Pecuniary Externalities in Economies with Downward Wage Rigidity

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Abstract

A pecuniary externality in economies with downward nominal wage rigidity leads firms to hire too many workers in expansions, which leads to too much unemployment in recessions. When firms hire more workers, firms fail to internalize that competition for workers between firms pushes up the aggregate wage, which imposes a negative externality over other firms. The externality can be resolved by a macroprudential tax on labor in expansions. In the calibrated model, the tax reduces the welfare cost of downward nominal wage rigidity by up to 90%, as it makes the economy significantly less exposed to unemployment crises.

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1. Introduction

A longstanding concern in economics, which dates back to at least Keynes, is that in low inflation environments the labor market may not clear because of downward nominal wage rigidity. This concern has been revived recently. For example, alarmed by globally declining rates of interest and inflation, the recent literature on secular stagnation is built on the assumption of downward nominal wage rigidity (e.g., Eggertsson et al., 2019; Benigno and Fornaro, 2018; Corsetti et al., 2019; Fornaro and Romei, 2019). Moreover, the interaction between downward nominal wage rigidity and a fixed nominal exchange rate has recently been suggested as a key driver of the unemployment experience during the Great Recession of some countries in the euro area (Schmitt-Grohé and Uribe, 2016).

One central tenet of the recent literature is that downward nominal wage rigidity—in combination with other frictions that limit the adjustment of the price level, such as a fixed nominal exchange rate or the zero lower bound constraint on policy rates—gives rise to an *aggregate demand externality* that can be reduced by macroprudential intervention in the form of restricting borrowing in times of robust economic performance. The argument goes as follows. In boom times, private agents fail to internalize that increasing borrowing leads to lower aggregate demand and employment when downward nominal wage rigidity binds in future recessions. As a result, private agents overborrow, and governments should intervene in financial markets, e.g., through implementing policies that limit capital inflows (see, in particular, Korinek and Simsek (2016), Farhi and Werning (2016), Schmitt-Grohé and Uribe (2016), and Fornaro and Romei (2019)).

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This paper shows that, *independent of demand elements*, downward nominal wage rigidity in and of itself generates a *pecuniary externality* in the labor market due to firms' not taking into account the effect that current labor demand has on aggregate wage inflation and thus on the probability that downward nominal wage rigidity binds in future recessions. This pecuniary externality which affects firms' hiring can be addressed via macroprudential intervention in the *labor market*, for example by a macroprudential tax on firms' hiring. Welfare losses created by the externality are large, reflected in deeper recessions accompanied by higher unemployment under laissez-faire compared to outcomes under the optimal prudential intervention.

We study an open economy model with incomplete international financial markets and a fixed nominal exchange rate. Firms produce a single consumption good which is freely traded across borders. Labor is the only factor of production. In the baseline model there is perfect competition in all markets, an assumption which will be relaxed below. There is a friction in the labor market: nominal wages cannot decline (much) below their previous-period level (Schmitt-Grohé and Uribe, 2016). Equilibrium output and employment are independent of households' demand for consumption at all times such that the model does not feature an aggregate demand externality.

We show that the equilibrium under laissez-faire is *constrained inefficient*. When firms hire more workers, competition for workers between firms pushes up the aggregate wage, which imposes a negative externality over other firms. As a result, a social planner that is constrained by the same frictions as private agents demands less labor in expansions, leading to lower wages and hence to less unemployment in recessions.

The constrained-efficient equilibrium can be decentralized with labor taxes. To show this, we study the Ramsey problem of choosing optimally payroll taxes on firms, rebated lump-sum to firms in equilibrium. Negative taxes are ruled out to prevent that *subsidies* are used to mechanically offset downward nominal wage rigidity.[1] The outcome of the Ramsey problem and the constrained-efficient allocation are shown to be identical. Intuitively, a payroll tax on firms reduces labor demand, which if chosen optimally, can restore the constrained-efficient allocation.

We next augment the model to an environment where firms have some market power in the labor market (monopsonistic competition, see Manning (2003)). The motivation for studying the monopsony model is that wage-setting firms internalize downward nominal wage rigidity, because a binding rigidity squeezes their monopsony profits. Firms react by behaving prudentially, compressing hiring and wage increases in expansions (similar to the work of Elsby (2009) in a different environment). The need for prudential intervention may therefore be absent in the monopsony model.

We show that the externality does not resolve when firms internalize downward nominal wage rigidity and thus behave prudentially at the private level. Intuitively, when firms offer higher wages to attract more workers, they internalize that it becomes more likely that they will be constrained by downward nominal wage rigidity in the future. However, as in the baseline model, firms fail to internalize that competition for workers between firms pushes up the *aggregate* wage, which imposes a negative externality over other firms.

The monopsony model also reveals that the externality is weaker when firms' market power is stronger (when labor market competition is weaker). The welfare effect, however, is ambiguous. While the externality is weaker when firms' market power increases, firms also charge larger monopsonistic mark-ups. In the calibrated model, the net effect is that welfare losses are U-shaped in the degree of labor market competition.[2]

[1] As is well understood, payroll subsidies on firms can be used to mechanically offset the effects of downward nominal wage rigidity (e.g., Farhi et al., 2014; Schmitt-Grohé and Uribe, 2016). Of course, should payroll subsidies in practice be available, these are always to be preferred for they implement the first-best (rather than a constrained-efficient) allocation. One could think of the German policy of "Kurzarbeit" as a form of payroll subsidy that has been used in practice. However, there could be fiscal limitations to such policies (Bianchi et al., 2019).

[2] That welfare may be hump-shaped in the degree of labor market competition has been emphasized by an earlier literature, which focused on the bargaining power of unions. The initial contribution is Calmfors and Driffill (1988). The arguments made are similar: when unions have more market power they may better internalize the effect of their actions on the economy, which may be welfare improving.

The externality has large negative effects on welfare and unemployment. In the quantitative analysis, we calibrate the model to a set of countries that either peg to the euro or are members of the euro area. The macroprudential tax on labor reduces the welfare cost of downward nominal wage rigidity by 90%, as mean welfare losses relative to first-best decline from 0.26% of permanent consumption under laissez-faire to 0.025% of permanent consumption under the optimal intervention.[3,4] This welfare gain reflects a drop in the frequency of deep crises. Under laissez-faire, unemployment exceeds 10% about once every 3.5 years on average, whereas the probability of such crises is close to zero under the optimal prudential intervention.

While the main text focuses on the behavior of firms, Appendix C demonstrates that the pecuniary externality result extends to the case where unions set wages in monopolistic competition (see Benigno and Ricci, 2011).[5] Intuitively, unions raise wages in expansions, not internalizing the rise in the aggregate wage as competition pushes up the wages of other unions. In the presence of downward nominal wage rigidity, this makes the laissez-faire outcome constrained inefficient. The general picture that emerges is thus that the externality affects labor market outcomes—regardless whether the wage setting power is on the households or on the firms.

Related literature.—One paper that highlights the same externality as the present paper is Bianchi (2016), but in Bianchi's work wages are flexible and the need for macroprudential intervention arises due to a financial friction (high wages make firms' equity constraints more binding)—whereas in the present analysis, intervention is necessary due to downward nominal wage rigidity.

Schmitt-Grohé and Uribe (2016) describe an aggregate demand externality in a similar economic environment. The key difference to their model is that the present model does not have a non-tradable sector, which implies that the demand externality does not arise in the present analysis. Even so, the pecuniary externality described here is present (but not discussed) in Schmitt-Grohé and Uribe (2016) as they study the same labor market.[6] The present model abstracts from a non-tradable sector in order to isolate the effects of the pecuniary externality. However, the model with a non-tradable sector is studied as an extension. In this case we show that the demand and pecuniary externality arise *jointly*, with rich implications for regulation (see Section 3 and Appendix D).

The labor market intervention described is prudential, to be distinguished from those policies that relax wage rigidity ex post. The paper thus adds to the literature on macroprudential intervention. Much of this literature is concerned with financial frictions (Bianchi and Mendoza, 2018; Dávila and Korinek, 2018; Lorenzoni, 2008; Jeanne and Korinek, 2010). However, some recent papers have shifted attention to nominal frictions. Farhi and Werning (2016) provide a generic treatment of inefficiency in economies with nominal rigidities. Korinek and Simsek (2016) and Fornaro and Romei (2019) study economies with nominal rigidities and a zero lower bound constraint on policy rates. Both papers study demand externalities, whereas the present paper studies a pecuniary externality.

The remainder of the paper is structured as follows. Section 2 introduces the baseline model. Section 3 presents the normative analysis. Section 4 studies the monopsony model. Section 5 presents the quantitative analysis. Section 6 concludes. An accompanying Online Appendix

[3] As mentioned earlier, under first-best, the government has the power to relax downward nominal wage rigidity ex post, e.g., through subsidizing labor demand, or through raising domestic prices / depreciating the nominal exchange rate (Friedman, 1953; Tobin, 1972; Schmitt-Grohé and Uribe, 2016).

[4] In the baseline calibration to which these numbers refer, there is perfect labor market competition such that there is no static distortion from firms' mark-ups. The welfare loss therefore isolates the cost of the pecuniary externality.

[5] The assumption that wage-setting power is with households (unions) is quite common in business cycle studies with wage rigidity, mostly in the context of Calvo wages (Galí and Monacelli, 2016; Galí, 2011), but also in the context of downward nominal wage rigidity (Benigno and Ricci, 2011).

[6] As explained in detail in Appendix D, Schmitt-Grohé and Uribe (2016) restrict their attention to capital controls intervention by restricting their planner to respect all private equilibrium conditions other than aggregate demand. As a result, they do not mention nor does their social planner address the pecuniary externality, even though it is at work in the labor market of their model.

contains proofs and derivations as well as model extensions.

