Taxation, Credit Frictions and the Cyclical Behavior of the Labor Wedge

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Abstract

Labor-income and consumption taxes are often referred to as the primary causes of the labor wedge and differences in hours worked across countries. While this can be potentially true in the long-run, its premise for explaining the cyclical behavior of the labor wedge is questionable. Using U.S. data over 1955-2019, this paper first studies whether taxation explains the cyclical behavior of the labor wedge. It is shown that the tax wedge, which combines both types of taxes, fails in accounting for the countercyclicality of the labor wedge. I then study other factors that may raise the labor wedge during recessions, such as credit frictions on the firms' side and price markups, and find that credit frictions are the primary reasons for this behavior. The empirical findings are consistent with the model-based results; the model with credit frictions successfully generates a countercyclical behavior of the labor wedge, whereas the model without credit frictions does not.

Keywords: Labor wedge; Credit frictions; Tax wedge; Business cycles.
JEL Classification: E24; E32; E44; H30.

1. Introduction

Taxation of labor income and consumption are often considered the key determinants of the labor wedge as they create a gap between the real wage and the marginal rate of substitution between labor and consumption (MRS). Taxes, particularly labor-income taxes, are also referred to in explaining the long-term trend of hours and differences in hours worked across countries. This paper goes beyond the existent literature by first investigating whether taxes can explain the cyclical behavior of the labor wedge. The paper finds that the tax wedge (which combines labor-income and consumption tax rates) moves in the opposite direction of the labor wedge during recession and non-recession times and, therefore, the rise in the labor wedge during recessions cannot be attributed to taxation. This finding leads to the question of what explains the cyclical behavior of the U.S. labor wedge.

To address this question, I use U.S. quarterly data over the period 1955:1-2019:2 and find that credit frictions, measured by the corporate credit spread, can account for this behavior

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of the labor wedge, even after controlling for the state of the economy. Other potential factors, such as variations in price markups, fail to do so. In addition, the paper shows that the investment tax rate is significant in explaining the behavior of the labor wedge even though it does not enter this wedge directly. It is also shown that the results of the model with credit frictions indicate a countercylical labor wedge whether tax rates are held constant or allowed to vary. The model with no credit frictions, on the other hand, delivers a procyclical behavior by the labor wedge, which is at odds with the empirical evidence that is presented in this study, and fails in accounting for basic business-cycle statistics.

I construct a business cycle model with labor-income and consumption taxation, credit constraints on firms and market power in the product market. The credit friction is introduced through a standard limited enforcement problem as in Kiyotaki and Moore (1997). Firms borrow to pay factors of production in advance (the standard "working capital" requirement), and borrowing is constrained by their beginning-of-period collateral. In the absence of credit frictions and market power in the product market, the labor wedge equals the tax wedge. But, credit frictions and markups in the product market make the labor wedge different from the tax wedge. Furthermore, while taxes affect the households' side of the labor market (hence, the households' side of the labor wedge), the other two distortions affect the firms' side. Key to this paper, the labor wedge in this setup is rising in the tightness of the credit constraint that firms face.

There is a voluminous literature on the labor wedge, its behavior and determinants. Shimer (2009) reviews the research on the labor wedge and describes its countercyclical behavior. He discusses multiple possible explanations for the cyclical behavior of the labor wedge, such as the rise in labor and consumption taxes, misspecification of either the marginal rate of substitution between labor and consumption or the marginal product of labor (MPL), a time-varying disutility of work, market power in the labor market, wage rigidity and labor market frictions. Shimer (2009) expresses doubts about the validity of these explanations, including labor market frictions and taxation.

Using a standard business cycle model with search and matching frictions, Cheremukhin and Restrepo-Echavarria (2014) study whether labor market frictions, given their role in explaining unemployment, can explain the labor wedge. They conclude that wage rigidity and endogenous job destruction are not very useful for explaining the behavior of the labor wedge, and suggest to give more attention to studying frictions equivalent to the matching shock in the model. Karabarbounis (2014) studies whether the variations in the labor wedge reflect variations in the gap between the MPL and the real wage or variations in the gap between the real wage and the MRS both for the U.S. and for other advanced nations. The author decomposes the labor wedge accordingly and finds that the fluctuations in the labor wedge occur mostly due to the fluctuations in the gap between the MRS and the real wage, particularly in the United States. Importantly, the latter study considers the tax-adjusted MRS, rather than only the MRS, which does not enable studying the effects of taxation on the labor wedge. In this regard, I show that the labor-income tax rate has negative effects on the labor wedge, whereas the consumption tax rate affects the labor wedge positively over the business cycle. The overall effect of the tax wedge, which is mostly negative, is due to the fact that the labor-income tax rate is more dominant. Considering the tax-adjusted MRS, thus, does not allow us to disentangle these different patterns. This is another reason for using the MRS, as opposed to its tax-adjusted counterpart, in this paper.

The aforementioned studies abstract from the possible role of credit frictions that firms and/or households may face. Credit frictions have been found to be very important in driving labor market outcomes as has been clearly documented by Jermann and Quadrini (2012). My work shows that firm-level credit frictions can generate a labor wedge, which is consistent with the results of Jermann and Quadrini (2012) and Arellano et al. (2012). I, however, go beyond these studies by first studying the cyclical effects of taxation on the labor wedge, by showing empirically that credit frictions can indeed explain the observed behavior of this wedge over the business cycle, and by carefully describing the cyclical behavior of the labor wedge in a standard business cycle model.

Some recent studies (e.g. and Karabarbounis (2014) and Cociubaa and Ueberfeldt (2015)) establish the fact that the trend of the labor wedge has been different than that of the tax wedge (or the labor-income tax rate) since at least the early 1980s, casting doubts in the ability of taxes in explaining the long-run trend of the labor wedge. They also imply that the predictions of standard representative-agent models, such as in Prescott (2004) and Ohanian et al. (2008), are counterfactual when applied to U.S. data. The latter two studies attribute the differences in hours worked across advances countries to taxation; in particular, hours worked per person are higher in the U.S. due to its lower tax rates.

However, the short-term association between the labor wedge and other factors may potentially be different from the long-term counterpart. In addition, prior to the 1980s, the U.S. labor wedge and taxes exhibited similar trends (both rising), which leads to the question about their cyclical behavior during that sample period. This paper provides answers to this question too: despite the positive long-term association between the tax wedge and the labor wedge in the first half of the sample, their cyclical components had been *negatively* correlated. This is an important result and it suggests that given the labor wedge the interpretation of a tax wedge has never been founded when the business-cycle behavior is concerned. It also suggests that factors affecting the labor wedge in one way in the long-term may have different (or non) short-term effects, and vice versa.

On the contrary, the credit spread has robust positive effects on the labor wedge during that sample period. Interestingly, this happens despite a slight rise in the credit spread and a significant drop in the labor wedge since the early 1980s. More than 30% of the short-run variations in the labor wedge can be accounted for by only the credit spread. In addition, short-run fluctuations in the price markup, as a proxy for fluctuations in product-market imperfections, do not have effects on the short-run behavior of the labor wedge.

The observation that credit frictions affect the labor wedge has an important implication: contrary to the findings of Karabarbounis (2014), distorting the firms' side of the labor market contributes to the labor wedge and, in fact, it is essential for explaining its observed behavior over the business cycle. In other words, the success of firm-level credit frictions to account for the labor wedge and the failure of the tax wedge (particularly labor-income taxation), suggest that the production side of the economy is the one that should be modified to better understand the short-term behavior of the labor wedge. At the very least, these results suggest that, in studying the cyclicality of the labor wedge, the demand side of the labor market is important as well.

I also conduct robustness analyses using the Generalized Method of Moments, Maximum Likelihood and Bayesian estimation. Furthermore, I show the results using an alternative measure for the credit conditions. The key insights of the paper are robust to these changes.

The remainder of the paper proceeds as follows. Section 2 outlines the model economy and discusses the labor wedge implied by this study. Section 4 presents the data that I use in this paper, the parameterization of the model, shows first-pass analyses about the behavior of the labor wedge, and presents the benchmark empirical result. Section 5 presents some robustness analysis. Model-based impulse responses are shown in Section 3.2. Section 6 concludes.

2. The Model

The economy is populated by households, a representative firm and the government. Households consume and supply labor to the firm on spot markets. The firm needs to pay (at least part of) its input costs before production takes place, thus giving rise to borrowing from households. Borrowing is constrained by the value of real estate that the firm owns. This is the source of the credit friction in the baseline model. To focus on the behavior of the labor wedge, the benchmark analyses assume a real model. I then show the results of a sticky-price model in the appendix.

2.1. Households

In each period t, the representative household purchases consumption c_t, supplies labor l_t, accumulates capital k_t, purchases real estate h_t (e.g., in the form of housing) and lends b_t^f to the firm at the beginning of the period at an intra-period gross real interest rate of R_t^f. In addition, the household has access to a one-period real government bond b_t that pays a gross real interest rate of R_t. Households pay labor-income taxes, consumption taxes, capital-income taxes and investment taxes.

The households' problem is given by:

$$\max_{\{b_t, b_t^f, c_t, h_{t+1}, k_{t+1}, l_t\}_{t=0}^{\infty}} \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \eta_t u(c_t, h_t, l_t) \tag{1}$$

where $\mathbb{E}_0$ is the expectation operator, $\beta < 1$ denotes the subjective discount factor of households, η_t is an exogenous shock to households' preferences and $u(c_t, h_t, l_t)$ is the period utility function from consumption, real estate and labor. This function satisfies: $\frac{\partial u}{\partial c} > 0$, $\frac{\partial^2 u}{\partial c^2} < 0$, $\frac{\partial u}{\partial h} > 0$, $\frac{\partial^2 u}{\partial h^2} < 0$, $\frac{\partial u}{\partial l} < 0$ and $\frac{\partial^2 u}{\partial l^2} < 0$.

Maximization is subject to the households' sequence of period budget constraints:

$$(1-\tau_t^l)w_t l_t + [r_t - \tau_t^k(r_t-\delta)]k_t + q_t h_t + R_{t-1}b_{t-1} + R_t^f b_t^f = (1+\tau_t^c)c_t + (1+\tau_t^i)i_t + b_t + b_t^f + q_t h_{t+1} \tag{2}$$

and the law of motion of capital:

$$k_{t+1} = (1-\delta)k_t + i_t \tag{3}$$

where w_t is the real wage, q_t is the market price of real estate, r_t is rental rate of capital, i_t is gross investment, δ denotes the depreciation rate of capital, τ_t^l, τ_t^c, τ_t^k and τ_t^i stand, respectively, for the labor-income tax rate, consumption tax rate, capital-income tax rate and the investment tax rate.

The optimal choices of consumption, labor supply, capital, real estate, lending to the firm and bond holdings yield the following optimization conditions:

$$R_t^f = 1 \tag{4}$$

$$-\frac{u_{l,t}}{u_{c,t}} = \left(\frac{1-\tau_t^l}{1+\tau_t^c}\right)w_t \tag{5}$$

$$u_{c,t} = \beta R_t \,\mathbb{E}_t\left(u_{c,t+1}\frac{\eta_{t+1}}{\eta_t}\frac{1+\tau_t^c}{1+\tau_{t+1}^c}\right) \tag{6}$$

$$u_{c,t} = \beta\,\mathbb{E}_t\left(\frac{\eta_{t+1}}{\eta_t}\frac{u_{c,t+1}}{1+\tau_{t+1}^c}\frac{1+\tau_t^c}{1+\tau_t^i}\left[(1+\tau_{t+1}^i)(1-\delta) + r_{t+1} - \tau_{t+1}^k(r_{t+1}-\delta)\right]\right) \tag{7}$$

$$u_{c,t} = \beta\,\mathbb{E}_t\left(\frac{1+\tau_t^c}{q_t}\left(u_{h,t+1} + q_{t+1}\frac{u_{c,t+1}}{1+\tau_{t+1}^c}\frac{\eta_{t+1}}{\eta_t}\right)\right) \tag{8}$$

where $u_{c,t}$ is the marginal utility of consumption in period t, $u_{h,t}$ is the marginal utility of housing in period t and $u_{l,t}$ is the marginal disutility of supplying labor in period t. Equation (4) governs the lending of households to the firm; as in Carlstrom and Fuerst (1998), households are basically passive suppliers of credit to the firm (this result is due to the intra-period nature of loans). Equation (5) is the standard labor supply condition stating that, at the optimum, the marginal rate of substitution between labor and consumption equals the after-tax real wage. Equation (6) is the standard consumption Euler equation and condition (7) is the standard capital supply condition with capital-income taxation. Equation (8) is an asset pricing-type condition, stating that the current marginal utility from consumption is equal to the marginal gain from real estate. The latter includes both a direct utility from holding real estate next period and the possibility to expand future consumption by the realized resale value of real estate.

2.2. The Firm

The firm hires labor and rents capital from households to produce using the following production technology:

$$y_t = z_t f(k_t, l_t) \tag{9}$$

where y_t and z_t are output and total factor productivity, respectively.

The firm pays its input costs before the realization of revenues, which requires borrowing at the beginning of period t. This assumption follows Carlstrom and Fuerst (1998), among others. Borrowing, however, is constrained by the value of the firm's assets which are only in the form of real estate. Therefore, collateral equals the beginning-of-period market value of the firm's real estate.

