73}$$

Appendix B – Steady state

In the steady state the model is defined by the following two blocks of equations. Concerning the real part of the economy, from equations (35)-(41), we have:

$$R = \frac{1}{\beta} \tag{74}$$

$$L = \left(\frac{1+\tau_S}{AK^{\alpha}\,(1-\alpha)} W \right)^{-\frac{1}{\alpha}} \tag{75}$$

$$Z = \alpha A \left(\frac{L}{K} \right)^{1-\alpha} \tag{76}$$

$$Q = 1 \tag{77}$$

$$I = \delta K \tag{78}$$

$$W = \frac{\upsilon \chi L^{\varepsilon}}{1-\tau_L} \frac{(1-h)C}{1-\beta h} \tag{79}$$

$$C = \left[(1-\bar{g})\, A \left(\frac{L}{K} \right)^{1-\alpha} - \delta \right] K \tag{80}$$

Concerning the financial sector of the economy, from equations (42)-(50), we have:

$$\begin{aligned}
\phi &= \frac{v}{\theta - \mu} && (81)\\
v &= \Omega && (82)\\
\mu &= \Omega\,(\beta R_k - 1) && (83)\\
\Omega &= 1 - \sigma + \sigma(v + \phi\mu) && (84)\\
R_k &= Z + (1 - \delta) && (85)\\
S &= N + D && (86)\\
\phi &= S/N && (87)\\
N &= (\sigma + \zeta)\,[Z + (1 - \delta)\,]S - (\sigma/\beta)\,D && (88)\\
S &= K && (89)
\end{aligned}$$

Some cumbersome algebra is then requested to obtain the steady state.

By using equations (83), (82), (81), one obtains:

$$\phi = \frac{\Omega}{\theta - \Omega\,(\beta R_k - 1)} \tag{90}$$

which substituted in (84) yields:

$$\Omega = 1 - \sigma + \frac{\sigma\Omega\theta}{\theta - \Omega\,(\beta R_k - 1)} \tag{91}$$

Combining (74), (85), (86) and (88) gives:

$$N = \frac{(\sigma + \zeta)\,R_k - (\sigma/\beta)}{1 - (\sigma + \zeta)\,R_k} D$$

which solved for D and substituted in (86), given (89), after rearranging yields:

$$K = \left[1 + \frac{1 - (\sigma + \zeta)\,R_k}{(\sigma + \zeta)\,R_k - \sigma/\beta}\right] N \tag{92}$$

that combined with (87) and (89) yields:

$$\phi = 1 + \frac{1 - (\sigma + \zeta)\,R_k}{(\sigma + \zeta)\,R_k - \sigma/\beta} \tag{93}$$

By combining (90) and (93), we get the following expression for R_k:

$$R_k = \frac{\beta\Omega + \theta(\beta - \sigma)}{(\zeta + \beta)\,\Omega\beta} \tag{94}$$

Equations (91) and (94) are a two equation system in two unknowns, Ω and R_k. The solution of the system clearly gives the steady state values for these two variables.

By substituting (94) into (91), one obtains the following second order polynomial equation in Ω:

$$\zeta\Omega^2 + [\zeta(\theta - 1)(1 - \sigma)\theta\sigma(1 - \beta)]\Omega - (1 - \sigma)(\zeta + \sigma)\theta = 0 \tag{95}$$

whose positive solution is chosen and substituted in (94) to obtain R_k. Once system (91) and (94) is solved, the steady-state values for μ, ϕ, υ are obtained straightforwardly.

Finally, by combining (79), (75), (80), and using (76) and (85), after cumbersome algebra, we get the expression for L only in terms of R_k:

$$L = \left(\frac{(1 - \tau_L)(1 - \alpha)\left(\frac{R_k - 1 + \delta}{\alpha}\right)\frac{1 - \beta\gamma}{1 - \gamma}}{\upsilon(1 + \tau_S)\chi\left[(1 - \bar{g})\frac{R_k - 1 + \delta}{\alpha} - \delta\right]} \right)^{\frac{1}{1+\varepsilon}} \tag{96}$$

Combining (76) and (85), and using the steady-state values for L and R_k, K is also obtained. Other steady-state values (S, I, C, W, D, N, Z) are then easily found recursively.

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