2. Baseline model

This section develops a model of a small open economy with downward nominal wage rigidity and a fixed nominal exchange rate. The economy is small in the sense that foreign variables are taken as given. The economy is populated by households and firms. Households consume, work and save in (incomplete) international financial markets. Firms produce a single consumption good which is freely traded across borders. Firms and households take prices and wages as given. This assumption is relaxed in Section 4, where we will assume that firms have some market power over wages. The business cycle is driven by shocks to total factor productivity (TFP).

2.1. Households

The economy is populated by a large number of households that maximize utility from consumption net of disutility from work

$$E_0 \sum_{t\geq 0} \beta^t U(C_t - G(H_t)), \quad \beta \in (0,1). \tag{1}$$

Here E_0 denotes mathematical expectation with respect to information at time 0, U is of the constant relative risk aversion type and $G(H_t) = H_t^{1+\varphi}/(1+\varphi)$, where $1/\varphi > 0$ is the Frisch elasticity of labor supply. The budget constraint is

$$P_t C_t + \frac{B_{t+1}}{R} = W_t H_t + \mathit{\Pi}_t + B_t, \quad R > 1. \tag{2}$$

Here C_t denotes consumption, P_t the domestic price level, $W_t H_t$ and $\mathit{\Pi}_t$ are labor income and profits accruing from firms, and B_{t+1} are nominal bonds which are traded across border at price $1/R$, respectively.[7]

The labor market is characterized by downward nominal wage rigidity. Following the analysis in Schmitt-Grohé and Uribe (2016), nominal wages cannot fall (much) below their previous-period level

$$W_t \geq \psi W_{t-1}, \quad \psi \geq 0. \tag{3}$$

It is important for the results that lagged wages enter equation (3). Under the alternative specification $W_t \geq \bar{W}$, $\bar{W} > 0$ (e.g., Bianchi and Mondragon, 2018), the equilibrium under laissez-faire is constrained efficient which implies that the need for prudential intervention disappears. This is because firms' current behavior has no impact on downward nominal wage rigidity in the future (see Appendix E.2).

Labor supply is given by the following expression

$$G'(H_t) \leq \frac{W_t}{P_t}. \tag{4}$$

The weak inequality in equation (4) reflects that when downward nominal wage rigidity binds, firms may demand less hours than households are willing to supply.

[7] In the main text households have Greenwood-Hercowitz-Huffman (GHH) preferences, which are commonly used in international business cycle models and in the literature studying macroprudential intervention (e.g., Bianchi and Mendoza, 2018; Mendoza and Yue, 2012). As is well known, GHH preferences eliminate the wealth effect on labor supply. Appendix E.1 studies how conclusions change in the presence of a wealth effect on labor supply. In this case, the constrained planner intervenes in the labor market *and* in financial markets because wealth effects impact labor market outcomes which are affected by the pecuniary externality. This motive for intervening in financial markets is, however, different than in the analysis by Schmitt-Grohé and Uribe (2016), where intervention is necessary to address a demand externality. See the Appendixes D and E.1 for details.

Taking first order conditions with respect to consumption and bonds gives the consumption Euler equation

$$1 = \beta R E_t \frac{U'(t+1)}{U'(t)} \frac{P_t}{P_{t+1}}, \tag{5}$$

where $U'(t) \equiv U'(C_t - G(H_t))$.

2.2. Firms

There is a large number of firms that are owned by the households. Firms take prices and wages as given. They use the technology $Y_t = a_t F(H_t) = a_t H_t^{\alpha}$, where $\alpha \in (0,1)$ is a parameter and where a_t denotes aggregate TFP, which is exogenous and stochastic. Firms maximize profits which yields the labor demand curve

$$a_t F'(H_t) = \frac{W_t}{P_t}. \tag{6}$$

2.3. Monetary policy

The consumption good is freely traded internationally. Thus the law of one price pins down P_t as the price of this good that prevails internationally $\bar{P}_t$ times the nominal exchange rate $\mathcal{E}_t$ (the price of foreign in terms of domestic currency)

$$P_t = \mathcal{E}_t \bar{P}_t,$$

where $\bar{P}_t$ is exogenous from the vantage point of the domestic economy. Note that monetary policy, by raising $\mathcal{E}_t$, could raise domestic prices. As this reduces the real value of wages, doing so is useful in an environment where nominal wages are downward rigid (Friedman, 1953). However, we now assume that the exchange rate is fixed at unity

$$P_t = \bar{P}_t, \tag{7}$$

which thus implies that the domestic price level is exogenous.

2.4. Market clearing and definition of equilibrium

In equilibrium, wages and profits equal total output: $W_t H_t + \Pi_t = P_t a_t F(H_t)$. The economy's resource constraint is thus

$$P_t C_t + \frac{B_{t+1}}{R} = P_t a_t F(H_t) + B_t. \tag{8}$$

The equilibrium under laissez-faire can now be defined as follows.

Definition 1. [EQUILIBRIUM UNDER LAISSEZ-FAIRE] *In the baseline model, the equilibrium under laissez-faire is a set of processes* $\{P_t, C_t, H_t, B_{t+1}, W_t\}_{t\geq 0}$ *such that equations* (5)-(8) *as well as either*

$$\begin{aligned} &i)\ [slack]\ G'(H_t) = W_t/P_t \ \text{if}\ W_t \geq \psi W_{t-1},\ \text{or else} \\ &ii)\ [binds]\ W_t = \psi W_{t-1}, \end{aligned}$$

where $U'(t) \equiv U'(C_t - G(H_t))$, *for given initial conditions* $W_{-1} > 0$ *and* B_0, *and for a given exogenous process* $\{a_t, \bar{P}_t\}_{t\geq 0}$, *are all satisfied.*

3. Normative analysis

This section presents the key findings of the paper, proceeding in two steps. Section 3.1 shows that the equilibrium under laissez-faire is constrained inefficient. Section 3.2 discusses implications for regulation.

3.1. *The constrained-efficient equilibrium*

Consider a benevolent planner with restricted planning abilities. Specifically, following the analysis in Bianchi (2016), consider a planner that chooses labor allocations on behalf of firms, but lets all remaining markets clear competitively. The planner is subject to the same frictions as the private economy; most notably, the planner respects downward nominal wage rigidity.

Definition 2. [PLANNING PROBLEM] *The constrained-efficient allocation solves*

$$\max_{\{C_t, B_{t+1}, H_t, W_t, P_t\}} \quad E_0 \sum_{t \geq 0} \beta^t U(C_t - G(H_t))$$

subject to the set of constraints

$$\begin{aligned}
&i) && P_t C_t + B_{t+1}/R = P_t a_t F(H_t) + B_t \\
&ii) && U'(t)/P_t = \beta R E_t (U'(t+1)/P_{t+1}) \\
&iii) && G'(H_t) \leq W_t/P_t \\
&iv) && W_t \geq \psi W_{t-1} \\
&v) && W_t/P_t \leq a_t F'(H_t) \\
&vi) && P_t = \bar{P}_t,
\end{aligned}$$

where $U'(t) \equiv U'(C_t - G(H_t))$, for given initial $W_{-1} > 0$ and B_0, and for the given exogenous process $\{a_t, \bar{P}_t\}_{t \geq 0}$.

The planner respects the resource constraint (constraint i)) and that consumption and borrowing decisions are taken by private agents (constraint ii)). Instead, the labor market does not clear competitively. While the planner respects labor supply as chosen by private agents (constraint iii)), the planner chooses labor demand on behalf of firms. In addition, the planner respects downward nominal wage rigidity (constraint iv)).

Constraint v) imposes that the planner cannot demand labor if the marginal product is below the real wage. Constraint vi) imposes that the planner cannot raise domestic prices. Without *either* constraint v) or vi), the planner could implement the first-best allocation. Without constraint v), the planner could set $a_t F'(H_t) = G'(H_t)$ even as $W_t/P_t > a_t F'(H_t)$. Without constraint vi), the planner could reduce W_t/P_t by raising domestic prices. When turning to decentralization below, ignoring constraint v) would appear as subsidies on firms' hiring ("fiscal devaluation"), whereas ignoring constraint vi) would appear as "external devaluation" (e.g., Farhi et al., 2014; Schmitt-Grohé and Uribe, 2016).

The following proposition presents labor demand as chosen by the constrained-efficient planner. This is the main proposition of the paper.

Proposition 1. [CONSTRAINED EFFICIENCY] *The equilibrium under laissez-faire is constrained inefficient.*

Proof. As shown in Appendix A.1, in the constrained-efficient equilibrium, the labor demand curve when downward nominal wage rigidity is slack is given by

$$a_t F'(H_t) = \frac{W_t}{P_t} + \frac{1}{U'(t)} \frac{1}{\varepsilon_t^G} \frac{W_t}{H_t} \beta \psi E_t \lambda_{t+1}^{sp}, \tag{9}$$

where the multiplier $\lambda_t^{sp} \geq 0$ associated with downward nominal wage rigidity (constraint iv) in Definition 2) is given by

$$\lambda_t^{sp} = -U'(t) \left(\varepsilon_t^F \frac{H_t}{W_t} \left(\frac{W_t}{P_t} - G'(H_t) \right) + \varepsilon_t^G \frac{H_t}{W_t} \left(a_t F'(H_t) - \frac{W_t}{P_t} \right) \right) + \beta \psi E_t \lambda_{t+1}^{sp}. \tag{10}$$

In (9) and (10), $\varepsilon_t^F < 0$ and $\varepsilon_t^G > 0$ denote the wage elasticities of labor demand and supply, respectively.[8] Instead, when downward nominal wage rigidity binds, the planner demands labor elastically as long as $a_t F'(H_t) \geq W_t/P_t$, and the planner demands labor according to $a_t F'(H_t) = W_t/P_t$, else. □

The constrained-efficient equilibrium can now be defined as follows.