Assuming that the firm uses real estate as collateral is common in the literature: Kiyotaki and Moore (1997) assume that borrowing is tied to the value of land, and Iacoviello (2005) assumes that entrepreneurs use real estate (in the form of housing) as collateral. Chaney, Sraer, and Thesmar (2012) show that, for U.S. firms over 1993-2007, appreciation in firms' real estate values led to a rise in investment that is mainly financed through additional debt issuance. This effect is particularly stronger for credit-constrained firms.[1]

As shown in Appendix A, the firm's problem with credit frictions can be reduced to the following maximization problem:

$$\max_{\{k_t, l_t, x_{t+1}\}_{t=0}^{\infty}} \mathbb{E}_0 \sum_{t=0}^{\infty} \gamma^t \left(1 - \tau_t^{\pi}\right) \left[(1 - m_t) z_t f(k_t, l_t) - w_t l_t - r_t k_t + q_t x_t - q_t x_{t+1}\right] \tag{10}$$

subject to:

$$\phi(w_t l_t + r_t k_t) \leqslant \kappa q_t x_t \tag{11}$$

where x_t is the firm's beginning-of-period stock of real estate, κ is the share of assets that can be used as collateral (or the loan-to-value ratio), τ_t^{π} is the tax rate on profits (Π_t), and ϕ is the fraction of factor payments that is paid in advance. Clearly, if $\phi = 0$ and $m_t = 0$, then the model collapses to the standard neoclassical growth model with no frictions. Furthermore, I think of this firm as being owned by an entrepreneur with a discount factor of γ, where $\gamma < \beta$. Notice also that the profit of this firm can be seen as the consumption of this entrepreneur whose utility function is linear in consumption, in line with the literature.

By denoting the Lagrange multiplier on condition (11) by μ_t , profit maximization gives the following factor demand functions and the choice of real estate:

$$(1 - m_t) z_t f_{l,t} = (1 + \phi \mu_t) w_t \tag{12}$$

$$(1 - m_t) z_t f_{k,t} = (1 + \phi \mu_t) r_t \tag{13}$$

$$q_t (1 - \tau_t^{\pi}) = \gamma \, \mathbb{E}_t \left[q_{t+1} (1 - \tau_{t+1}^{\pi} + \kappa \mu_{t+1})\right]. \tag{14}$$

The firm, thus, hires labor and rents capital so that the marginal product of each input is a markup over its factor price (alternatively, $\phi \mu_t$ resembles a spread above what the firm would pay in the absence of credit frictions). The total markup in this case is a result of the market power in the product market and the credit friction; in particular, the net markup is

[1] Furthermore, if we assume another type of asset that can be used as collateral, with the collateral constraint continuing to read $\phi(w_t l_t + r_t k_t) \leqslant \kappa n w_t$ and $n w_t$ is net worth, the results would hold qualitatively. Real estate has the advantage of being easier to incorporate in the model and it also enables keeping the real structure of the model.

given by $\frac{\phi\mu_t+m_t}{1-m_t}$. Therefore, the credit friction is equivalent to an endogenous markup that drives a wedge between the marginal product of labor and the real wage. If no exogenous markups are assumed ($m_t = 0$), the only markup will be due to the credit friction.[2] Condition (14) is an asset-pricing condition that results from the choice of real estate; in what follows it will determine the tightness of the credit constraint in the steady state.

There are two reasons for introducing a market power in the production sector. First, to capture realism and because market power in itself renders the real wage and the marginal product of labor unequal. Second, since the credit friction manifests itself as a markup, it is useful to account for exogenous markups so that, in the formal econometric analyses to follow, I can control for markups when assessing the effects of credit frictions on the labor wedge. In the absence of the exogenous markup, the results could be biased due to an omitted variable problem.

I close this subsection with a note on the borrowing constraint. The assumption in this section is that the working capital requirement applies to both hiring labor and renting capital. Assuming that renting capital is also subject to this requirement reflects the idea that firms borrow to increase their stock of capital. In their benchmark model, Jermann and Quadrini (2012) assume that the working capital covers, among others, the wage payments and investment in capital. My specification here is essentially similar to theirs. However, in subsection 3.5, I will also show the results when only the wage payments are subject to the working capital requirement. Furthermore, I abstract from intertemporal borrowing because they have no direct effect on the form of the labor demand condition and, hence, the wedge that I will derive in what follows.

2.3. The Government

The government collects labor-income taxes, consumption taxes, capital-income taxes, investment taxes, profit taxes and issues real debt to finance an exogenous stream of real government expenditures (g_t) in addition to the repayment of last-period debt. The government budget constraint in period t is, thus, given by:

$$\tau_t^l w_t l_t + \tau_t^c c_t + \tau_t^k (r_t - \delta) k_t + \tau_t^i i_t + \tau_t^\pi \Pi_t + b_t = g_t + R_{t-1} b_{t-1}. \tag{15}$$

2.4. Market Clearing

In addition to labor market clearing, the markets of goods and real estate clear:

$$z_t f(k_t, l_t) + (1-\delta) k_t = c_t + k_{t+1} + g_t \tag{16}$$

$$h_t + x_t = 1 \tag{17}$$

[2]This result is similar to the result in the "output model" of Carlstrom and Fuerst (1998). In their model, agency costs, which arise due to the monitoring activities of lenders, induce differences between the marginal products of capital and labor and their respective factor prices.

where condition (17) assumes that real estate is in a fixed supply, in line with Kiyotaki and Moore (1997) and Iacoviello (2005), among others. As noted by Iacoviello (2005), this is not unrealistic assumption if we give real estate the broad interpretation of land. Alternatively, one may think that the production of "real estate" is exactly equal to the value of real-estate depreciation, thus leaving the total supply of real estate fixed. In this regard, the U.S. depreciation rate of housing is relatively low, averaging around 2.1% a year over the period 1960-2011. This estimate is in line with Harding et al. (2007).

2.5. The Competitive Equilibrium

Definition 1 (Competitive Equilibrium). *Given the exogenous processes* $\{z_t, g_t, m_t, \tau_t^l, \tau_t^c, \tau_t^k, \tau_t^i, \tau_t^\pi\}$, *the competitive equilibrium is a sequence of allocations* $\{b_t, c_t, l_t, k_t, q_t, w_t, r_t, h_t, x_t, R_t, R_t^f, \mu_t\}$ *that satisfy the equilibrium conditions (4)-(8) and (11)-(17).*

Notice that in the benchmark specification m_t is exogenous, but in the alternative specification it will be endogenously determined. The tightness of the credit constraint (μ_t) will be an endogenous variable throughout the model-based analyses.

2.6. The Labor Wedge

I now turn to discussing the labor wedge that comes out of this model. First, letting τ_t being the tax wedge, we have:

$$1 - \tau_t = \frac{1 - \tau_t^l}{1 + \tau_t^c} \tag{18}$$

and, therefore, the tax wedge reads:

$$\tau_t = \frac{\tau_t^l + \tau_t^c}{1 + \tau_t^c}. \tag{19}$$

The tax wedge is increasing in both tax rates and, since $\tau_t^l < 1$, it is also less than 1. Using this definition of the tax wedge, condition (5) can be rewritten as:

$$-\frac{u_{l,t}}{u_{c,t}} = (1 - \tau_t) w_t. \tag{20}$$

Finally, the combination of the modified labor supply condition (20) and the labor demand condition (12) gives:

$$-\frac{u_{l,t}}{u_{c,t}} = \left(\frac{(1 - \tau_t)(1 - m_t)}{1 + \phi\mu_t}\right) z_t f_{l,t}, \tag{21}$$

which suggests that the tax wedge, the credit friction and the price markup drive a wedge between the marginal rate of substitution between labor and consumption and the marginal product of labor, which is the labor wedge. More specifically, the labor wedge is the difference between 1 and the term in parentheses, and it can be written as:

$$LW_t = \frac{m_t + \tau_t(1 - m_t) + \phi\mu_t}{1 + \phi\mu_t}. \tag{22}$$

This wedge involves not only the tax wedge but also the tightness of the credit constraint and the degree of imperfections in the product market. In particular, the wedge is increasing in τ_t, μ_t and m_t. Therefore, other things equal, a rise in the tightness of the credit constraint or the markup will lead to a rise in the labor wedge even if the tax wedge does not change. Put differently, the tax-adjusted labor wedge is increasing in these two factors. Furthermore, this wedge is clearly less than one as long as the tax wedge (τ_t) is less than 100%, which, as outlined above, is the case. In what follows, I first present the model-based results and then test whether the predictions of the regarding the role of credit frictions in driving the labor wedge are supported by the empirical evidence using U.S. data.

3. Quantitative Analyses

The parameter values and functional forms as well as the results that are obtained of the model are outlined in this section.

3.1. Parameterization and Functional Forms

The time unit is a quarter and hence the discount factor β is set to 0.99, implying an annual interest rate of roughly 4%. Households' preferences are governed by the following period utility function:

$$u(c_t, h_t, l_t) = \ln c_t + \psi \ln h_t - \chi \frac{l_t^{1+\theta}}{1+\theta} \tag{23}$$

with ψ and χ being scaling parameters that measure the relative weights on real estate and the disutility of labor, respectively. The parameter θ is set to 0.25 so that the labor supply elasticity is 4, which helps in capturing the volatility of total hours in a model with no extensive margin, as is the case in this paper.

The firm produces using the following production technology:

$$f(k_t, l_t) = k_t^{\alpha} l_t^{1-\alpha} \tag{24}$$

with $\alpha = 0.34$ being the capital share, which is in line with the existing literature.

Using the steady-state version of condition (14), the steady-state value of the Lagrange multiplier, μ, reads:

$$\mu = \frac{(1 - \tau^{\pi})(1 - \gamma)}{\gamma\kappa} \tag{25}$$

indicating that the credit constraint will be binding in the steady state when $\gamma < 1$. The Lagrange multiplier is higher for lower values of γ and κ. On the other hand, it will approach zero if κ approaches infinity or γ approaches 1.

Following Abo-Zaid (2015), I set the credit friction parameter ϕ to 0.50. The latter is based on multiple data sources as outlined in the above-mentioned study. To estimate the value of κ, I make use of the fact that borrowing by the firm is equal to the collateral: $b_t^f = \kappa_t q_t x_t$. I use data on borrowing of corporate nonfinancial businesses from the Flow of Funds Accounts of the Federal Reserve Board for b_t^f, and the value of gross private non-residential fixed assets, from the Bureau of Economic Analyses (BEA), as a proxy for $q_t x_t$. I then calculate the loan-to-value ratio for each period as the ratio of these two quantities. The implied average value of κ is 0.28, which is within the range of the usually used values: for example, Jermann and Quadrini (2012) used 0.16, while Iacoviello (2005) used 0.89. In this respect, my paramterization of this parameter is closer to that of former study than the latter, but the results of the paper with $\kappa = 0.89$ are very similar to those with the benchmark value of κ.

I set $\gamma = 0.977$ in order to account for the average credit spread (which is 2.75%) over the sample period. In this respect, the equivalent to the credit spread in the model is $\phi\mu$. I set $\tau^\pi = 0.34$ to match the average corporate tax rate from BEA data. Then, using condition (25) and the assumed values of γ and κ, the implied value of the Lagrange multiplier in the steady state, μ, is 0.055. Therefore, credit frictions generates a "markup" $\phi\mu$ of 2.75% as targeted. This value of γ may be somewhat high, but it helps in capturing the size of the credit friction as outlined. None of the key results changes if a plausible lower γ is used.

Using these functional forms, the labor wedge can be calculated as:

$$LW_t = 1 - \frac{\chi}{1-\alpha}\left(\frac{c_t}{y_t}\right) l_t^{1+\theta} \tag{26}$$

which, other things equal, shows a negative relationship with the labor input. I then use this condition and the data on consumption, output and hours to calculate the labor wedge over the sample period. The parameter χ is set so that the mean of the labor wedge obtained from the data is equal to the mean of the labor wedge in the model (i.e. to be consistent with condition (22)). The latter is 0.37, which is consistent with the tax wedge calculated from U.S. data, an average markup of 10% (which is in line with the literature) and the above parameter values.

3.2. Quantitative Results

Since the focus is on labor-income and consumption taxes (as only they enter the labor wedge), I assume that the profit tax rate, capital-income tax rate and investment tax rate are all constant in the following experiments. In particular, $\tau^i = 0.03, \tau^k = 0.30$ and $\tau^\pi = 0.34$. The values of τ^i and τ^k are based on the calculations of McDaniel (2007). Furthermore, as will be illustrated in the empirical analysis, the price markup rate is insignificant; therefore, I set $m_t = 0.1$. The assumption of a fixed markup rate (as opposed to an exogenous process) allows us to analyze the effects of other shocks on the economy.[3]

[3] The case with an endogenous markup is shown in Appendix B.

I study two cases. First, the labor-income and consumption tax rates are set to their steady state values. The goal of this experiment is to demonstrate how credit frictions can lead to cyclical variations in the labor wedge even when these two tax rates are held constant. Second, labor-income and consumption tax rates respond to changes in output according to the following fiscal policy rules:

$$\ln\left(\frac{\tau_t^l}{\tau^l}\right) = \rho_l \ln\left(\frac{\tau_{t-1}^l}{\tau^l}\right) + (1-\rho_l)\lambda_l \ln\left(\frac{y_t}{y}\right) \tag{27}$$

$$\ln\left(\frac{\tau_t^c}{\tau^c}\right) = \rho_c \ln\left(\frac{\tau_{t-1}^c}{\tau^c}\right) + (1-\rho_c)\lambda_c \ln\left(\frac{y_t}{y}\right) \tag{28}$$

The coefficients of these rules are set based on the empirical evidence; I regress the cyclical component of each tax rate on its lagged value and the output gap in order to allow for tax rate smoothing and the dependence of the tax rates on the state of the economy. The implied parameter values are $\rho_l = 0.54, \rho_c = 0.74, \lambda_l = 0.32, \lambda_c = -0.15$. Therefore, the labor-income tax rate negatively responds to output's deviations from the steady state, whereas the consumption tax rate responds positively. Fiscal policy rules along these lines have been extensively used in the literature; see, for example, Leeper et al. (2010), Leeper et al. (2012) and Kliem and Kriwoluzky (2014).

This experiment is undoubtedly more realistic, and it is meant to highlight the role of credit frictions in generating a countercyclical behavior by the labor wedge when variations in the tax wedge are allowed. In particular, since the tax wedge declines and the credit spread increases in recessions, it is important to investigate which factor dominates within a computable framework.

I study impulse responses to shocks to government expenditures, the credit conditions and the households' discount factor. I focus on demand-side shocks and financial shocks due to their significance during the Great Recession. Government expenditures, the households' discount factor and the loan-to-value ratio are, respectively, governed by the following AR(1) processes:

$$\ln\left(\frac{g_t}{g}\right) = \rho_g \ln\left(\frac{g_{t-1}}{g}\right) \exp(\varepsilon_{g,t}) \tag{29}$$

$$\ln\left(\frac{\eta_t}{\eta}\right) = \rho_\eta \ln\left(\frac{\eta_{t-1}}{\eta}\right) \exp(\varepsilon_{\eta,t}) \tag{30}$$

$$\ln\left(\frac{\kappa_t}{\kappa}\right) = \rho_\kappa \ln\left(\frac{\kappa_{t-1}}{\kappa}\right) \exp(\varepsilon_{\kappa,t}) \tag{31}$$

with $\varepsilon_{g,t}$, $\varepsilon_{\eta,t}$ and $\varepsilon_{\kappa,t}$ being the shocks to government expenditures, the discount factor and the loan-to-value-ratio, respectively. These shocks are $\varepsilon_{g,t} \sim \mathcal{N}(0,\sigma_g^2)$, $\varepsilon_{\eta,t} \sim \mathcal{N}(0,\sigma_\eta^2)$ and $\varepsilon_{\kappa,t} \sim \mathcal{N}(0,\sigma_\kappa^2)$, where the standard deviations are set in each simulation to account for the volatility of the U.S. GDP. Furthermore, $\rho_g = 0.90$, $\rho_\eta = 0.92$ and $\rho_\kappa = 0.95$. To calculate ρ_η, I first calculate the time-varying value of β from the consumption Euler equation (6) and then find the implied AR(1) coefficient. The AR(1) coefficient of the credit shock ρ_κ is calculated from the series of κ that has been described in Subsection 3.1, and the AR(1) coefficient of the government expenditures is set following the literature.

3.3. Model with No Credit Frictions

I start with the results of the model that abstracts from credit frictions. Figure 1 shows the behavior of key economic variables when the tax rates on consumption and labor income are fixed at their steady-state values and the results when these two tax rates are allowed to vary with the state of the economy as in conditions (27) and (28). For each case, I consider shocks to government expenditures ("g shock"), a shock to the loan-to-value ratio ("κ shock") and a preference shock ("β shock"). Furthermore, since the steady state value of the Lagrange multiplier on the collateral constraint μ is zero, I show the actual deviations from the steady state rather than the percentage deviations, but, of course, the figures for the percentage deviations from the steady state are similar.

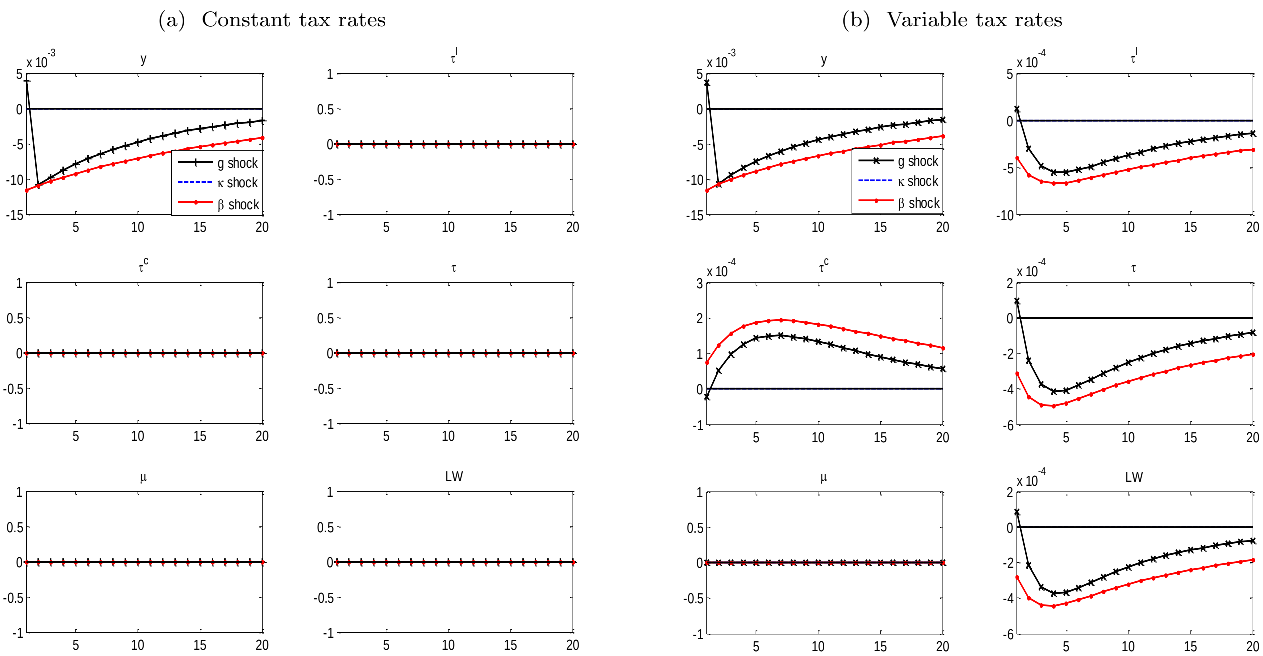

Figure 1: Impulse responses to negative one standard deviation shocks. Note: deviations from the deterministic steady state. Model without credit frictions.

Consider first the case when the tax rates are fixed. A negative shock to government spending and a negative preference shock lead to a drop in output. However, since the tax rates are constant and the model abstracts from credit frictions, the labor wedge does not respond on impact. A credit shock in this case is irrelevant because the model abstracts from credit frictions to begin with (namely $\mu_t = 0$ for all t). In either case, the decline in output is not accompanied by a rise in the labor wedge, which contradicts the empirical findings that will be discussed in the next section.

When the labor-income and consumption tax rates respond to the fluctuations in output, the decline in output leads to a decline in the labor-income tax rate and to a rise in the consumption tax rate. Since the labor-income tax rate is significantly more dominant than the consumption tax rate, the tax wedge declines in response (but it falls by slightly less than the fall in the labor-income tax rate). This behavior is consistent with the empirical findings. Absent credit frictions, the labor wedge declines in response to the decline in the tax wedge. In fact, the two wedges coincide in this case because the only source of fluctuations in the labor wedge is the tax wedge. Most importantly, the labor wedge declines together with output, implying a procyclical labor wedge. This result is clearly at odds with the empirical evidence. Therefore, the model with no credit frictions fails in replicating the cyclical behavior of the labor wedge regardless of the assumption about the two tax rates and, consequently, the tax wedge.

3.4. Benchmark Model with Credit Frictions

When the two tax rates are kept constant, the negative shocks lead to a reduction in labor, capital and output as well as to a tighter credit constraint (Figure 2). Interestingly, the labor wedge clearly increases in response, thus generating a countercyclical behavior of this wedge. The behavior of the labor wedge mimics that of the Lagrange multiplier on the credit constraint and goes clearly in the opposite direction of output. Therefore, despite no changes (in particular, no rise) in the tax wedge, the labor wedge increases due to the rise in the tightness of the credit constraint. It also appears that the financial shock generates the biggest drop in output and the largest rise in the labor wedge (as well as slowest return to the steady state).

I then allow the consumption and labor-income tax rates to respond to changes in output. The behavior of the tax rates and the tax wedge is consistent with the empirical findings.[4] The decline in the tax wedge in itself should lead to a decline in the labor wedge. However, as the credit constraint tightens more, the labor wedge increases in response to the shocks, suggesting again a countercyclical behavior of the labor wedge. This case illustrates the key insights of the paper in a powerful way: despite the decline in the tax wedge, the labor wedge increases in response to negative shocks.[5]

[4]In response to a preference shock, output initially declines as demand declines. However, the accumulation of capital that occurs due to the shift of agents from consumption to saving leads to a rebound in output, and, consequently, in the tax rates. This explains the behavior of output and tax rates in this figure.

[5]I do not introduce a variable investment tax rate in order to study the effects of the credit friction on the labor wedge without having (potentially) another factor that can lead to a rise in this wedge in downturns, which may make it harder to disentangle the role of credit frictions in driving the results. Allowing for variations in the investment tax rate does not significantly change the impulse-responses of either the model with or without credit frictions. One possible reason for this result is the low investment tax rate. For this reason, I do not report these results here.

(a) Constant tax rates (b) Variable tax rates

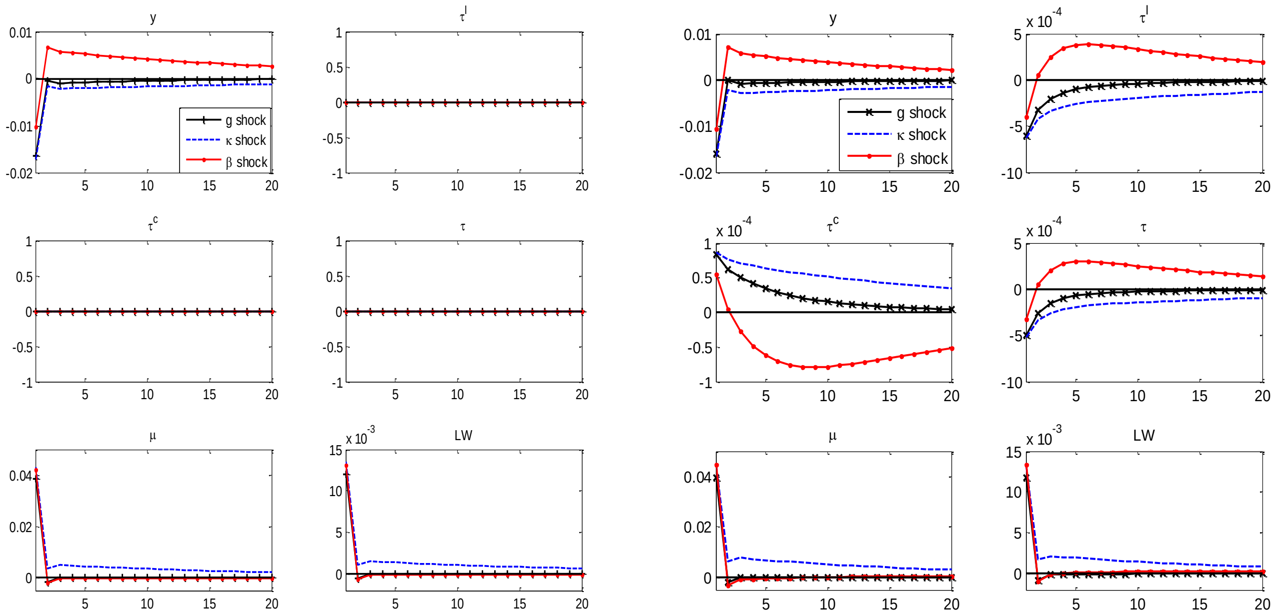

Figure 2: Impulse responses to negative one standard deviation shocks. Note: deviations from the deterministic steady state. Benchmark model with credit frictions.

3.5. Alternative Specification of the Borrowing Constraint

In this subsection, I assume that the firm borrows working capital to finance only part of the wage payment, but not the rental of capital. By so doing, I follow one of the scenarios that Jermann and Quadrini (2012) consider in their robustness analyses. Under this assumption, the collateral constraint reads:

$$\phi w_t l_t \leqslant \kappa q_t x_t. \tag{32}$$

The demand conditions for labor and capital are then, respectively, given by:

$$(1 - m_t) z_t f_{l,t} = (1 + \phi\mu_t) w_t \tag{33}$$

$$(1 - m_t) z_t f_{k,t} = r_t. \tag{34}$$

Therefore, only the capital demand condition differs from its benchmark counterpart. The combination of the labor supply condition (20) and the new labor demand condition (33) then gives the same labor wedge expression as in condition (22). Namely,

$$LW_t = \frac{m_t + \tau_t(1 - m_t) + \phi\mu_t}{1 + \phi\mu_t} \tag{35}$$

and, thus, the assumption about what input is subject to the working capital requirement is not important, at least qualitatively.