Definition 3. [CONSTRAINED-EFFICIENT EQUILIBRIUM] *The constrained-efficient equilibrium is a set of processes* $\{P_t, C_t, H_t, B_{t+1}, W_t, \lambda_t^{sp}\}_{t\geq 0}$ *such that equations* (5), (7)-(8) *and* (10) *as well as either*

> *i) [slack] equation* (9) *and* $G'(H_t) = W_t/P_t$ *if* $W_t \geq \psi W_{t-1}$, *or else*
> *ii) [binds lightly]* $W_t = \psi W_{t-1}$ *and* $G'(H_t) = W_t/P_t$, *if* $a_t F'(H_t) \geq W_t/P_t$ *or else*
> *iii) [binds strongly]* $a_t F'(H_t) = W_t/P_t$ *and* $W_t = \psi W_{t-1}$,

where $U'(t) \equiv U'(C_t - G(H_t))$, *for given initial conditions* $W_{-1} > 0$ *and* B_0, *and for a given exogenous process* $\{a_t, \bar{P}_t\}_{t\geq 0}$, *are all satisfied.*

The laissez-faire outcome is constrained inefficient due to a pecuniary externality which affects labor demand. To understand the externality, take a look at Figure 1 which provides a stylized representation of the labor market in this model. The left panel shows constrained-efficient labor demand when downward nominal wage rigidity is slack (equation (9), blue solid, downward sloping). It is located to the left of labor demand under laissez-faire (equation (6), green dashed). This reflects a non-negative wedge which appears in equation (9): the wedge becomes larger, the larger is the expected utility-cost of a binding rigidity in the future $E_t \lambda_{t+1}^{sp} \geq 0$. The blue upward-sloping line is labor supply—equation (4) holding with equality.

[Figure 1 about here.]

Assume first that downward nominal wage rigidity is slack. Under laissez-faire, equilibrium in the labor market is given by point B. This also corresponds to the frictionless level $a_t F'(H_t) = G'(H_t)$. The constrained-efficient equilibrium is given by point A. The planner finds it optimal to reduce hiring below the frictionless level, because wages are lower at point A compared to point B. The Harberger triangle represented by the ABC area denotes the second-order welfare loss of restricting employment below the frictionless level. The benefit of doing so is that with lower wages, the expected future cost of downward nominal wage rigidity is lower, which represents a first-order welfare gain. The equilibrium when downward nominal wage rigidity is slack obtains when ψW_{t-1} is sufficiently small (the leftmost part in the right panel).

Assume next that downward nominal wage rigidity binds. Assume first that it binds "lightly" ($W_A < \psi W_{t-1} < W_B$). In this case, the planner finds it optimal that hours are determined by labor supply: wages are determined by $W_t = \psi W_{t-1}$ and hours are pinned down by $G'(H_t) = W_t/P_t$. Intuitively, at (H_A, W_A) it holds that $a_t F'(H_t) > W_t/P_t$, from equation (9). As downward nominal wage rigidity binds, this raises wages and increases labor supply. The planner finds it optimal that firms absorb the additional labor supply as long as the marginal product is still above the real wage (i.e., above the marginal rate of substitution between consumption and leisure; compare Definition 3). In Figure 1 right panel, this intermediate region is depicted by the part of equilibrium hours that slopes upward in wages, between the two vertical lines.

Finally, when downward nominal wage rigidity binds "strongly" ($\psi W_{t-1} > W_B$) the labor market is rationed, as hours are determined purely by labor demand—equation (6), which holds both under laissez-faire and in the constrained-efficient equilibrium (compare again Definition 3).

[8] Labor demand is

$$F'^{-1}\left(\frac{W_t}{P_t}\frac{1}{a_t}\right) = H_t = H_t(W_t).$$

The elasticity is defined as $\varepsilon_t^F \equiv H_t'(W_t)(W_t/H_t) < 0$. It is negative because F is assumed to be strictly concave. Elasticity ε_t^G is defined symmetrically for labor supply. See Appendix A.1 for details.

Turning back to Figure 1, in the right panel, this region is depicted by the part of equilibrium hours that slopes downward in wages. Mirroring the right panel, the red pluses in the left panel depict how equilibrium hours change in the constrained-efficient equilibrium—by tracing their movement along the labor demand and supply curves—as downward nominal wage rigidity becomes gradually more binding.

The intuition for the externality is as follows. When firms hire more workers, they are taking wages as given. They fail to internalize that through competition for workers, more hiring pushes up the aggregate wage—in equilibrium, the economy moves along an upward-sloping labor supply curve. In contrast, the planner internalizes that hiring is associated with an increase in wages. This leads the planner to restrict hiring, and the laissez-faire outcome to be constrained inefficient.[9]

An important property of the constrained-efficient equilibrium is that it is time consistent. This is despite the fact that the planner takes expectations of private agents as a constraint—see the Euler equation (constraint ii)) in Definition 2. The equilibrium is time consistent, because constraint ii) is *slack* in equilibrium: if unconstrained, the planner would *choose* the same Euler equation as private agents (Bianchi, 2016). In this model, private agents' borrowing and consumption decisions are therefore efficient. This also implies that, while the model features a pecuniary externality, the *aggregate demand externality* that is described in the literature does not arise. The planner has no incentive to intervene in financial markets (compare Schmitt-Grohé and Uribe, 2016; Fornaro and Romei, 2019; Farhi and Werning, 2016).

The demand externality reappears once we augment the model by a non-tradable sector, as in the model by Schmitt-Grohé and Uribe (2016). Intuitively, households' demand for non-tradables leads to non-tradables price inflation, which also generates *wage* inflation in the non-tradable sector. This interlinks wages and aggregate demand. Such a linkage is absent in the present model, because the price of tradables is independent of households' demand for tradables. However, this does not mean that the pecuniary externality disappears in the model with non-tradables. In fact, in this case both externalities arise *jointly*, with rich implications for regulation.[10]

3.2. Implications for regulation

Because the externality affects labor demand, we show first that policies which change labor demand can be used to decentralize the constrained-efficient allocation. Consider a tax $\tau_t^w \geq 0$ levied on the payroll paid by firms, rebated lump-sum to firms in equilibrium. With the payroll tax in place, labor demand becomes

$$a_t F'(H_t) = \frac{(1+\tau_t^w)W_t}{P_t}. \tag{11}$$

Negative taxes are ruled out to prevent that *subsidies* are used to mechanically offset downward nominal wage rigidity, echoing constraint v) in Definition 2 of the planner. All other equilibrium conditions are unchanged by the intervention.[11]

A *regulated* equilibrium can be defined following Definition 1, once labor demand (6) is replaced by labor demand (11). The regulated equilibrium depends on the path $\{\tau_t^w \geq 0\}$ chosen by the policy maker. This yields the second proposition of the paper.

[9] In the textbook real business cycle model, firms hire workers by taking wages as given. In equilibrium, this raises wages because the economy moves along an upward-sloping labor supply curve. However in this case, the externality does not lead to social inefficiencies in line with the first welfare theorem. In the current analysis, this no longer holds because markets are not frictionless. This allows us to show that the equilibrium is constrained inefficient.

[10] This is explored in detail in Appendix D. We mention here two interesting findings: in the model with non-tradables, the planner intervenes *jointly* in financial markets and in the labor market. Second, the two interventions operate as partial substitutes. For example, the necessary intervention in financial markets becomes larger in the absence of the intervention in the labor market.

[11] Taxing sales revenue is an alternative, in which case labor demand becomes $(1-\tau_t^p)a_t F'(H_t) = W_t/P_t$, where $\tau_t^p \geq 0$. Either tax reduces labor demand in expansions. If appropriately chosen, this makes firms internalize exactly the pecuniary externality.

Proposition 2. [DECENTRALIZATION] *Consider the Ramsey problem of choosing* $\{\tau_t^w \geq 0\}$ *to maximize welfare* (1) *over regulated equilibria. The outcome of the Ramsey problem and the constrained-efficient equilibrium coincide.*

Proof. In Appendix A.2. □

Two remarks are in order. First, since the problem of the planner is time consistent, the Ramsey problem in Proposition 2 is also time consistent (Bianchi, 2016). Second, in Proposition 2 it was implicitly assumed that downward nominal wage rigidity affects the wage received by workers W_t, not the labor cost faced by firms $(1 + \tau_t^w)W_t$. This appears a natural assumption if wage stickiness derives from the worker side, e.g., a loss in worker morale after a wage cut (Bewley, 1999). However, it should be noted that the constrained-efficient allocation cannot be decentralized with payroll taxes on firms if downward nominal wage rigidity applies to the labor cost faced by firms.[12,13]

Taxing labor demand and supply are commonly seen as equivalent. Does this imply that taxing labor *supply* can also be used for decentralization? The answer is yes and no. Consider a payroll tax $\tilde{\tau}_t^w \geq 0$ levied on households' wage income, rebated lump-sum in equilibrium. Households' wage income thus becomes $(1 - \tilde{\tau}_t^w)W_tH_t$. This tax changes labor supply, as equation (4) needs to be replaced by

$$G'(H_t) \leq \frac{(1 - \tilde{\tau}_t^w)W_t}{P_t}. \tag{12}$$

All other equilibrium conditions are unchanged by the intervention.

A rise in $\tilde{\tau}_t^w$ reduces hiring in expansions. However, this also *increases* W_t whereas W_t declines in case the tax is levied on firms. Hence this policy cannot be used to decentralize the constrained-efficient allocation in case downward nominal wage rigidity applies to (the gross wage) W_t.[14] On the other hand, this policy *can* be used in case downward nominal wage rigidity applies to the *net* wage $(1-\tilde{\tau}_t^w)W_t$. Intuitively, in this case the rise in W_t does not matter, because W_t is not directly affected by downward nominal wage rigidity (see Appendix A.2 for a derivation). The conventional wisdom that the economic incidence of a labor tax is independent of the formal incidence holds in case *net* wages are affected by downward nominal wage rigidity.[15]

Turn back to the case where the tax is levied on firms. It turns out that τ_t^w admits a closed-form representation. To derive an equation for τ_t^w, first define *potential employment* H_t^p as solving

$$G'(H_t^p) = \frac{W_t}{P_t}, \tag{13}$$

implying that $H_t = H_t^p$ whenever labor supply is not rationed. Second, define *unemployment* u_t as

$$u_t \equiv 1 - \frac{H_t}{H_t^p} \geq 0. \tag{14}$$

As in Schmitt-Grohé and Uribe (2016), we thus identify "unemployment" as an involuntary reduction in hours worked. Appendix E.3 demonstrates that adopting household preferences as in Galí et al. (2012) yields the same reduced-form equations (13)-(14), while allowing us to reinterpret H_t^p as aggregate *participation* or the labor force, and u_t as arising at the *extensive* margin, consistent with its empirical counterpart.

Assume now that downward nominal wage rigidity is slack in the current period, binding strongly in the next period, and slack again in all periods thereafter. As shown in Appendix A.2,

[12] That is, in case $W_t \geq \psi W_{t-1}$ is replaced by $(1 + \tau_t^w)W_t \geq \psi(1 + \tau_{t-1}^w)W_{t-1}$.

[13] In this case, a tax on sales revenue would still be feasible

[14] Symmetrically, *subsidizing* labor supply would successfully reduce wage inflation, but it would also lead to higher employment, whereas equilibrium hiring falls in the constrained-efficient allocation.

[15] Poterba et al. (1986) argue that, because work contracts are commonly denominated in terms of gross wages, it is natural to assume stickiness at the level of gross wages rather than at the level of net wages. This implies that payroll taxes levied on households could not be used to decentralize the constrained-efficient allocation.

the following expression holds for the optimal tax:

$$\tau_t^w = \frac{\varphi}{1-\alpha}\psi^{\frac{\varphi+1}{\varphi}} E_t \xi_{t,t+1} \left(\frac{P_t}{P_{t+1}}\right)^{\frac{1}{\varphi}} (1-u_{t+1})(1-(1-u_{t+1})^{\varphi}). \tag{15}$$

The optimal tax depends negatively on the wage elasticity of labor supply, which in this model equals the Frisch elasticity: $\varepsilon_t^G = 1/\varphi$. When ε_t^G is large, a tax on labor is costly as this leads to a strong decline of employment. In line with the optimal income tax literature, in this case the optimal tax is therefore smaller (Saez, 2001). This also implies that a more inelastic labor supply calls for larger taxes. In the limit when labor supply is *inelastic*, the tax implied by equation (15) is plus infinity. This is because in this case, the trade-off associated with taxing labor disappears.[16,17] Notice that τ_t^w also depends positively on the wage elasticity of labor *demand*: $|\varepsilon_t^F| = 1/(1-\alpha)$ under the assumed production function. When labor demand is elastic, firms ration employment strongly when downward nominal wage rigidity binds, which justifies a larger ex-ante intervention.

The tax in equation (15) also depends on the stochastic discount factor $\xi_{t,t+1} \equiv \beta(U'(t+1)/U'(t))(P_t/P_{t+1}) \geq 0$, on price inflation and on unemployment expected for next period. As an example for yearly frequency, assume that $\varphi = 3$, $\alpha = 2/3$, that wages can fall four percent before downward nominal wage rigidity binds ($\psi = 0.96$), that there is no price inflation ($\bar{P}_t = \bar{P}_{t+1}$), that the discount factor is four percent ($\xi_{t,t+1} = 0.96$), and that there is a 5% chance of a crisis in the next year with 10% unemployment. The implied optimal tax is $\tau_t^w = 0.0998$, or about 10%. This example shows that the optimal tax can be quite large. However, this computation ignores general equilibrium effects: per effect of charging the tax, the probability of the crisis in the next year is reduced. Such general equilibrium effects are taken care of in the quantitative application in Section 5.

4. A monopsony model

This section departs from the assumption of wage-taking firms but instead assumes that firms have some market power in the labor market. The motivation for studying this model extension is that under monopsonistic competition, firms are making rents and behave as purposeful wage-setters. This gives firms incentives to internalize downward nominal wage rigidity because when this rigidity binds, firms' monopsony rents are squeezed. By the logic described in Elsby (2009), firms react in a prudential manner, reducing hiring and compressing wage increases in expansions.

While this section draws on the insights in Elsby (2009), it should be made clear that his and the present model are not directly comparable. Elsby (2009) considers an efficiency-wage model where single-worker firms face a labor effort supply function that has a kink at $W_t = W_{t-1}$, motivated by Bewley (1999). As a result, downward nominal wage rigidity arises *endogenously.* Here we impose it exogenously for the benefit of tractability: while Elsby (2009)'s analysis is essentially in partial equilibrium, we study the general equilibrium when many firms interact.

The monopsony model is used to answer the following questions. How is the pecuniary externality affected when firms behave prudentially at the private level? And is there still a role for macroprudential intervention?

4.1. Economic environment

Households' utility function (1) is unchanged from the baseline model. As in the baseline model, there is a large number of firms, however, the firm index is now made specific: $i \in [0, 1]$.

[16] Recall that equation (15) is derived by assuming that downward nominal wage rigidity is slack in the current period. Yet, when the tax is large enough, this assumption becomes violated because downward nominal wage rigidity starts to bind. In this case, taxes should be such that downward nominal wage rigidity binds "lightly" (Section 3.1), as wages are reduced by as much as possible while firms are still willing to hire the full labor supply.

[17] The assumption of inelastic labor supply is in fact made often in the literature (e.g., Fornaro and Romei, 2019; Eggertsson et al., 2019). In Schmitt-Grohé and Uribe (2016), the baseline model also has inelastic labor supply, however, elastic labor supply is considered as a model extension.

Households' budget constraint (2) is thus replaced by

$$P_tC_t + \frac{B_{t+1}}{R} = \int_0^1 W_t(i)H_t(i) + \Pi_t(i)di + B_t. \tag{16}$$

In budget constraint (16), each household supplies labor to (and receives profits from) the entire universe of firms. We may thus think of each household as consisting of a large number of workers, and pooling their resources. This implies that total income at the household level is $\int_0^1 W_t(i)H_t(i) + \Pi_t(i)di$.

As in the baseline model, households take wages as given. Households attempt to direct labor supply to those firms that pay the highest wage. In each period they maximize

$$\max_{(H_t(i))_{i\in[0,1]}} \int_0^1 W_t(i)H_t(i)di \quad \text{s.t.} \quad \left(\int_0^1 H_t(i)^{1+\frac{1}{\eta}}di\right)^{1/\left(1+\frac{1}{\eta}\right)} \leq H_t, \quad \eta > 0. \tag{17}$$

As shown in Appendix B.1, problem (17) has an interior optimum characterized by a set of firm-specific labor supply curves

$$H_t(i) = \left(\frac{W_t(i)}{W_t}\right)^\eta H_t, \quad i \in [0,1], \tag{18}$$

where $W_t = (\int_0^1 W_t(i)^{1+\eta}di)^{1/(1+\eta)}$ is the wage index (the aggregate wage).

Equation (18) reveals that parameter η is the wage elasticity of labor supply *as faced by individual firms*. Unless $\eta = \infty$, a firm may pay a lower wage than its competitors and still not lose all of its workers. Intuitively, this set-up captures the idea that frictions in the labor market exist, whereby workers find it difficult to quickly change their employer. This gives firms market power—it makes firms *monopsonistic competitors* (Manning, 2003).[18] The lower the elasticity η, the stronger the market power of firms. As will be shown below, the baseline model (perfect competition) is nested as the limit point $\eta = \infty$.

As in the baseline model, the labor market is characterized by downward nominal wage rigidity: $W_t(i) \geq \psi W_{t-1}(i)$ for all $i \in [0,1]$.

Replacing $H_t(i)$ by equation (18), and using the aggregator for H_t and the wage index W_t, we obtain total wage income $\int_0^1 W_t(i)H_t(i)di = W_tH_t$. Using this in budget constraint (16) and taking first order conditions with respect to H_t, we obtain (aggregate) labor supply: equation (4), which is unchanged from the baseline model. Finally, households' Euler equation (5) is also unchanged from the baseline model.

As in the baseline model, firms face the technology $Y_t(i) = a_tF(H_t(i)) = a_tH_t(i)^\alpha$. The heart of the monopsony model is the problem of firms.

Definition 4. [FIRM PROBLEM MONOPSONY MODEL] *In the monopsony model, each firm* $i \in [0,1]$ *solves the following dynamic problem*

$$\Gamma_t(W_{t-1}(i)) = \max_{(H_t(i),W_t(i))} \left\{U'(t)\left(a_tF(H_t(i)) - \frac{W_t(i)}{P_t}H_t(i)\right) + \beta E_t\Gamma_{t+1}(W_t(i))\right\}$$

subject to the set of constraints

$$\begin{array}{ll} i) & H_t(i) \leq (W_t(i)/W_t)^\eta H_t, \\ ii) & W_t(i) \geq \psi W_{t-1}(i), \end{array}$$

by taking as given the aggregate variables $\{a_t, P_t, H_t, W_t, U'(t)\}$.