The impulse responses for this model are reported in Figure 3. Briefly, these results indicate again that the model with credit frictions can account for the countrecyclical behavior

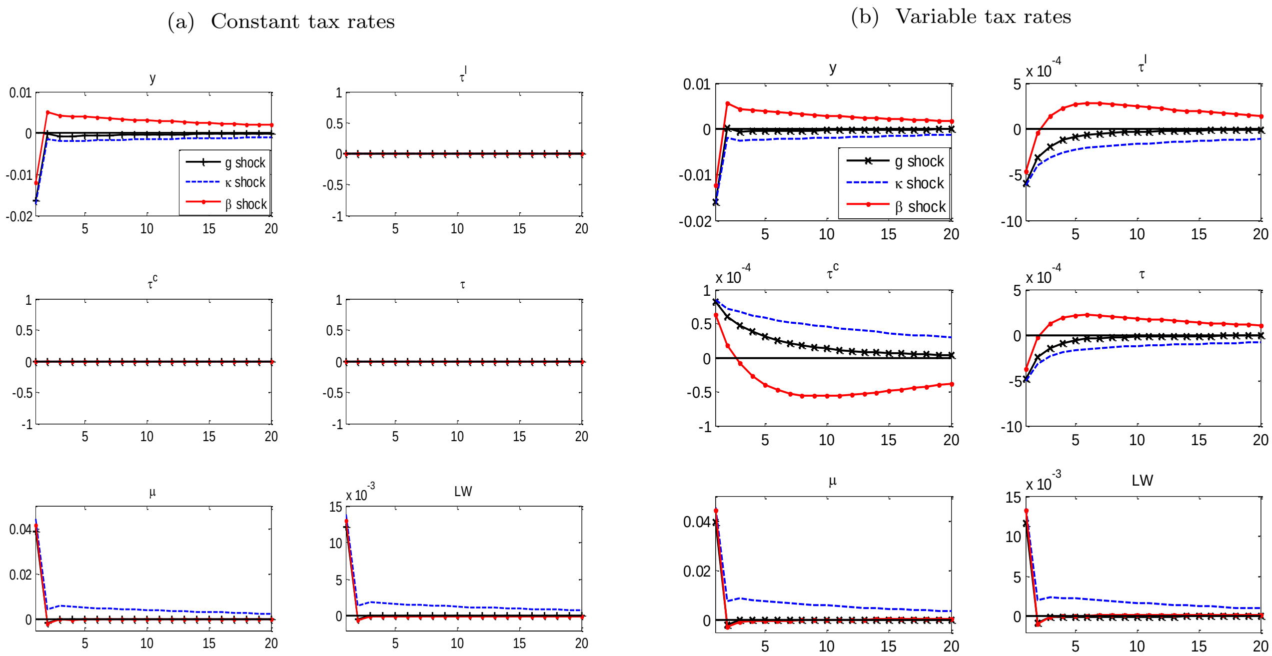

Figure 3: Impulse responses to negative one standard deviation shocks. Note: deviations from the deterministic steady state. Model with credit frictions and an alternative collateral constraint.

of the labor wedge. In fact, there are almost no differences between these results and those from the benchmark model. The model with no credit frictions has been discussed above and, therefore, the results are not shown here.[6]

4. Empirical Analyses

I first describe the data, functional forms and the parameterization that are used to calculate the labor wedge. I then move to provide description of the behavior of the labor wedge, taxes and the credit spread, both in the long run and at business cycle frequencies.

4.1. Data Description

The main analyses are conducted with quarterly data. Unless otherwise stated, the data are available in the FRED database of the Federal Reserve Bank of St. Louis. The tax rates data are obtained from Karabarbounis (2014), and extended by the current study until 2019:2. I calculate the consumption tax rate and the labor-income tax rate following the aforementioned study. The tax wedge is then calculated using condition (19). Total hours are obtained from Cociubaa et al. (2012) and extended by the current study until

[6]In the previous version of this paper, I also studied the case with real estate being a factor of production as follows: $f(k_t, x_t, l_t) = k_t^{\alpha} x_t^{\nu} l_t^{1-\alpha-\nu}$. Following Iacoviello (2005), I set to $\nu = 0.03$. These results are almost indistinguishable from the results with the benchmark production function. One possible reason for this finding is the relatively low share of real estate in the production function, but other plausible values of ν deliver similar results.

2019:2. Following Gali et al. (2007), I use the inverse of the (non-farm) unit labor cost as a proxy for the price markup. I use the real gross domestic product (GDP) and real personal consumption expenditures for output and consumption, respectively.

Following Curdia and Woodford (2010) and Gertler and Karadi (2011), among others, the benchmark analyses use a measure of the (corporate) credit spread as a proxy for the credit friction. I use the credit spread between the Moody's Seasoned Corporate Bond Yield (BAA) and the 1-Year Treasury Constant Maturity Rate (GS1) as the measure of the credit conditions. To focus on the cyclical behavior, all data have been detrended using the Hodrick-Prescott (HP) filter, with a smoothing parameter of 1600. To control for the state of the economy, I use the detrended (log) real GDP in some of my regressions. This variable will be referred to as the "output gap" in what follows.

4.2. Taxes, Hours and the Labor Wedge: Trends

The tax wedge (τ_t) and the labor wedge (LW_t) are both depicted in Figure 4. Both series have been rising between the beginning of the sample and the late 1970s. From that point, the tax wedge continued to rise while the labor wedge declined. By inspecting the two components of the labor wedge, it is clear that the continuous rise in the tax wedge is due to the labor-income tax rate only as the consumption tax rate actually declined, albeit moderately. Since most of the tax wedge is due to labor-income taxation, it is not surprising that the behavior of the tax wedge closely mimics that of the labor-income tax rate.

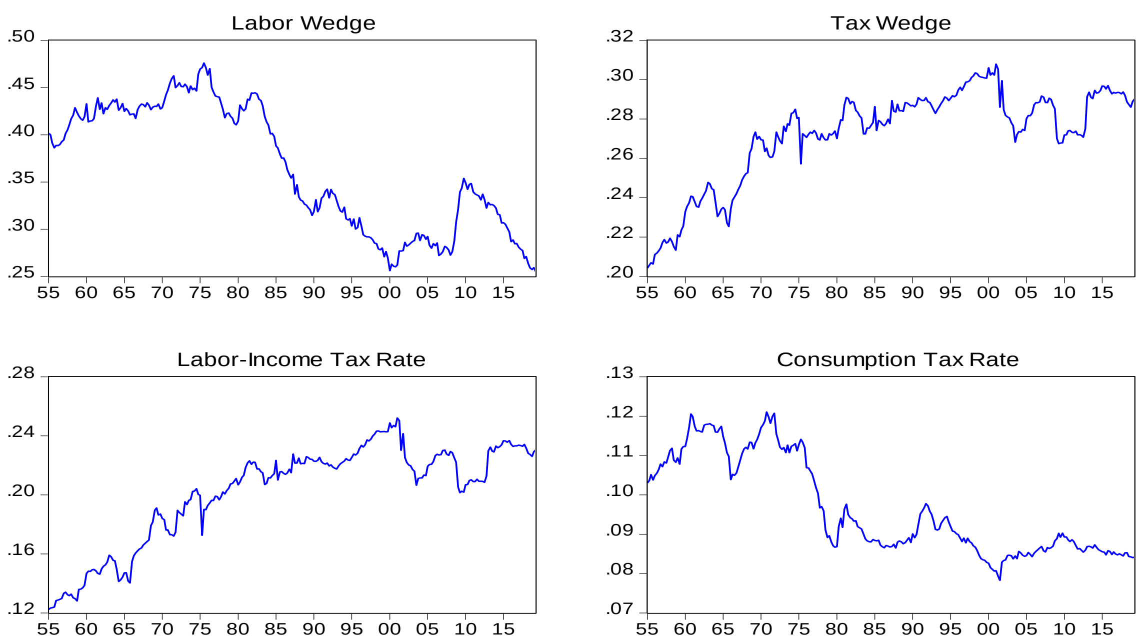

Figure 4: The labor wedge, tax wedge, labor-income tax rate and consumption tax rate.

The opposite trends of the tax wedge and the labor wedge in the second half of the sample underscore why the ability of taxation to explain the trend of the labor wedge in the U.S. has been questioned in recent years. In turn, they raise interest in studying the causes of this divergence and factors that do indeed explain the long-term behavior of the labor wedge. The same applies to the behavior of total hours per person (not shown): they continued to rise after the early 1980s despite the continuous rise in the tax wedge. As discussed in Cociubaa and Ueberfeldt (2015), among others, this fact raises questions about the applicability of the standard representative-agent model with taxation to U.S. labor-market data. Clearly, the labor wedge and total hours are (inversely) related, which implies that if taxes fail to explain the long-run behavior of hours then they are likely to fail in explaining the long-run behavior of the labor wedge.

4.3. Taxes, Hours and the Labor Wedge: Cyclical Behavior

I turn now to discuss the cyclical behavior of the labor wedge, hours and taxes. Figure 5 presents the cyclical component of the labor wedge together with the cyclical components of the tax wedge and its components. The shaded areas indicate NBER recession dates.

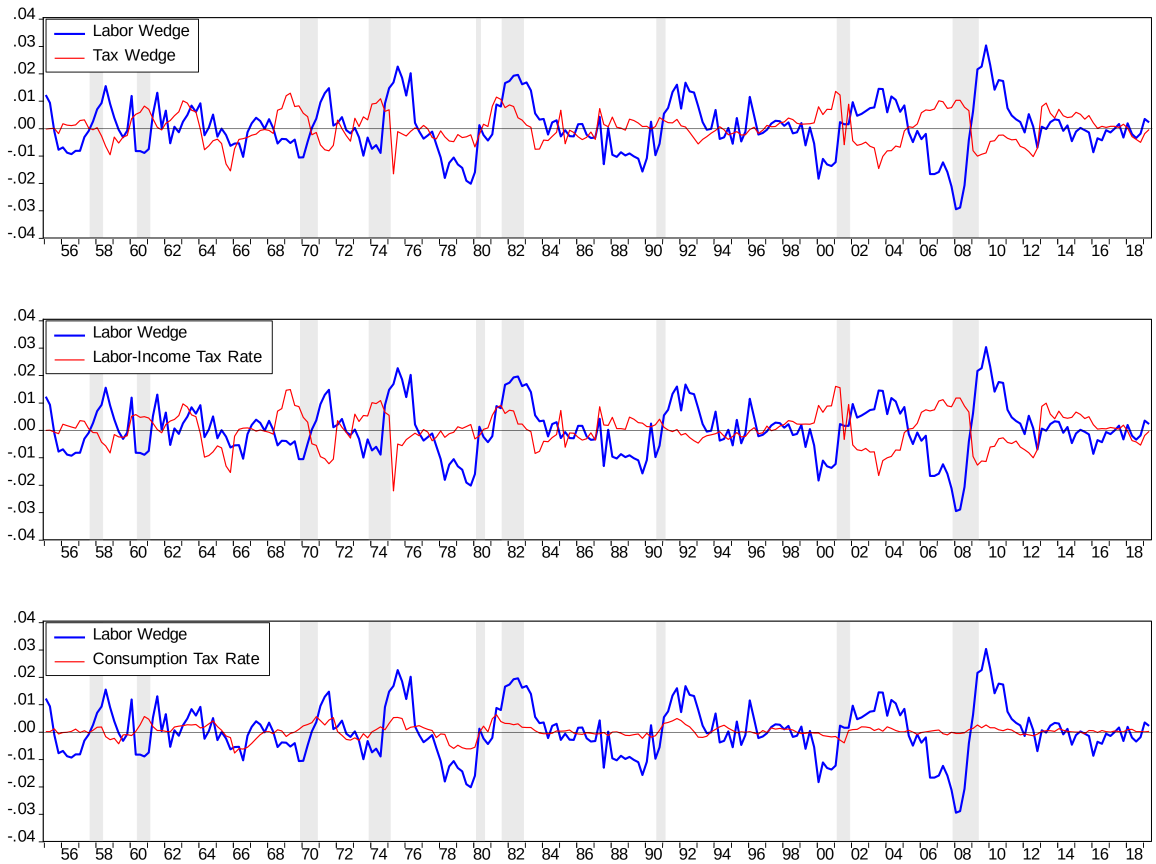

Figure 5: The cyclical components of the labor wedge, the tax wedge, the labor-income tax rate and the consumption tax rate.

The first key observation that comes out of this figure is the failure of taxation to account for the short-run behavior of the labor wedge throughout the *entire* sample, and not only in its second half. Once more, the behavior of labor tax rate dictates that of the tax wedge; both decline during recessions and rise during booms relative to their trends. This behavior is exactly the opposite of the behavior of the labor wedge, which rises in recessions and falls in expansions. Indeed, at business cycle frequencies, the correlation coefficients between the labor wedge and the tax wedge is -32%, and the correlation coefficient between the labor tax rate and the labor wedge is -45%. On the other hand, consumption taxation appears to be positively correlated with the labor wedge throughout the entire sample period; the correlation coefficient between the two cyclical components is 46%. The second main observation is the different correlation patterns between the short run and the long run (e.g. during the first half of the sample). Therefore, in addressing the determinants of the labor wedge, it is important to distinguish between the short run and the long run.

4.4. Credit Frictions and the Labor Wedge

Having described the behavior of consumption and labor-income tax rates and their association with the labor wedge, I turn now to discussing the role of credit frictions. Figure 6 shows that the labor wedge and the credit spread had similar trends in the first half of the sample, but different trends in the second. In particular, while the labor wedge dropped significantly since the early 1980s, the credit spread actually exhibited a slight increase. On face value, this observation renders the credit spread as not a good explanatory variable for the long-term behavior of the wedge over the last three decades of the sample.