[18] For example, these frictions may include ignorance among workers about labor market opportunities or mobility costs. Or workers may not leave the firm due to firm-specific non-pecuniary benefits.

The value function Γ_t denotes the present value of (utility-weighted, real) profits, which has time index t for it depends on aggregate states. The utility weights reflect that firms are owned by the households. Firms face equation (18) as a constraint, but holding only with weak inequality: if firms receive a large labor supply and downward nominal wage rigidity binds, they may decide to ration employment.[19] In equilibrium, all firms are identical and index $i \in [0, 1]$ disappears. Hence in equilibrium, households' individual labor supply holds *with equality* as we anticipated in equation (18)—and the rationing of employment arises from aggregate labor supply (4) as in the baseline model.[20]

The problem of firms is solved in Appendix B.1. When downward nominal wage rigidity is slack, (aggregate) labor demand is given by

$$a_t F'(H_t) = \frac{\eta + 1}{\eta} \frac{W_t}{P_t} + \frac{1}{U'(t)} \frac{1}{\eta} \frac{W_t}{H_t} \beta \psi E_t \lambda_{t+1}, \tag{19}$$

where $\lambda_t \geq 0$ is a non-negative multiplier which measures the increase in the utility value of the present value of firms' real profits when downward nominal wage rigidity is relaxed by a marginal unit.[21] It solves the recursive expression

$$\lambda_t = -U'(t) \eta \frac{H_t}{W_t} \left(a_t F'(H_t) - \frac{\eta + 1}{\eta} \frac{W_t}{P_t} \right) + \beta \psi E_t \lambda_{t+1}. \tag{20}$$

Instead, labor demand when downward nominal wage rigidity binds has the same properties as in the equilibrium of the constrained-efficient planner (see the definition of equilibrium, Definition 5, below, and compare with Definition 3).

All other equilibrium conditions are as in the baseline model. The resource constraint is still given by equation (8). Monetary policy is specified as in Section 2. The equilibrium under laissez-faire can thus be defined as follows.[22]

Definition 5. [EQUILIBRIUM MONOPSONY MODEL] *In the monopsony model, the equilibrium under laissez-faire is a set of processes* $\{P_t, C_t, H_t, B_{t+1}, W_t, \lambda_t\}_{t \geq 0}$ *such that equations* (5), (7)-(8) *and* (20) *as well as either*

i) [slack] equation (19) *and* $G'(H_t) = W_t/P_t$ *if* $W_t \geq \psi W_{t-1}$, *or else*
ii) [binds lightly] $W_t = \psi W_{t-1}$ *and* $G'(H_t) = W_t/P_t$, *if* $a_t F'(H_t) \geq W_t/P_t$ *or else*
iii) [binds strongly] $a_t F'(H_t) = W_t/P_t$ *and* $W_t = \psi W_{t-1}$,

where $U'(t) \equiv U'(C_t - G(H_t))$, *for given initial conditions* $W_{-1} > 0$ *and* B_0, *and for a given exogenous process* $\{a_t, \bar{P}_t\}_{t \geq 0}$, *are all satisfied.*

Definition 5 collapses to Definition 1 once $\eta \to \infty$. This establishes that the monopsony model nests the baseline model as a special case.

4.2. Constrained efficiency and policy implications

As for the baseline model, the relevant efficiency benchmark for the monopsony model is the constrained-efficient equilibrium from Definition 3. This is because the baseline model and the

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[19] This happens when $a_t F'(H_t(i)) < W_t(i)/P_t$, in which case hiring the full labor supply would reduce the profits of firm i. Instead, firm i chooses to ration employment according to $a_t F'(H_t(i)) = W_t(i)/P_t$.

[20] In the general case where firms ration labor supply asymmetrically, households' intra-period labor supply problem changes because some firms (but not all) ration labor supply. To save on notation, equation (18) anticipates the symmetric equilibrium and is therefore specified with equality. However, in the *firms'* problem it is important to specify equation (18) with *inequality*, as firms are not wage-taking agents such that their behavior depends on the fact that they may ration labor supply in the future. More details are in Appendix B.1.

[21] Formally, it is the Lagrange multiplier attached to constraint ii) in Definition 4.

[22] More details on the monopsony model and an overview of equilibrium conditions are in Appendix B.1.

monopsony model differ only in terms of their labor demand—which is exactly the margin that is chosen freely by the planner.[23]

Comparing Definitions 3 and 5 reveals that the equilibrium under laissez-faire is *constrained inefficient*. This is because, when downward nominal wage rigidity is slack, firms' (aggregate) labor demand (equation (19)) and constrained-efficient labor demand (equation (9)) are not identical. There are three differences which are discussed in turn.

The first difference is a monopsonistic mark-up $(\eta + 1)/\eta \geq 1$. The mark-up is larger, the lower is the wage elasticity of labor supply η that is faced by individual firms. This inefficiency is well understood. The second difference reflects another distortion due to firms' market power: the labor demand curves feature a different shadow value of marginally relaxing downward nominal wage rigidity, $\lambda_t \neq \lambda_t^{sp}$. This difference arises because for firms λ_t represents the utility-value of transferring higher rents to households by relaxing downward nominal wage rigidity by a marginal unit. It is well understood that firms misperceive the social value of their rents from market power.[24]

The third difference is the pecuniary externality. Formally, it appears in the fact that the planner discounts the expected utility cost of downward nominal wage rigidity by using the *aggregate* wage elasticity ε_t^G, whereas firms use their *individual* elasticity η. Under the assumption $\eta > \varepsilon_t^G$, firms discount the utility loss more strongly than the planner, implying that firms *underestimate* the true social cost of downward nominal wage rigidity.

The assumption $\eta > \varepsilon_t^G$ is empirically plausible. Recall that in this model, the elasticity of aggregate labor supply equals the Frisch elasticity: $\varepsilon_t^G = 1/\varphi$. While the parameter φ is controversial because micro and macro estimates of this parameter often do not coincide (Keane and Rogerson, 2012), Galí (2011) notes that most studies assume that φ is between 1 and 5. This implies that η needs to exceed a number between 0.2 and 1, which in turn implies that the mark-up by firms must exceed $(\eta + 1)/\eta = 200\%$. This appears to be an unreasonably strong degree of market power.[25]

To understand the role played by the two elasticities, take a look at Figure 2, which reproduces the left panel of Figure 1. Recall that points A and B represent the constrained-efficient equilibrium and the equilibrium under laissez-faire in the baseline model, respectively. The new (red, dashed-dotted) downward-sloping line is labor demand in the monopsony model, equation (19). Point D is therefore the equilibrium in the monopsony model. It has lower hiring and wages compared to the baseline model, reflecting that firms behave prudentially. However, hiring and wages are not reduced as much as in the constrained-efficient equilibrium. This difference reflects the pecuniary externality.[26]

[Figure 2 about here.]

Imagine the economy is initially in point A. Firms perceive that, should they hire more workers associated with point E, this raises $W_t(i)$ to the level associated with point E. This is because the thin dashed-dotted line is labor supply *as faced by individual firms*. Firms internalize that

[23] The planner first chooses all firm i's labor demand to be identical. The planner then chooses aggregate labor demand along the lines of Definition 2.

[24] Appendix B.2 considers the problem of a *single* monopsonist. Compared to the case of monopsonistic competitors that is studied in the main text, the single monopsonist internalizes the pecuniary externality but still exercises market power. This allows us to separate these two effects on the efficiency properties of equilibrium. It turns out that the monopsonist uses the same λ_t as do the monopsonistic competitors, while the expected utility cost of downward nominal wage rigidity is discounted by using elasticity ε_t^G (as in the constrained-efficient allocation). This establishes that $\lambda_t \neq \lambda_t^{sp}$ represents a distortion due to market power, rather than a distortion due to the pecuniary externality.

[25] This being said, some estimates in Manning (2003) of the individual-firm labor supply elasticity are as low as $\eta = 0.75$. Other articles obtain higher estimates. For example, Depew and Srensen (2013) argue that the literature tends to obtain estimates of η in between 1 and 10.

[26] To make transparent the effects of the externality, this discussion ignores that changes in η also shift the labor demand curve due to changes in the mark-up $(\eta+1)/\eta$. Both effects go, in fact, in the same direction: as η falls, labor demand shifts unambiguously to the left.

higher wages $W_t(i)$ make it more likely that they will be constrained by downward nominal wage rigidity in the future themselves. However, as in the baseline model, firms fail to internalize that competition for workers between firms pushes up the *aggregate* wage W_t. In equilibrium, W_t and $W_t(i)$ coincide which in the figure gives rise to an upward shift of firm-specific labor supply (the red arrow pointing upwards), which now passes through the new equilibrium point D. Relative to point E, wages have increased further, which is not internalized by individual firms.

Point E lies below point D because individual labor supply is drawn flatter than aggregate labor supply ($\eta > \varepsilon_t^G$). As a result, the externality becomes more severe when η increases (less market power by firms) as this flattens out individual labor supply even further (point D moves closer to point B). In the limit of perfect competition (the baseline model), firm-specific labor supply is completely flat.