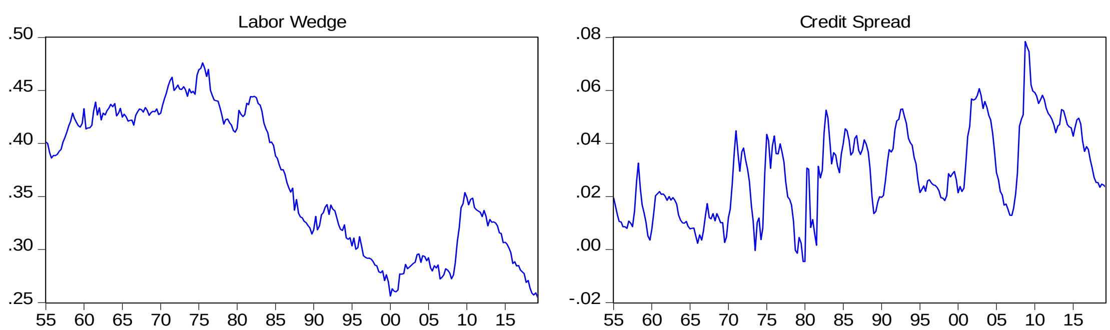

Figure 6: The labor wedge and the credit spread.

On the other hand, the credit spread is strongly correlated with the labor wedge over the business cycle (Figure 7). Interestingly, this pattern holds for the entire sample period, suggesting once more that the short-run associations between the labor wedge and other variables can be completely different from the long-run associations. Crucially, the credit spread increases during recessions and falls in expansions, and the two series seem to track each other closely. In this respect, the correlation coefficient for the full sample is 55%. Furthermore, the variations in the credit spread are smaller than the variations in the labor wedge, suggesting that other factors can account for the full cyclical variations in the labor wedge, but the differences between the variations of both series are small.

These figures raise interest in exploring the effects of credit frictions on the labor wedge more formally, which is the goal of the next section. While some previous work has mentioned that credit frictions can generate a labor wedge, testing their effects on the labor wedge has not, to my knowledge, been done. Furthermore, the role of credit frictions in explaining the labor wedge can be better tested when actual taxes, which are natural candidates for explaining the labor wedge, are explicitly present in the model. This paper adds to the literature by precisely doing that, in addition to exploring the importance of other factors that can potentially explain the cyclical behavior of the labor wedge.

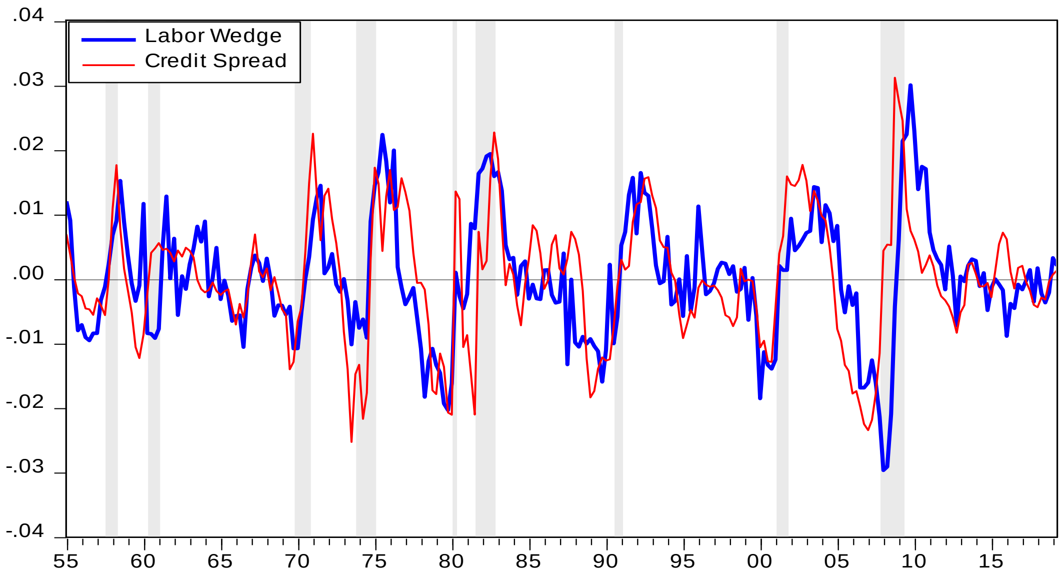

Figure 7: The cyclical components of the labor wedge and the credit spread.

4.5. Econometric Analysis

To test for the effects of the corporate credit spread on the labor wedge, I estimate the following linear condition:

$$\widehat{LW}_t = \alpha_1 \widehat{\tau}_t + \alpha_2 \widehat{m}_t + \alpha_3 \widehat{\mu}_t + \varepsilon_t \tag{36}$$

which is derived from log-linearization of condition (22) around the non-stochastic steady state of the model (with log deviations being denoted by hats) and ε_t is an error term.[7] In this regard, the log deviations of the variables in the model are the proxies for the cyclical components of the corresponding variables in the data.

I start the analyses by using Ordinary Least Squares (OLS). A possible challenge to this approach is the fact that the credit spread and the labor wedge may co move over the business cycle. In theory, there could be a bi-directional causation, but it is hard to see how the labor wedge in itself causes the credit spread, particulary if the state of the economy is controlled for. The more likely scenario is that changes in the costs of borrowing of firms affect labor hiring and, as a result, output (with both labor and output entering the calculation of the labor wedge as in condition (26)). However, to experiment on the baseline OLS results, the robustness analyses section will also show the results using the Generalized Method of

[7]Because equation (36) has no constant term, the regressions will have no constant term. However, the results with a constant term are almost identical to the results of this section. Given that the model uses the cyclical behavior of each variable, the constant term is not statistically different from zero.

Moments (GMM) with instrumental variables as well as using a Bayesian approach. In addition, I will use Maximum Likelihood estimation (MLE) to test whether the model with the credit spread performs better than the model that abstracts from the spread.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
$\widehat{\tau_t}$	-0.559*** (0.102)	-0.3217** (0.102)	-0.666*** (0.110)	-0.183 (0.101)			
$\widehat{\tau_t^l}$					-0.441*** (0.092)		
$\widehat{\tau_t^c}$						1.629* (0.250)	
$\widehat{m_t}$		-0.649 (1.290)	-3.541** (1.440)	0.825 (1.266)	-0.851 (1.201)	4.732*** (1.219)	
$\widehat{\mu_t}$		0.483*** (0.0527)		0.269*** (0.066)	0.427*** (0.054)	0.414*** (0.057)	0.540*** (0.050)
$\widehat{y_t}$				-0.262*** (0.052)			
Adj. R^2	0.106	0.338	0.123	0.396	0.369	0.410	0.315
N	258	258	258	258	258	258	258

Table 1: Dependent variable- cyclical component of the labor wedge. Results of OLS estimation. Standard errors in parentheses. * significant at the 10% level, ** significant at the 5% level, *** significant at the 1% level.

The regression results are shown in Table 1. Consider first the specification with only the tax wedge as the explanatory variable. The tax wedge fails to explain the observed cyclical behavior of the labor wedge; in particular, the tax wedge has a negative, as opposed to a positive, coefficient. The results of estimating equation (36) are reported in column (2). The tax wedge continues to have negative effects and to be statistically significant. The measure of firms' markup is not statistically significant, thus casting doubt about its ability to explain the behavior of the labor wedge. On the other hand, the credit spread is very statistically significant and, importantly, has a positive sign. Therefore, the observations from the previous section are confirmed; credit frictions can explain the cyclical behavior of the labor wedge. Column (3) shows that excluding the credit spread from the specification reduces the ability of the model to explain that labor wedge by roughly two thirds. Column (4) shows that tax wedge ceases to be significant when the model accounts for the output gap. The size of the coefficient of the credit spread changes, but it remains significant at almost all levels. Furthermore, the model explains nearly 40% of the variations in the labor wedge, which is a significant improvement from the model with the tax wedge only.

Since the co-movement between the labor-income tax rate and the labor wedge differs from the co-movement between the consumption tax rate and the labor wedge, I introduce each tax rate individually in the fifth and the sixth columns. The labor-income tax rate has indeed a negative coefficient, whereas the consumption tax rate has a positive coefficient. The credit spread remains very significant with a positive sign. The last column reports the results when taxes and the markup are excluded from the specifications. The ability of the credit spread is well illustrated in this regression: the coefficient of the credit spread is positive, and the adjusted R^2 is nearly 32%, which is three times the adjusted R^2 of the regression with the tax wedge only.

The results of this section are very significant and they stand in contrast to the findings about the importance of taxes in explaining the *long-term* behavior of the labor wedge. For example, Ohanian et al. (2008) show that the tax wedge positively explains the long-term behavior of the labor wedge for a panel of OECD data. My results, at least for the U.S., indicate that the tax wedge has either a negative or insignificant (mostly negative) coefficient when the *short-term* behavior of the labor wedge is considered.

Table 2 reports the results for total hours as the dependent variable. The tax wedge is significant in explaining the cyclical behavior of total hours, particularly when the state of the economy is not controlled for. The coefficient of the credit spread is negative and statistically significant in all specifications. Similar to the case with the labor wedge, accounting for the state of the economy reduces the size of the coefficient of the credit spread but not its statistical significance. Furthermore, the credit spread alone accounts for 45% of the variations in total hours, while the tax wedge alone explains only 12%. The labor-income tax rate and the consumption tax rate have opposing effects. Most importantly, unlike the tax wedge, the credit spread does explain the decline in total hours during recessions: tighter credit conditions lead to a fall in labor demand and, as a result, labor in equilibrium. Therefore, exploring the firms' side of the labor market is very important for understanding the short-term behavior of total hours.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
$\widehat{\tau}_t$	0.228***	0.144***	0.303***	0.060*			
	(0.039)	(0.035)	(0.041)	(0.031)			
$\widehat{\tau}^l_t$					0.189***		
					(0.036)		
$\widehat{\tau}^c_t$						-0.620***	
						(0.086)	
$\widehat{m}_t$		1.146**	2.481***	0.261	1.197***	-1.022**	
		(0.445)	(0.543)	(0.389)	(0.410)	(0.420)	
$\widehat{\mu}_t$		-0.223***		-0.095***	-0.200***	-0.201***	-0.252***
		(0.018)		(0.020)	(0.018)	(0.017)	(0.017)
$\widehat{y}_t$				0.157***			
				(0.016)			
Adj. R^2	0.115	0.481	0.179	0.624	0.516	0.541	0.450
N	258	258	258	258	258	258	258

Table 2: Dependent variable- cyclical component of total hours. Standard errors in parentheses.
* significant at the 10% level, ** significant at the 5% level, *** significant at the 1% level.

5. Robustness Analysis

I start this section by re-conducting the analyses using alternative estimation methods. I then examine the role of investment taxation in driving the cyclical behavior of the labor wedge and show the results using an alternative measure for the credit conditions.

5.1. Instrumental Variable Approach

I show here the results using GMM with instrumental variables. Following existing studies with macroeconomic models (e.g. Gali and Gertler (1999), Ravenna and Walsh (2006), Murray (2006) and Gali et al. (2007)), I use the lags of variables as instruments. As has been discussed by West et al. (2009), the basis for using the lags of variables as instruments is that, usually, if a given variable is a legitimate instrument, then so are lags of that variable. Furthermore, the use of lags of variables helps overcoming the possibility of endogenously and bi- directional causality: it is unlikely that the current value of the dependent variable affects the past values of the variables (namely, the past cannot be caused by the future).

	(1)	(2)	(3)	(4)	(5)
$\widehat{\tau_t}$	-0.446***	-0.375	-0.642***		
	(0.162)	(0.167)	(0.159)		
$\widehat{\tau_t^l}$				-0.499***	
				(0.148)	
$\widehat{\tau_t^c}$					1.818***
					(0.320)
$\widehat{m_t}$	-2.379	-1.629	-5.649***	-1.573	4.8237***
	(2.215)	(2.124)	(1.990)	(1.972)	(1.497)
$\widehat{\mu_t}$	0.476***	0.481***	0.472***	0.403***	0.407***
	(0.074)	(0.076)	(0.071)	(0.077)	(0.058)
J-Stat	26.461	21.749	120.322	21.236	15.441
P-Value	(0.438)	(0.475)	(0.640)	(0.506)	(0.843)
First-Stage F-Stat	30.420	36.485	23.434	25.813	26.370
P-Value	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
N	258	258	238	258	258

Table 3: Dependent variable- cyclical component of the labor wedge. Results of GMM estimation. Results of estimating condition (36). Standard errors in parentheses. * significant at the 10% level, ** significant at the 5% level, *** significant at the 1% level. IVs for columns (1): four lags of the credit spread, tax wedge, output gap, labor wedge, commodity price index inflation, markup, non-farm business sector hourly compensation inflation. IVs for column (2): as in column (1), but excluding the lags of the labor wedge. IVs for column (3): as in column (1) and four lags of housing starts. IVs for columns (4)-(5): as in column (1), but with lags of the labor-income (consumption) tax rate replacing the tax wedge. *J-Stat* is the statistic for the hypothesis that the over-identifying restrictions are satisfied. The data on housing starts are available since 1959:1.

I use three different groups of instruments. First, the group of instruments includes the lags of the dependent variable as well as other independent variables. Second, the same group of instruments but without the lags of the dependent variable. Third, the first group of instruments and the lags of the number of housing starts. The latter help in checking the robustness of the results because it is likely not to be affected by the labor wedge. Table 3 reports the GMM results with instrumental variables. The F-statistics of the first-stage estimations suggest that the possibility of weak instruments is rejected; these F-statistics are well above the thresholds that have been proposed by Stock and Yogo (2005). The J Test indicates that the over-identification restrictions are satisfied.

In general, The results support the OLS estimates. The tax wedge does not have a positive effect on the labor wedge, and in fact the effects on business cycle frequencies appear to be negative.The labor-income tax rate has negative effects and the consumption tax rate have positive effects. The markup rate is mostly insignificant. The credit spread, however is very robust; it has positive effects and significant at all levels.

5.2. Maximum Likelihood Estimation

Table 4 reports the results of Maximum Likelihood Estimation (MLE). All coefficients are very comparable with the OLS and GMM estimates and the credit spread is significant in all specifications. The bottom two rows report the results of the likelihood ratio (LR) test. In particular, I test whether the model with the credit spread outpreforms the restricted model that abstracts from the spread. The P-values indicate that the model without the credit spread is rejected in favor of the model that account for it, thus supporting the earlier findings that the credit spread is important for explaining the cyclical behavior of the labor wedge.

	(1)	(2)	(3)	(4)	(5)	(6)
$\widehat{\tau_t}$	-0.210**	-0.650***				
	(0.090)	(0.111)				
$\widehat{\tau_t^l}$			-0.315***	-0.703***		
			(0.074)	(0.086)		
$\widehat{\tau_t^c}$					1.326***	2.334***
					(0.205)	(0.219)
$\widehat{m_t}$	-0.198	-3.230***	-0.385	-2.236**	4.082***	6.150***
	(0.997)	(1.190)	(0.966)	(1.121)	(1.154)	(1.162)
$\widehat{\mu_t}$	0.539***		0.495***		0.470***	
	(0.042)		(0.044)		(0.041)	
LR-Stat		92.712		75.689		79.974
P-Value		(0.000)		(0.000)		(0.000)
N	258	258	258	258	258	258

Table 4: Dependent variable- cyclical component of the labor wedge. Results of Maximum Likelihood estimation. Standard errors in parentheses. LR-Stat: the statistic for the likelihood ratio test. The bottom row reports the P-value for rejecting the hypothesis that the restricted model (without the credit spread) is true. Each even-numbered column is compared to the following column. * significant at the 10% level, ** significant at the 5% level, *** significant at the 1% level.

5.3. Bayesian Estimation

Figure 8 shows the distribution of the coefficients of the tax wedge, markup and credit spread that result of estimating condition (36) using Basysian estimation with Markov Chain Monte Carlo (MCMC) and Gibbs sampling. Consistent with the benchmark results, the tax wedge has a negative coefficient (albeit not statistically different from zero at the 95% level). The markup rate is not significant, whereas he credit spread is statistically significant. These results suggest that either the tax wedge cannot explain the labor wedge or the effects of its components cancel each other. This possibility is illustrated in Table 5, where the results are shown for the labor-income and consumption tax rates individually. The labor-income tax rate has a negative coefficient while the consumption tax rate has a positive coefficient. The credit spread is very significant. These analyses support the role of the credit spread in explaining the cyclical behavior of the labor wedge at the same time that they cast doubt about the role of taxation.

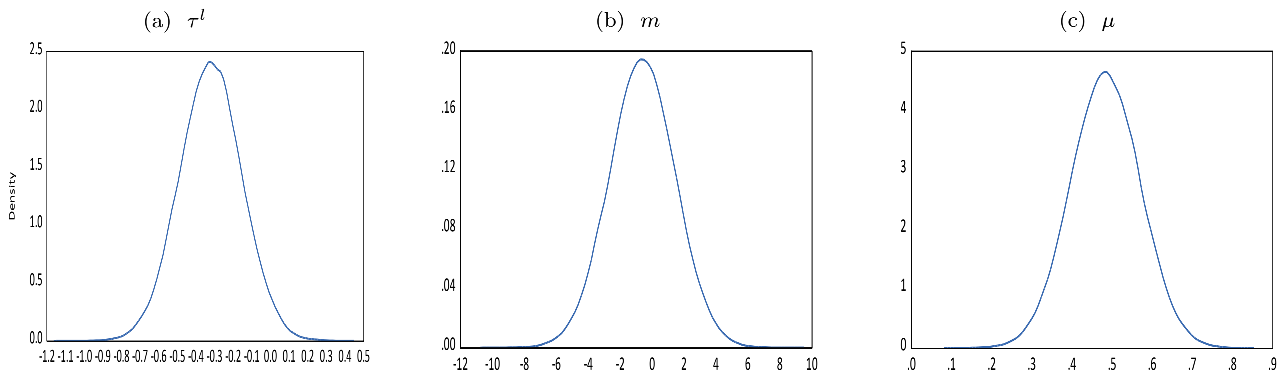

Figure 8: Posterior distributions (density) for the coefficients of condition (36) with 100,000 MCMC draws and a burn-in of 10,000 draws.

	(1)	(2)	(3)
$\widehat{\tau}_t$	-0.321 (-0.645, 0.004)		
$\widehat{\tau}^l_t$		-0.441 (-0.738, -0.141)	
$\widehat{\tau}^c_t$			1.610 (0.779, 2.443)
$\widehat{m_t}$	-0.617 (-4.659, 3.437)	-0.821 (-4.676, 3.031)	4.533 (0.501, 8.532)
$\widehat{\mu}_t$	0.484 (0.315, 0.652)	0.427 (0.252, 0.601)	0.415 (0.245, 0.583)
N	258	258	258

Table 5: Posterior estimates for the coefficients of condition (36) with 100,000 MCMC draws and a burn-in of 10,000 draws. 95% confidence interval in parentheses.

5.4. Investment Taxation

This subsection studies the possible effects of investment taxation on the cyclical behavior of the labor wedge. The investment tax rate does not affect the labor wedge directly, which is a reason for abstracting from it in most analyses. However, investment taxation affects capital accumulation and, consequently, the marginal product of labor. It, therefore, may have indirect effects over the labor wedge that are worthy of investigation.

I use the annual tax data set of McDaniel (2007), which has been extended to cover the period 1950-2015 for 15 OCED countries, including the U.S. The database covers the average tax rate on households income, average payroll tax rate, average tax rate on capital income, average tax rate on consumption expenditures and the average tax rate on investment. Following the definitions in McDaniel (2007), the average tax rate on labor income is the sum of the first two tax rates.

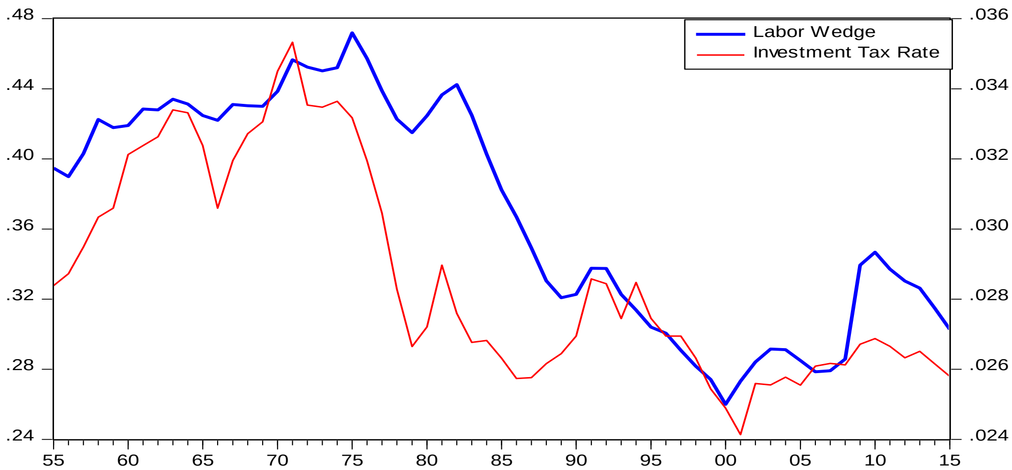

Figure 9: The labor wedge and the investment tax rate.

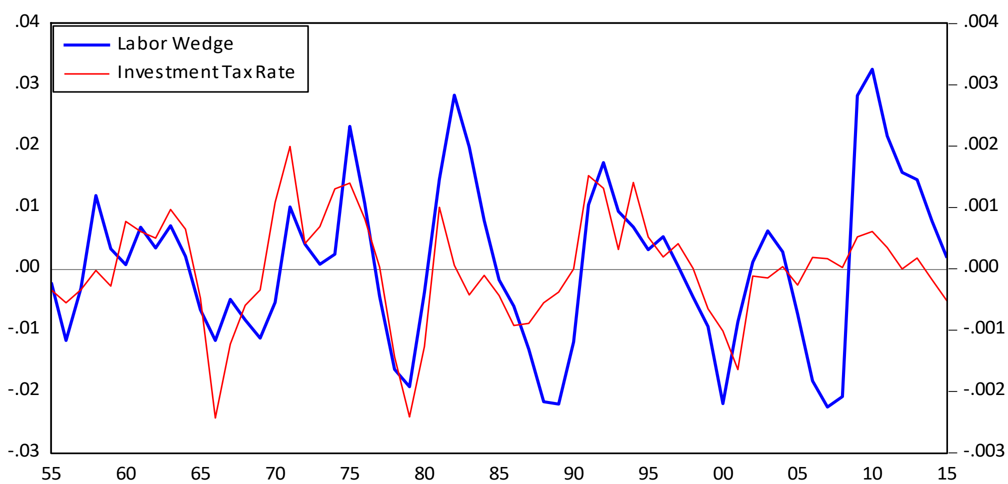

Figure 10: The cyclical components of the labor wedge and the investment tax rate.

Figure 9 presents the co-movement between the labor wedge and the investment tax rate. Despite the differences in magnitudes, the two series have remarkably similar trends along the entire sample period (the correlation coefficient between both series is 82%). This correlation holds also when the cyclical components of both series are considered (Figure 10); both variables tend to rise in recessions and decline in booms, and the correlation coefficient between both is 55%. To put matters into perspective, the correlation coefficient between the labor wedge and the consumption tax rate at business cycle frequencies is 55% and the correlation coefficient between the labor wedge and the labor tax rate is -43%.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	OLS				GMM	MLE		
$\widehat{\tau_t}$	-0.524** (0.207)		-0.335 (0.230)	-0.487** (0.204)	-0.547*** (0.073)	-0.405** (0.205)	-0.715*** (0.200)	-0.189 (0.218)
$\widehat{\tau_t^i}$	6.268*** (1.457)	5.482*** (1.489)		5.042*** (1.580)	6.806*** (0.552)	5.932* (1.360)	8.330*** (1.311)	
$\widehat{m_t}$	-3.495* (1.853)	-1.636 (1.779)	-4.115* (2.107)	-4.113** (1.848)	-3.352*** (0.937)	-2.298* (1.797)	-3.175 (1.961)	-2.928 (2.520)
$\widehat{\mu_t}$	0.449*** (0.122)	0.580*** (0.116)	0.650*** (0.129)	0.298* (0.146)	0.514*** (0.039)	0.452*** (0.108)		0.730*** (0.127)
$\widehat{y_t}$				-0.174* (0.096)				
Adj. R^2	0.540	0.497	0.401	0.558				
J-Stat *P-Value*					13.711 (0.993)			
LR-Stat *P-Value*							14.137 (0.000)	19.640 (0.000)
N	61	61	61	61	61	61	61	61

Table 6: Dependent variable- cyclical component of the labor wedge. Estimation results with investment taxation. Standard errors in parentheses. * significant at the 10% level, ** significant at the 5% level, *** significant at the 1% level. LR-Stat in column 7: the statistic for the likelihood ratio test that the restricted model (without the credit spread) is true. LR-Stat in column 8: the statistic for the likelihood ratio test that the restricted model (without the investment tax rate) is true. Columns (7) and (8) are compared to column 6.

In Table 6, I present the results with the tax rate on investment using OLS, GMM and MLE. Using all methods of estimation, the investment tax rate has a significant positive coefficient; a rise in the investment tax rate leads to a higher labor wedge. The first four columns also reveal that the investment tax rate considerably improves the ability of the model to explain the cyclical behavior of the labor wedge. For comparison, the inclusion of the tax wedge has a much smaller effect on the adjusted R^2.

The Likelihood Ratio statistic in column 7 indicates that the model with the credit spread dominates the model that does not account for it. Similarly, the Likelihood Ratio statistic in column 8 shows that accounting for investment taxation improves the ability of the model to explain the behavior of the labor wedge. This is a very interesting finding given that the investment tax rate does not explicitly enter the labor wedge and, almost always, is abstracted from in the labor wedge literature and macroeconomic models in general. Finally, to focus on investment taxation and to economize in presentation, I only show the results with $\widehat{\tau}_t$, but the results with $\widehat{\tau_t^l}$ and $\widehat{\tau_t^c}$ are similar.

5.5. Alternative Measure for the Credit Conditions

So far, I used the credit spread as the proxy for the credit conditions of firms. This subsection considers an alternative measure, which is based on allowing κ to be time varying and then estimating its value over the sample period using U.S. data. A decline in the value of κ implies tighter credit conditions and, therefore, we should expect this variable to be procyclical as firm's credit conditions worsen in recessions. I estimate the value of κ as discussed in subsection 3.1. Due to the unavailability of quarterly data on private non-residential fixed assets, the analyses are conducted only at the annual frequency. The cyclical components of this series and the labor wedge are shown in Figure 11. The measure of κ_t is declining in downturns and rising in upturns, and the two series show a clear negative correlation over the business cycle: lower κ implies tighter credit conditions and, as a result, higher labor wedge. Indeed, the correlation coefficient between both series is nearly -47%.

The estimation results are reported in Table 7. The tax wedge mostly has negative effects whereas the markup rate does not have any robust effects. The measure of credit conditions is statistically significant and has a negative value as expected. The Likelihood Ratio test confirms that the model with this measure of credit conditions performs better than the model that abstract from credit conditions. Overall, the analyses of this subsection largely confirm the above findings, particularly regarding the implications of the credit conditions for the behavior of the labor wedge.