An implication is that the pecuniary externality becomes weaker when firms have more market power (as η declines), which has a positive effect on welfare. However, this does not imply that more market power by firms is necessarily welfare improving. This is because, as η declines, firms' monopsonistic mark-up $(\eta + 1)/\eta$ rises. As shown in Section 5, in the calibrated model, the net effect is that welfare losses are U-shaped in the degree of labor market competition.

To summarize, the externality does not resolve when firms internalize downward nominal wage rigidity and behave prudentially at the private level. This implies that there is still a role for macro-prudential intervention. Appendix B.3 proves the analogue of Proposition 2 for the monopsony model: a labor tax can be used to decentralize the constrained-efficient allocation. More generally, Appendix B.3 demonstrates that all insights from Section 3.2 go through (largely) unchanged for the monopsony model.

5. Quantitative analysis

This section demonstrates that the externality has large negative effects on welfare and unemployment. Calibration is discussed in Section 5.1. Section 5.2 presents results of the quantitative analysis.

5.1. Calibration and numerical implementation

We target a set of 12 countries that either peg to the euro or are part of the euro area. The countries are Bulgaria, Estonia, Ireland, Greece, Spain, Italy, Cyprus, Latvia, Lithuania, Portugal, Slovenia and Slovakia. The time-span considered is 2000Q1-2018Q4, at a quarterly frequency.

This set of countries is targeted because Schmitt-Grohé and Uribe (2016) provide an estimate for parameter ψ for these countries. Recall that ψ measures by how much nominal wages can decline before downward nominal wage rigidity binds, making it the key parameter for the impact of this friction quantitatively. By using aggregate wage dynamics, Schmitt-Grohé and Uribe (2016)'s estimate is $\psi = 0.993$ at a quarterly frequency after accounting for technology growth, which implies that nominal wages can decline up to 2.8 percent per year. Clearly, this estimate of ψ is merely suggestive. For example, it has been argued that aggregate wage data may not be informative about wage rigidity for what matters for employment adjustment is the wage rigidity of new hires (Pissarides, 2009). In this regard, there is evidence that wages of new hires are quite flexible (e.g., Haefke et al., 2013, for the US). On the other hand, Gertler et al. (2019) argue that composition effects due to workers moving to better jobs in expansions lead to an understatement of the true degree of wage rigidity, and that after controlling for this composition effect, wages appear quite sticky at the relevant margin of new hires.[27] To take account of this debate, a sensitivity analysis will explore how results change with respect to changes in ψ.

[27] In a recent survey, Elsby and Solon (2019) point out that nominal wages appear quite downward flexible when looking at administrative data. In contrast, Jo (2019) argues that models with downward nominal wage rigidity are the most consistent with empirical findings regarding the shape and cyclicality of wage change distributions in the US.

In the baseline calibration, we assume that labor market competition is perfect (the baseline model / the monopsony model as $\eta \to \infty$). This enhances transparency, because welfare losses arise exclusively due to the pecuniary externality (whereas when firms have market power, welfare effects also reflect changes in mark-ups). It will also be discussed how model predictions change when $\eta < \infty$.

One parameters that matters for the externality is the aggregate labor supply elasticity $1/\varphi$. As mentioned in Section 4.2, there is considerable uncertainty regarding plausible values for this parameter. We use $\varphi = 3$ in the baseline calibration, and the effects of changes in φ will be explored in a sensitivity analysis.

Turn now to the model's stochastic structure. The business cycle is driven by shocks to TFP, which are assumed to have a log-Normal AR(1) structure

$$\log(a_t) = \rho_a \log(a_{t-1}) + \sigma_a v_t, \tag{21}$$

where $v_t \sim^{iid} \mathcal{N}(0,1)$, $\sigma_a > 0$ and $\rho_a \in [0,1)$.

We pick the pair (ρ_a, σ_a) to match the volatility and autocorrelation of real GDP of the countries in the sample. As in Schmitt-Grohé and Uribe (2016), OECD data on manufacturing output is used to proxy for the fact that in the model, all goods are internationally tradable. We first HP-filter the series, then compute the standard deviation and autocorrelation of the cyclical component for all countries.[28] The arithmetic average across countries is $\sigma(y) = 7.1\%$ and $\rho(y) = 0.77$. The calibrated parameters are $\rho_a = 0.9$ and $\sigma_a = 0.023$.[29]

We assume constant inflation in the anchor country: $\bar{P}_t = \bar{\pi}\bar{P}_{t-1}$. The average HICP inflation in the eurozone during the sample period was 1.7% yearly, which yields $\bar{\pi} = 1.00425$. Taking account of trend inflation matters because of the "greasing the wheels effect" (Tobin, 1972).[30] We use EMU-convergence-criterion bond yields to proxy for the nominal borrowing rate R. The arithmetic average across time and countries is $R = 1.0116$ at a quarterly frequency (a yearly nominal rate of 4.6%). In the baseline model, α equals the labor share of income. Here we use the standard value $\alpha = 2/3$. For U we assume a coefficient of relative risk aversion $\sigma = 2$, a value commonly used in international business cycle studies (e.g., Mendoza and Yue, 2012). Finally, the time discount factor is $\beta = 0.9926$, calibrated to obtain a mean ratio of foreign assets to annual GDP of -52 percent, in line with the average foreign asset to GDP ratio of the countries in the sample.[31] The calibrated parameters are summarized in Table 1.

[Table 1 about here.]

The model is solved globally by using a fixed point iteration over conditional expectations. We use the routine developed by Rouwenhorst (1995) to implement the TFP process (21), which is superior to the more common Tauchen algorithm when the approximated process has a high autocorrelation. Because of the presence of trend inflation, the model is not stationary. Therefore, we first define the model in stationary terms before applying the solution procedure. The model's equilibrium conditions in terms of stationary variables are in Appendix F.

5.2. Results of the quantitative analysis

Figure 3 shows policy functions for hours, wages, the wedge term appearing in equations (9) and (19), and the optimal tax τ_t^w appearing in equation (11). In the wedge term, *elasticity* denotes

[28] There is no data available for Cyprus and Bulgaria. For this part of the calibration, these two countries are the therefore omitted from the sample.

[29] Given quarterly frequency, the value for σ_a appears quite high, but this reflects the high measured standard deviation of tradable output in the sample. However, these numbers are in line with Schmitt-Grohé and Uribe (2016), who estimate a quarterly standard deviation of (de-trended) tradable output $\sigma(y) = 6.5\%$ during 1981-2011 for Greece.

[30] The two parameters $\bar{\pi}$ and ψ enter the model symmetrically. Sensitivity checks with respect to ψ can thus be understood as sensitivity checks with respect to higher trend inflation.

[31] In order to obtain a well-defined asset distribution, we impose a borrowing limit of 150% foreign debt to (steady-state) GDP, which however in equilibrium is almost never binding.

the relevant labor supply elasticity, corresponding to *elasticity* $= \infty$ under laissez-faire (perfect competition), and to *elasticity* $= 1/\varphi = 1/3$ under the optimal intervention.[32]

[Figure 3 about here.]

As Figure 3 shows, hours and wages rise in expansions, and hours fall sharply and wages are bounded below in recessions. In recessions, the constrained-efficient and the equilibrium under laissez-faire coincide, reflecting that the planner respects the same frictions as the private economy. However, in expansions hiring is lower in the constrained-efficient equilibrium, inducing less wage inflation. This represents an endogenous wedge term affecting labor demand in the constrained-efficient equilibrium, which becomes larger the larger is the expansion.[33] The wedge is decentralized via a tax on labor, which is positive during expansions, and zero in recessions.

[Figure 4 about here.]

Figure 4 shows stationary distributions. The upper left panel shows unemployment as defined in equation (14). Under laissez-faire, mean unemployment is 2.7%, and by excluding the mass point at zero, it rises to 5.6%.[34] This compares with a mean unemployment rate of 10.9% in the countries in the sample. The model thus accounts for a large chunk of unemployment in these countries, even though other frictions that generate unemployment are not included in the model, and most notably search frictions.[35] The probability mass to the right of 10% unemployment is 7.4%. Given quarterly calibration, this implies that once every 3.5 years, the labor market is rationed by at least 10%, which appears sizable. The probability mass to the right of 2% unemployment is 34.3%.

The stationary distribution for unemployment is shifted to the left under the optimal intervention. The probability mass to the right of 2% unemployment drops from 34.3% to 2.3%. The probability mass to the right of 10% unemployment drops all the way to zero. The mean unemployment rate is reduced to 0.16% and to 2.8% by excluding the mass point at zero. Overall, the intervention thus makes the economy significantly less exposed to unemployment crises.[36] The upper right panel reveals that the tax on labor underlying the intervention is in fact quite small. The distribution is tightly centered around a mean tax rate of 3.9%.

The lower row shows stationary distributions for output Y_t and net foreign assets to GDP, $B_{t+1}/(4P_tY_t)$. The distribution of output has less mass on the left under the intervention, reflecting that recessions are less frequent. The distribution of assets is hardly affected by the intervention. This is noteworthy in light of previous studies, which emphasized shifts in the distribution of external assets reflecting that the private equilibrium "overborrows" (e.g., Schmitt-Grohé and Uribe, 2016; Bianchi, 2011). As emphasized before, here a different externality is at work which operates through the labor market. This implies that the distribution of external assets is hardly affected by the intervention.

To assess the welfare implications of the intervention, it is convenient to express welfare losses in terms of consumption equivalents

$$E_0 \sum_{t\geq 0} \beta^t U(C_t(1+\iota_0) - G(H_t)) \equiv E_0 \sum_{t\geq 0} \beta^t U(C_t^{fb} - G(H_t^{fb})), \tag{22}$$

[32] Here we exploit that the monopsony model nests the baseline model as a special case when $\eta \to \infty$. Appendix B.4 shows the equivalent of Figure 3 in case firms' monopsony power is strong: $\eta = 5$.