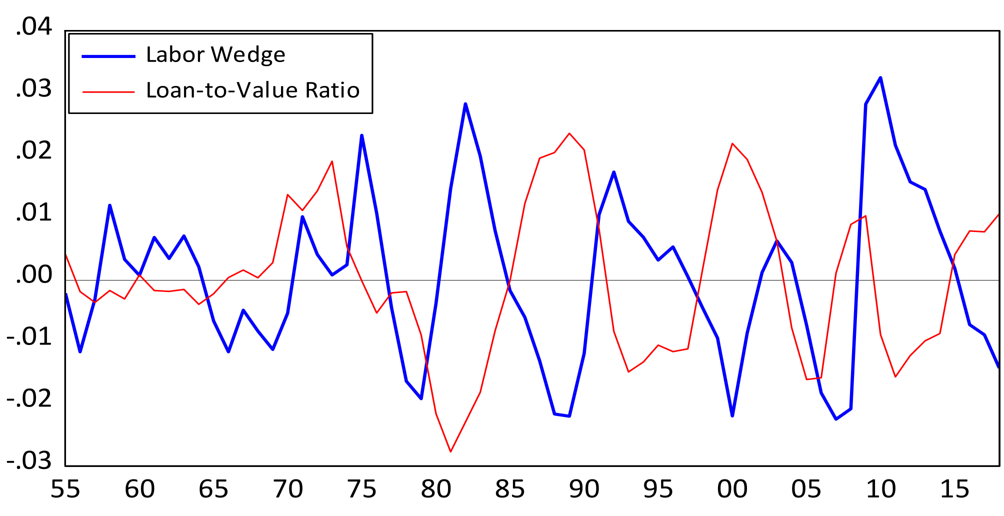

Figure 11: The cyclical components of the labor wedge and the loan-to-value ratio (κ).

	(1)	(2)	(3)	(4)	(5)	(6)
		OLS		GMM	MLE	
$\widehat{\tau_t}$	-0.540**	-0.749*	-0.152	-0.762***	-0.320	-0.645***
	(0.241)	(0.251)	(0.170)	(0.095)	(0.201)	(0.245)
$\widehat{m_t}$	-3.613	-6.300**	-2.490	-6.438***	-3.012	-5.463**
	(2.397)	(2.437)	(1.635)	(1.161)	(2.215)	(2.393)
$\widehat{\kappa_t}$	-0.425***		-0.538***	-0.561***	-0.364***	
	(0.127)		(0.087)	(0.116)	(0.119)	
$\widehat{y_t}$			-0.485***			
			(0.057)			
Adj. R^2	0.263	0.142	0.659			
J-Stat				13.336		
P-Value				(0.981)		
LR-Stat						17.703
P-Value						(0.000)
N	64	64	64	64	64	64

Table 7: Dependent variable- cyclical component of the labor wedge. Standard errors in parentheses. Credit friction measure: cyclical component of κ_t. Standard errors in parentheses. LR-Stat : the statistic for the likelihood ratio test that the restricted model (without the credit spread) is true. * significant at the 10% level, ** significant at the 5% level, *** significant at the 1% level.

Finally, comparing all empirical findings of the paper to the model-based findings indicate that a business cycle model with credit frictions can explain the observed cyclical behavior of the labor wedge. Specifically, the model with credit frictions can predict a rise in the labor wedge during recessions even if the tax wedge declines or remains unchanged. This is particularly interesting given that the model abstracts from labor-market frictions, a time varying disutility of work, sticky wages and other potential determinants of the labor wedge. Furthermore, at business cycle frequencies, the labor wedge and the tax wedge should not be viewed as isomorphic.

6. Conclusions

The first main purpose of this paper is to study the effects of taxation on the cyclical behavior of the labor wedge. Using quarterly data for 1955:1-2019:2, it is shown that the tax wedge has negative, as opposed to positive, effects on the labor wedge. Therefore, the tax wedge cannot explain the rise of the labor wedge during recessions. Decomposing the tax wedge into consumption taxes and labor-income taxes reveals that the labor-income tax rate has negative effects while the consumption tax rate has positive effects on the labor wedge.

I then study whether firm-level credit frictions can affect the behavior of the labor wedge. By using the corporate credit spread as the measure for credit frictions, it is shown that this factor alone can explain more than 30% of the cyclical variation in the labor wedge. Importantly, the credit spread can account for the rise in the labor wedge during recessions and its decline in expansions even after controlling for the state of the economy. The price markup rate, which is another factor considered in this study as a potential determinant of short-run fluctuations in the labor wedge, has been found to be mostly insignificant.

These results are robust to the use of an alternative source of tax data and multiple estimation methods. In addition, using annual data for the investment tax rate, I show that the behavior of the latter is very similar to that of the labor wedge, both in the short term and in the long term. This is an interesting result since investment taxation does not directly affect the labor wedge. However, due to its effect on capital accumulation, investment taxation affects the marginal productivity of labor and, hence, the labor wedge. This is among the novel results of the paper.

The analyses also reveal that factors may have different effects on the labor wedge in the short vs. the long run. For example, while the tax wedge had positive effects on the trend of the labor wedge in the first half of the sample, its cyclical component had negative effects on the cyclical component of the labor wedge during the same period. By the same token, some factors may not be important for the trend of the labor wedge, but they can assist in understanding its short-run behavior. For this reason, distinguishing between the short run and the long run is important when the determinants of the labor wedge are studied.

The model with firm-level credit frictions proposed by this study well accounts for the cyclical behavior of the labor wedge; the model-based impulse responses imply a countercyclical behavior of the labor wedge following government expenditure shocks, preference shocks and financial shocks. These results hold whether labor-income and consumption tax rates (and hence, the tax wedge) are held constant or allowed to fluctuate with the state of the economy. The mere existence of credit frictions is the driving force of the countercyclicality of the labor wedge at business cycle frequencies. In fact, when the tax rates are responding to the state of the economy, the tax wedge declines, which limits the rise of the labor wedge during downturns. In this regard, the effect of the credit friction on the labor wedge outweighs that of taxation. On the other hand, the model without credit frictions fails to generate a countercyclical labor wedge.

This paper is part of a very timely line of research that studies the behavior of the labor wedge and its determinants. The paper also adds to the growing literature on the effects of credit frictions on the economy in the light of the Great Recession episode. The study suggests that the firms' side of the labor wedge is very important for understanding its behavior over the business cycle. Therefore, considerable attention should be given to explaining this component of the labor wedge, in addition to the households' component.

Compliance with Ethical Standards

Conflict of Interest: The author declares that he has no conflict of interest.
Ethical approval: This article does not contain any studies with human participants or animals performed by any of the authors.

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Appendix

A. The Firm's Problem

At the beginning of the period, the firm obtains a loan b_t^f from households, which is repaid at the end of the period at a gross interest rate of R_t^f. Borrowing is constrained by the beginning-of-period firm's collateral. Formally, the firm's problem is to:

$$\max_{\{k_t, l_t, x_{t+1}, b_t^f\}_{t=0}^{\infty}} \mathbb{E}_0 \sum_{t=0}^{\infty} \gamma^t (1-\tau_t^{\pi}) \Big[(1-m_t) z_t f(k_t, l_t) + b_t^f - w_t l_t - r_t k_t + q_t x_t - q_t x_{t+1} - R_t^f b_t^f \Big] \tag{A.1}$$

subject to:

$$b_t^f - \phi(w_t l_t + r_t k_t) \geq 0 \tag{A.2}$$

and

$$\kappa q_t x_t - b_t^f \geq 0 \tag{A.3}$$

Letting υ_t and ω_t be the Lagrange multipliers on the constraints (A.2) and (A.3), respectively, the optimality condition with respect to b_t^f reads:

$$\omega_t = R_t^f + \upsilon_t - 1 \tag{A.4}$$

Similarly, the first order conditions with respect to l_t and k_t yield:

$$(1-m_t) z_t f_{l,t} = (1+\phi\upsilon_t) w_t \tag{A.5}$$

$$(1-m_t) z_t f_{k,t} = (1+\phi\upsilon_t) r_t \tag{A.6}$$

Recalling that $R_t^f = 1$ from the household's problem, equation (A.4) becomes:

$$\omega_t = \upsilon_t \tag{A.7}$$

and, therefore, the two Lagrange multipliers are equal. By renaming the Lagrange multiplier as μ_t, we get conditions (12)-(13) in the text.

Alternatively, conditions (A.2) and (A.3) can be combined to get:

$$\phi(w_t l_t + r_t k_t) \leqslant \kappa q_t x_t \tag{A.8}$$

which is condition (11) in the text.

Substituting $R_t^f = 1$ in (A.1), the profit function is given by:

$$\max_{\{k_t, l_t, x_{t+1}, b_t^f\}_{t=0}^{\infty}} \mathbb{E}_0 \sum_{t=0}^{\infty} \gamma^t \left[(1-m_t) z_t f(k_t, l_t) - w_t l_t - r_t k_t + q_t x_t - q_t x_{t+1} \right] \tag{A.9}$$

which is condition (10) in the text. Therefore, the optimization problem of the firm is to maximize (A.9) subject to (A.8). Letting μ_t be the Lagrange multiplier on (A.8), the choice of labor, capital and real estate yields conditions (12)-(14) in the text.

B. The Sticky-Price Model

A short description of the sticky-price model is presented in this appendix. The economy is populated by households, intermediate-good firms (or entrepreneurs) that produce intermediate goods and final-good firms. Households consume differentiated final goods and supply labor on spot markets, and intermediate-good firms hire labor and rent capital to produce homogenous intermediate goods. Final-good firms are monopolistic competitors that purchase intermediate goods and costlessly produce final goods. The pricing of a final-good firm is subject to a direct resource cost, which is the source of price rigidity in this model.

B.1. Households

In each period t, the representative household purchases a composite consumption index of final goods c_t, supplies labor l_t, purchases real estate h_t and lends B_t^f to the firm at the beginning of the period at an intra-period gross nominal interest rate of R_t^f. In addition, the household has access to a one-period nominal government bond B_t that pays a gross nominal interest rate of R_t. Households maximize their expected present discounted lifetime utility given by:

$$\max_{\{b_t, b_t^f, c_t, h_{t+1}, k_{t+1}, l_t\}_{t=0}^{\infty}} \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \eta_t u(c_t, h_t, l_t) \tag{B.1}$$

subject to the households' sequence of period budget constraints (in real terms) of the form:

$$(1-\tau_t^l) w_t l_t + [r_t - \tau_t^k (r_t - \delta)] k_t + q_t h_t + \frac{R_{t-1} b_{t-1}}{\pi_t} + R_t^f b_t^f = (1+\tau_t^c) c_t + (1+\tau_t^i) i_t + b_t + b_t^f + q_t h_{t+1} \tag{B.2}$$

and the law of motion of capital:

$$k_{t+1} = (1-\delta) k_t + i_t \tag{B.3}$$

where P_t is the aggregate price level, $\pi_t = \frac{P_t}{P_{t-1}}$ is the gross inflation rate and all other variables are defined as in the text.

Optimization by households then yields:

$$R_t^f = 1 \tag{B.4}$$

$$-\frac{u_{l,t}}{u_{c,t}} = \left(\frac{1-\tau_t^l}{1+\tau_t^c}\right) w_t \tag{B.5}$$

$$u_{c,t} = \beta R_t \, \mathbb{E}_t \left(\frac{u_{c,t+1}}{\pi_{t+1}} \frac{\eta_{t+1}}{\eta_t} \frac{1+\tau_t^c}{1+\tau_{t+1}^c} \right) \tag{B.6}$$

$$u_{c,t} = \beta \, \mathbb{E}_t \left(\frac{\eta_{t+1}}{\eta_t} \frac{u_{c,t+1}}{1+\tau_{t+1}^c} \frac{1+\tau_t^c}{1+\tau_t^i} \left[(1+\tau_{t+1}^i)(1-\delta) + r_{t+1} - \tau_{t+1}^k (r_{t+1} - \delta) \right] \right) \tag{B.7}$$

$$u_{c,t} = \beta \, \mathbb{E}_t \left(\frac{1+\tau_t^c}{q_t} \left(u_{h,t+1} + q_{t+1} \frac{u_{c,t+1}}{1+\tau_{t+1}^c} \frac{\eta_{t+1}}{\eta_t} \right) \right) \tag{B.8}$$

B.2. Intermediate-Good Firms

The firm hires labor and rents capital from households to produce using the following production technology:

$$y_t = z_t f(k_t, l_t) \tag{B.9}$$

where y_t and z_t are output and total factor productivity, respectively.

The problem of the intermediate-good firm is to:

$$\max_{\{k_t, l_t, x_{t+1}\}_{t=0}^{\infty}} \mathbb{E}_0 \sum_{t=0}^{\infty} \gamma^t \left(1 - \tau_t^{\pi}\right) \left[p_t z_t f(k_t, l_t) - w_t l_t - r_t k_t + q_t x_t - q_t x_{t+1}\right] \tag{B.10}$$

subject to:

$$\phi(w_t l_t + r_t k_t) \leqslant \kappa q_t x_t \tag{B.11}$$

By denoting the Lagrange multiplier on condition (B.11) by μ_t , we get:

$$p_t z_t f_{l,t} = (1 + \phi\mu_t) w_t \tag{B.12}$$

$$p_t z_t f_{k,t} = (1 + \phi\mu_t) r_t \tag{B.13}$$

$$q_t(1 - \tau_t^{\pi}) = \gamma\, \mathbb{E}_t \left[q_{t+1}(1 - \tau_{t+1}^{\pi} + \kappa\mu_{t+1})\right]. \tag{B.14}$$

with p_t being the real price of intermediate-good firms (the price of output of the firm divided by the aggregate price level P_t). These conditions are similar to (12)-(14) with $p_t = 1 - m_t$.