[33] The wedge also shoots up when downward nominal wage rigidity binds, due to the multiplier λ_t^{sp} turning positive. However, in this region, labor demand is determined by $a_t F'(H_t) = W_t/P_t$ (see Definition 3), such that the wedge has no effect on the equilibrium allocation.

[34] The mass point arises as firms hire the full labor supply when downward nominal wage rigidity is slack.

[35] Michaillat (2012) considers a model where unemployment due to search and rationing may arise jointly.

[36] Notice that the payroll tax and thus the intervention itself does not lead to unemployment. While the tax reduces employment, it does so via a reduction in wages. This implies that lower employment is not measured as unemployment according to equation (14). Intuitively, when wages are lower workers are less willing to work—i.e., workers are still "on their labor supply curve".

where the right-hand side captures policy functions under first-best (no downward nominal wage rigidity). The equilibrium under laissez-faire and the constrained-efficient equilibrium are both assessed against the benchmark in equation (22). The difference between the two losses then captures the welfare benefits of the prudential intervention.

Figure 5 shows the mean of the stationary distributions for ι_0 in the baseline calibration and additionally by varying the parameters ψ, φ and η. Recall that the baseline calibration is $\psi = 0.993$, $\varphi = 3$ and $\eta = \infty$.

[Figure 5 about here.]

In the baseline calibration, losses under laissez-faire are 0.26% of permanent consumption. Losses with the intervention in place are reduced to 0.025% of permanent consumption. The prudential intervention thus reduces the welfare cost of downward nominal wage rigidity significantly, by about 90% in the baseline calibration.

The upper left panel in Figure 5 changes the degree of downward nominal wage rigidity ψ. Clearly, welfare losses fall as wages become more downward-flexible. More interestingly, the relative distance between the two welfare losses is not much affected when ψ is lowered. Therefore, the externality is still relevant, in the sense that it strongly *exacerbates* the cost of downward nominal wage rigidity.

The upper right panel changes the wage elasticity of aggregate labor supply $1/\varphi$. The relative distance between the two welfare losses increases as the elasticity drops, indicating that the externality becomes stronger as aggregate labor supply becomes steeper. This is in line with the intuition provided in Section 3.

Finally, the lower row in Figure 5 changes firms' market power as measured by the (inverse) wage elasticity of individual labor supply $1/\eta$.[37] The left panel shows welfare losses (as in the upper two panels of the figure), while the right panel shows firms' monopsonistic mark-ups implied by different levels of $1/\eta$.

Recall that when firms have market power, differences vis-à-vis the constrained-efficient equilibrium arise both due to the pecuniary externality and due to firms' charging monopsonistic mark-ups. Note first that welfare losses under the optimal intervention are independent of η, because this parameter does not appear in the constrained-efficient equilibrium. In contrast, welfare losses under laissez-faire have a U-shape. When market power is strong, welfare losses are dominated by large mark-ups, as can be seen in the right panel. Welfare losses drop as competition increases. However, the result flips when $1/\eta$ becomes too low: welfare losses are dominated by the externality, and start to increase in the degree of labor market competition.[38]

6. Conclusion

A pecuniary externality in economies with downward nominal wage rigidity leads firms to hire too many workers in expansions, which leads to too much unemployment in recessions. The externality can be resolved by a tax on labor in expansions.

The present analysis hints at a number of open questions. First, while the main text studies the behavior of firms, Appendix C shows that households' labor supply decisions are also constrained inefficient. Studying the interaction between firms' and unions' hiring decisions in a context of downward nominal wage rigidity therefore provides an interesting aspect for future research.

Similarly, Appendix D shows that the pecuniary externality and aggregate demand externalities of the type studied in Schmitt-Grohé and Uribe (2016) in general interact. Exploring in more depth the nature of this interaction and how this shapes prescriptions for macroprudential regulation in a quantitative setting hence provides another avenue for future research.

[37] The origin thus corresponds to perfect competition.

[38] The minimum point is reached at $\eta \approx 1/0.045$. At this point, welfare losses (on average) are only slightly above those in the constrained-efficient allocation. To see why this can happen, note that starting from a large η, the larger mark-up associated with a decline of η tends to be *welfare improving*: it reduces labor demand in expansions, as does the planner in the constrained-efficient allocation.

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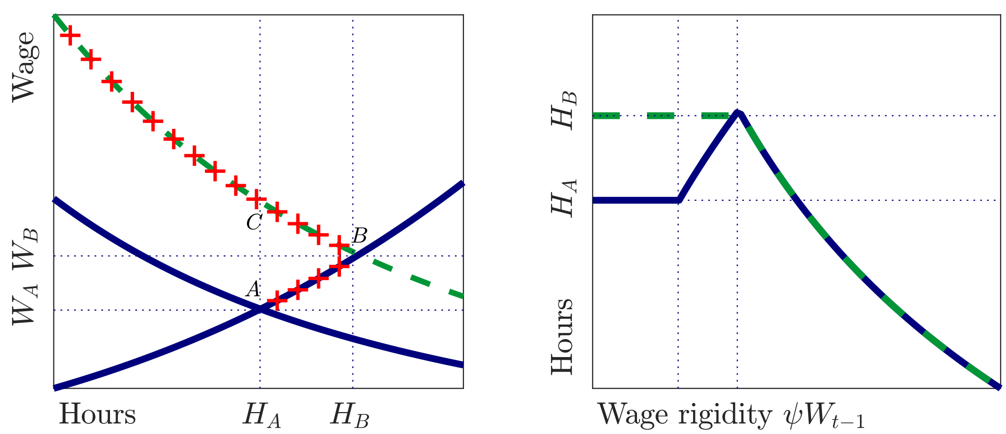

Figure 1: Labor market outcomes: baseline model and constrained-efficient equilibrium.

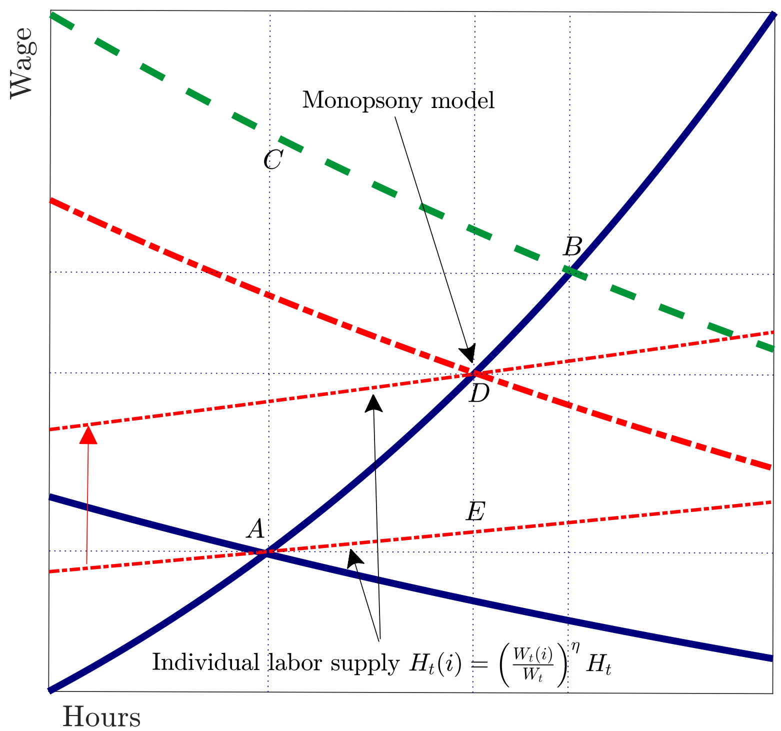

Figure 2: Labor market outcomes: monopsony model.

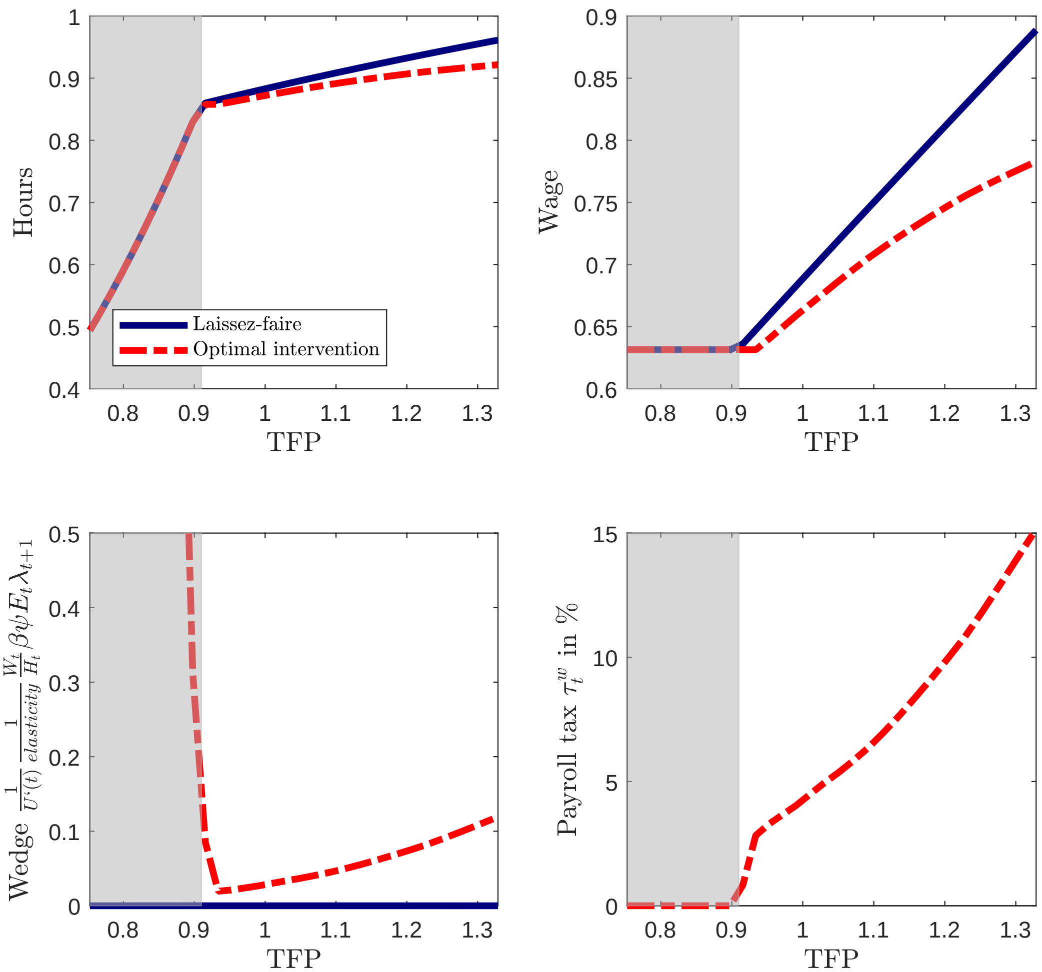

Figure 3: Policy functions. The gray area is the region where downward nominal wage rigidity binds under laissez-faire. The constrained-efficient equilibrium is indicated by "Optimal intervention". Lagged wages are set two, foreign assets are set one standard deviation below the mean of the stationary distribution.

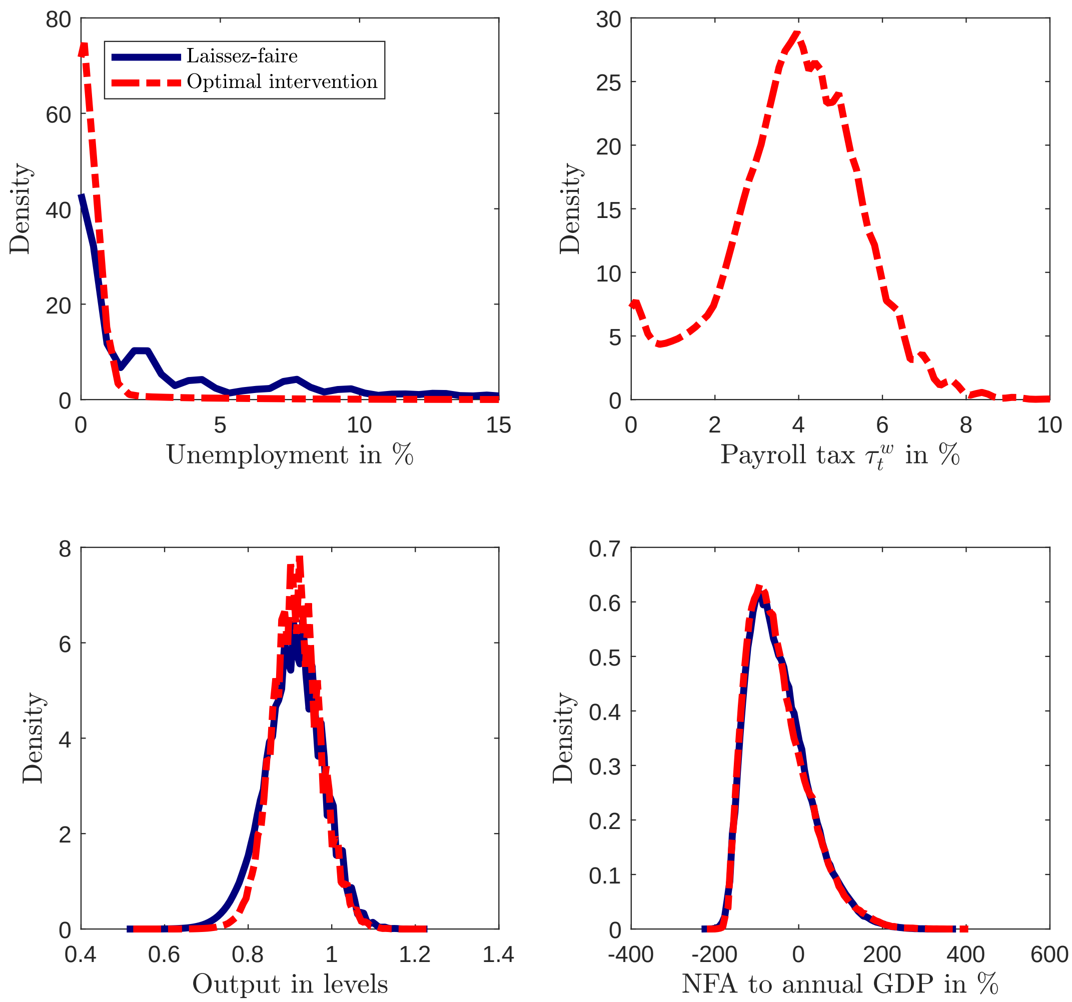

Figure 4: Stationary distributions.

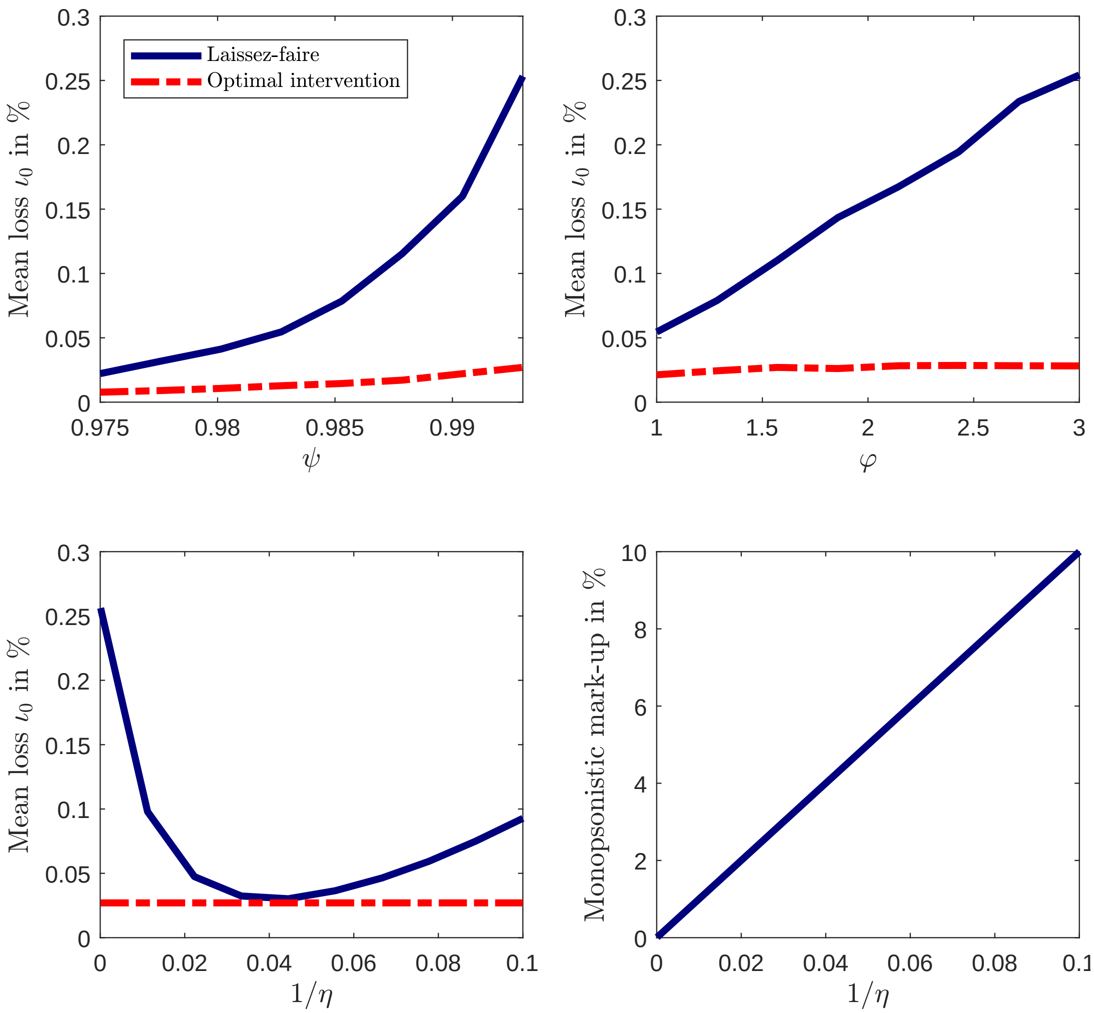

Figure 5: Welfare effects and sensitivity vis-à-vis variation in ψ, φ and η. Shown are welfare losses relative to first-best, respectively. The lower right panel shows the monopsonistic mark-up $(\eta+1)/\eta-1$, in percent.

List of Tables

Parameter and description of parameter		*Value assigned*
β	Time discount factor	0.9926
$\bar{\pi}$	Trend inflation	1.00425
R	Nominal gross borrowing rate	1.0116
ψ	Downward nominal wage rigidity	0.993
α	Labor share	2/3
φ	Inverse Frisch elasticity	3
σ_a	Volatility TFP innovations	0.023
ρ_a	Autocorrelation TFP	0.90

Table 1: Calibration table.