B.3. Final-Good Firms

Firms in this market are monopolistically competitive. Each final-good firm j purchases homogenous intermediate goods from intermediate-good firms at a relative price of p_t and transforms each unit of the intermediate good into a final good using a one-to-one technology. Each firm chooses its own price $P_{j,t}$ to maximize profits subject to the downward-sloping demand for its product. The pricing of a final-good firm is subject to a quadratic adjustment cost as in Rotemberg (1982), expressed in units of the final good:

$$\Phi_{j,t} = \frac{\varphi}{2}\left(\frac{P_{j,t}}{P_{j,t-1}} - 1\right)^2 y_t \tag{B.15}$$

where φ is a parameter that governs the degree of price rigidity. In a symmetric equilibrium, in which all firms set the same price, Rotemberg pricing yields the following forward-looking Phillips curve:

$$1 - \varphi(\pi_t - 1)\pi_t + \beta\varphi\, \mathbb{E}_t\left[\frac{u_{c,t+1}}{u_{c,t}}(\pi_{t+1} - 1)\pi_{t+1}\frac{y_{t+1}}{y_t}\right] = \epsilon(1 - mc_t) \tag{B.16}$$

with mc_t being the real marginal cost of the final-good firm, which in equilibrium equals p_t. The labor demand condition (B.12) can then be written as:

$$mc_t z_t f_{l,t} = (1 + \phi\mu_t) w_t \tag{B.17}$$

which is the more familiar condition of labor demand, but augmented by the Lagrange multiplier on the credit constraint.

B.4. The Government

The government collects labor-income taxes, consumption taxes, capital-income taxes, investment taxes, profit taxes and issues real debt to finance an exogenous stream of real government expenditures g_t and to repay the last-period debt. The government budget constraint in period t reads:

$$\tau_t^l w_t l_t + \tau_t^c c_t + \tau_t^k (r_t - \delta) k_t + \tau_t^i i_t + \tau_t^\pi \Pi_t + b_t = g_t + \frac{R_{t-1} b_{t-1}}{\pi_t}. \tag{B.18}$$

B.5. Market Clearing

In addition to labor market clearing, the markets of goods and real estate clear:

$$z_t f(k_t, l_t) + (1 - \delta) k_t = c_t + k_{t+1} + g_t \tag{B.19}$$

$$h_t + x_t = 1. \tag{B.20}$$

B.6. The Labor Wedge- Results

Households' optimization gives the following labor supply condition:

$$-\frac{u_{l,t}}{u_{c,t}} = \left(\frac{1 - \tau_t^l}{1 + \tau_t^c}\right) w_t \tag{B.21}$$

And, from the combination of the solutions to the intermediate-good firm and final-good firms' problems, we get the following demand condition for labor:

$$mc_t z_t f_{l,t} = (1 + \phi\mu_t) w_t \tag{B.22}$$

with mc_t being the real marginal cost of firms. By combining the labor demand and labor supply conditions and defining $m_t = 1 - mc_t$, we get the following expression for the wedge:

$$LW_t = \frac{m_t + \tau_t (1 - m_t) + \phi\mu_t}{1 + \phi\mu_t} \tag{B.23}$$

which is exactly as equation (22). Therefore, the general form of the labor wedge does not change with the introduction of sticky prices and monopolistic competition in the product market. This setup, however, has the advantage of allowing the markup m_t to be an endogenous object, which helps in judging the ability of credit frictions to explain the cyclical behavior of the labor wedge when not only the behavior of the tax wedge is taken into account, but also the behavior of the price markup. In this respect, one would expect a rise in the real marginal cost in downturns and, a result, a fall in the markup. In other words, the markup is procyclical.[8] The decline in the markup in itself pushes towards a lower labor wedge. The behavior of the labor wedge in this setup depends on the strength of each channel: following negative shocks, the tax wedge and the markup rate push towards a lower labor wedge while the credit friction calls for a higher labor wedge.

This concludes the description of the model.

B.7. *Quantitative Results*

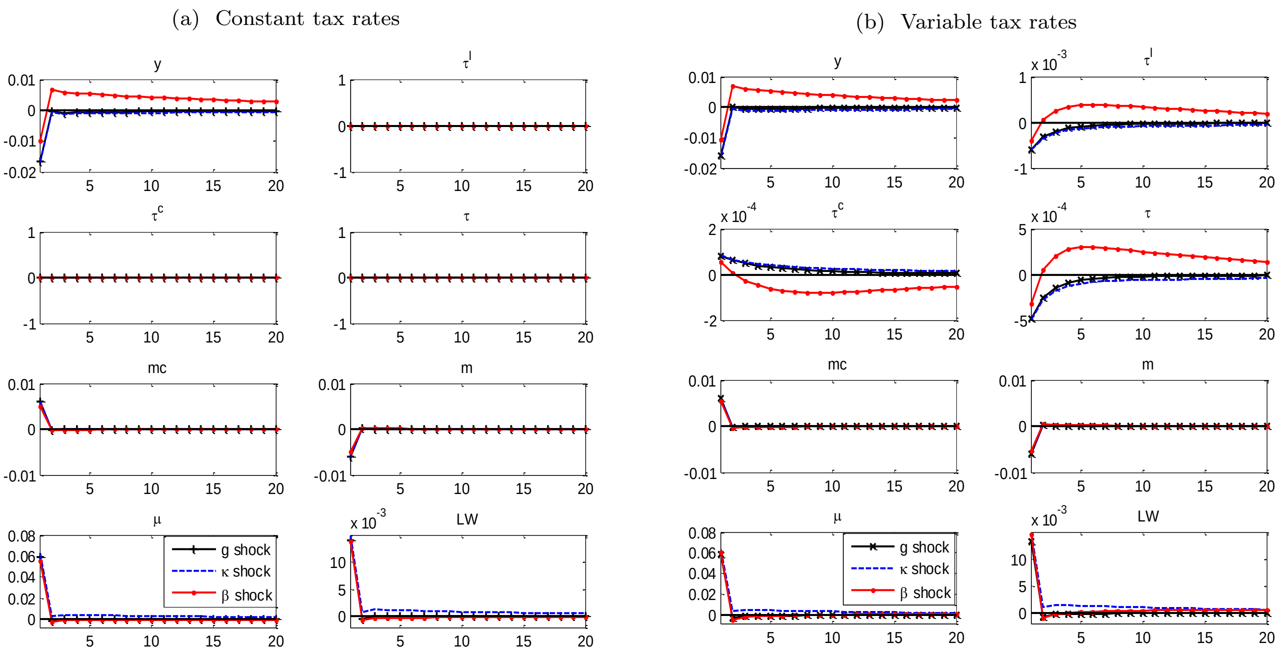

Figure B.1: Impulse responses to negative one standard deviation shocks. Note: deviations from the deterministic steady state. Sticky-price model with credit frictions.

The results are shown in Figure B.1. With constant tax rates, output declines, the marginal cost rises and the credit conditions tighten more in response to negative shocks. The markup declines as a result of the rise in the marginal cost, which, in isolation, calls for a decline in the labor wedge. However, the rise in the tightness of the credit constraint outweighs the decline in the markup rate, leading to a rise in the labor wedge on impact. The results with time-varying tax rates are similar. The tax wedge and the markup rate decline, while the credit constraint tightens. The rise in the credit tightness appears to be significantly stronger, which leads to a rise in the labor wedge on impact. The labor wedge, once more, displays a countercyclical behavior regardless of the assumption about taxation. These results confirm the earlier findings from the real model and they suggest that firm-side credit conditions are key to explaining the cyclical fluctuations of the labor wedge.[9]

[8] The cyclicality of the price markup has been debated in the literature. In this respect, Gali et al. (2007) find a procyclical markup, and Nekarda and Ramey (2013) show that the markup is either procyclical or acyclical.

[9] In the absence of credit frictions, the labor wedge exhibits a procyclical behavior. This happens because both the tax wedge τ_t and the markup rate m_t fall in recessions, thus pushing the labor wedge down.

B.8. Model vs. Data

I close this section with a brief summary regarding the model's ability to account for the volatility of the labor wedge and it association with output. I use the sticky-price model because it allows for a variable markup and, therefore, it is the broader version of this setup. Table B.1 compares the performances of three different cases: the model without credit frictions and variable tax rates, the model with credit frictions and constant tax rates and the model with credit frictions and variable tax rates. For the model with no credit frictions, only shocks to government spending and preferences are relevant.

		$sd(LW)/sd(y)$	*Corr(LW,y)*
U.S. Data		0.737	-0.600
No Credit Frictions	g shock	0.107	0.839
	β shock	0.073	0.955
	κ shock	-	-
	All shocks	0.123	0.910
Credit Frictions Only	g shock	0.828	-0.987
	β shock	0.621	-0.397
	κ shock	0.890	-0.991
	All shocks	0.781	-0.789
Credit Frictions and Taxes	g shock	0.828	-0.987
	β shock	0.663	-0.379
	κ shock	0.892	-0.992
	All shocks	0.793	-0.770

Table B.1: The relative standard deviation of the labor wedge and the correlation coefficient of the labor wedge with output. The model without credit frictions corresponds to the model with only variable tax rates and markup.

The model without credit frictions not only suggests a procyclical labor wedge, but also accounts for a very small portion of the volatility of the labor wedge relative to the volatility of output. Introducing credit frictions increases the model's ability to replicate the volatility of the labor wedge significantly. And, the combination of credit frictions with variable tax rates improves the model's predictive power more. However, credit frictions alone account for most of the variations in the model, and abstracting from variable tax rates does not change matters considerably. Comparing Panel (a) and Panel (b) of Figure 2 indicates that the model with only credit frictions well captures the behavior of the labor wedge.

With a government spending shock and a credit friction shock, the volatility of the labor wedge is slightly overestimated, and the opposite holds for a preference shock. The actual standard deviation, however, lies well inside the range of the standard deviations that the model with credit frictions predicts. On the other hand, abstracting from credit frictions makes the volatility of the labor wedge well below its empirical counterpart.

The model with credit frictions overestimates the correlation of the labor wedge with output for government spending and credit friction shocks and underestimates it for preference shocks. However, the true correlation between output and the labor wedge is within the model's predictions. This can be better seen when all shocks are introduced simultaneously. Both the volatility of the labor wedge and its correlation with output are pushed closer to their values in U.S. data, and thus the model performs well not only in replicating the direction of the labor wedge following shocks but also its volatility and quantitative association with output at business cycle frequencies.

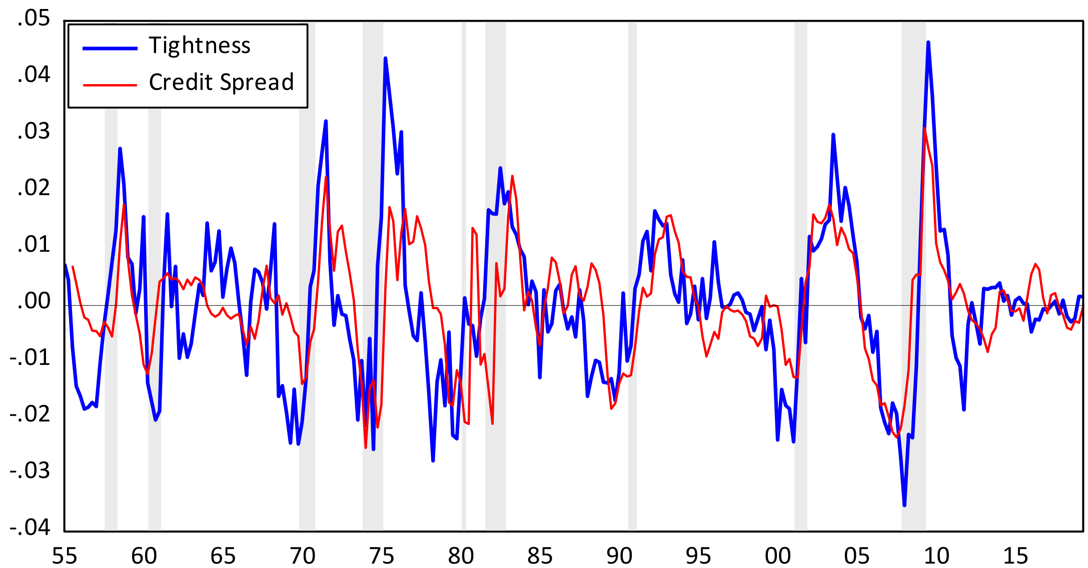

Figure B.2: The cyclical components of the the credit spread and the tightness of the collateral constraint (μ_t).

Finally, Figure B.2 shows that the choice of the credit spread as a proxy for credit frictions is adequate. I calculate the Lagrange multiplier on the credit constraint (μ_t) as a residual from condition (12) using U.S. data (on the markup and labor share) and the functional forms. In particular, the functional form implies $\mu_t = \frac{1}{\phi}\left(\frac{(1-\alpha)(1-m_t)y_t}{w_t l_t} - 1\right)$. Defining $s_t = \frac{w_t l_t}{y_t}$ as the labor share, we have $\mu_t = \frac{1}{\phi}\left(\frac{(1-\alpha)(1-m_t)}{s_t} - 1\right)$. I then calculate its cyclical component and compare it to the cyclical component of the credit spread.

The two series mostly exhibits a strong correlation over the business cycle and it appears that this correlation has been tighter in the second half of the sample. This exercise provides another support of the choice of the modeling device (that is centred around firm-side credit constraints) as the tightness of the collateral constraint captures the cyclical changes in the severity of firms' financial conditions throughout the sample period. In addition, this figure supports the mapping between the model and the empirical analyses of the paper.