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Tax policies, informality, and real wage rigidities*

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Abstract

Developing countries have a vast informal sector generally associated with low productivity levels. The response of informal employment to tax policies might depend on labor market rigidities. This paper proposes a theoretical framework consisting of a search and matching model with segmentation in the labor market to understand how tax policies and enforcement interact to determine the size of the formal sector. The analytical results show that decreasing payroll taxes increases formal employment demand, and enforcement expenditure decreases informal employment offers. The model suggests that a tax policy combination leads to a significant impact on informality reduction. Moreover, the magnitude of the effect of tax policies depends on real wage rigidities, i.e., when the economy faces high real wage rigidities, the tax policies have a higher effect on informality reduction.

Keywords: Informality, payroll taxes, fiscal policy, enforcement, search frictions, shirking, developing countries.

JEL Classification: E26, E62, J21, J46, J31, O17, K42.

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1 Introduction

The informal sector, defined as the part of the labor force that does not comply with government regulations, has a large size that persists over time. Specifically, developing countries have a vast informal sector generally related to low productivity levels (Perry, 2010). Informality is related to less pension and health coverage, workers without unemployment compensation, and less tax revenue via widespread tax evasion (Schneider & Enste, 2000). Also, the persistence of informality could be a response to rigidities in the labor market, with a combination of high non-wage costs and high minimum wages (Maloney, 2004). Existing literature, such as Mondragón-Vélez et al. (2010) and Santa María et al. (2010), highlight the labor market rigidities' relevance to understanding informality's persistence.

Accordingly, this paper sheds light on understanding the effect of tax policy that seeks to reduce informality in an economy with real wage rigidities and restrictions associated with the search and matching process in the labor market. The model seeks to understand how the combination of labor policies and the enforcement capacity of labor regulations could decrease the size of the informal sector, increase formal workers, and increase tax revenues in an economy with real wage rigidities in the formal sector. Specifically, the model proposed in this paper is similar in spirit to Martin & Wang (2020), which builds a model with a search and matching frictions in the labor market that includes a shirking mechanism. However, we include a government in a dual labor market with informal and formal workers.

We develop a general equilibrium model to understand the role of tax policies in an economy with real wage rigidities through shirking mechanisms and search and matching processes. The model is based on Martin & Wang (2020), who modified the search and matching model summarized in Pissarides (2000), incorporating a shirking mechanism by Shapiro & Stiglitz (1984). We extend this model by including an informal sector with no labor market frictions. Our model has formal and informal firms hiring formal and informal workers, respectively. The formal firm can hire formal workers by a matching process as Diamond (1982), Mortensen & Pissarides (1994), and Pissarides (2000). In contrast, given the marginal labor productivity, the informal firm has no friction and hires informal workers. Unemployed in the economy, search for a job in the formal or informal sector. If the unemployed become employed in the formal firm, they could be shirking or non-shirking workers as in Shapiro & Stiglitz (1984).

The real wage rigidities in the formal sector come from the shirking mechanism. That is, the workers have an additional disutility to become non-shirking workers in terms of the real wage. The real wage increase is a consequence of the incentive from the firm to hire non-shirking workers. The government's primary objective is to increase its revenues through two tax policies: to reduce payroll tax in the formal sector and increase the expenditure on law enforcement in the informal sector. The first policy decreases the

cost of hiring in the formal sector, but the other increases the cost of working in the informal sector. In this sense, combined mechanisms reduce informality and increase formal labor in the economy. Given the above, the increase in the number of formal workers leads to an increased tax base and government income.

The main model results suggest that tax policies, such as variations in payroll taxes and law enforcement expenditures, are relevant instruments for reducing informal employment. The effectiveness of each policy depends on the economy's real wage rigidities. The results show that a decrease in payroll taxes increases formal worker demand, while the increase in law enforcement expenditure reduces the size of the informal sector. Therefore, both tax policies combination would have a significant impact on reducing informality. These results hold under scenarios of real wage rigidities. In this sense, the model suggests that complementing state capacity and labor policies is essential to reduce informality and encourage formal employment. Also, the simulation results show the existence of a policy with constant government expenditure, where it is possible to reduce payroll taxes with increases in law enforcement expenditure. In addition, there is a scenario where it is possible to decrease the payroll taxes to increase public goods expenditure and formal employment. Furthermore, we document a case where increases in enforcement spending lead to a peak in public expenditure with low levels of informal employment. The model also suggests a more significant effect of tax policies in the informal employment reduction when the economy presents high real wage rigidities.

This paper contributes to the literature that aims to understand the relationship between tax policies, enforcement expenditure, and labor informality. Regarding payroll taxes, findings of D'Erasmo & Boedo (2012) and Haanwinckel & Soares (2021) suggest that reductions in payroll tax seem to generate an increase in formalization. Also, in line with the previous results Pratap & Quintin (2006); Santa María et al. (2010) and Osorio-Copete (2016) show that reductions in payroll tax have a significant effect on reducing the informality. In addition, Saraçoğlu (2020) shows that a decrease in the payroll taxes by the employee and the employer could reduce informality. The authors highlight the mixed effect of payroll tax policies on economic welfare and the effect of increasing enforcement policy in decreasing informality levels in Turkey.

Furthermore, Rocha et al. (2018) study the causal effect of reducing the tax burden on firms. The authors found a positive effect in the reduction of informality given the reduction in tax burden. Hence, the literature highlights the relevance of tax policies in reducing informality. Accordingly, this research contributes to the evidence favoring reducing tax burdens and payroll taxes to decrease informality. On the other hand, Meghir et al. (2015), Ulyssea (2018), Bardey & Mejía (2019), and Acosta-Henao (2020), Aruoba (2021), Liu-Evans & Mitra (2022) find strong evidence in favor of informality reduction as a consequence of increasing in law enforcement expenditure. Also, in line with the results presented in this study, Maiti & Bhattacharyya (2020) has recently proposed an economic growth model that incorporates both formal and informal sectors, in which it is possible to find an optimal level of enforcement to enhance economic growth while

reducing informality.

However, this research differs from the conclusion proposed by Ulyssea (2010), Almeida & Carneiro (2012), and Charlot et al. (2015), in which an increase in enforcement expenditure could lead to an increase in unemployment. Specifically, Charlot et al. (2015) defines the formal and informal sectors with matching frictions and points out that fiscal policies such as reducing taxes and increasing enforcement can generate a trade-off between informality and unemployment, given the reduction of informal firms and the limited capacity of formal employment to compensate for the loss of informal employment.

In contrast to the above literature, the present paper assumes an informal sector close to the dualistic subsistence view without search and matching frictions (La Porta & Shleifer, 2014). Our results show that increasing enforcement can lead to a decrease in unemployment. This last result is more in line with the contribution of Meghir et al. (2015) and Dix-Carneiro et al. (2021), who find no effect on unemployment with increases in enforcement. Hence, the research contributes to the debate on the possible enforcement effects on unemployment and informality. Indeed, the paper explores the link between labor market rigidities, informality, unemployment, and enforcement expenditures.

Regarding research on the reduction of informality with tax policies in Colombia, the results of the present paper come to a similar conclusion with Antón (2014), Kugler & Kuler (2015), Fernández & Villar (2017), and Garlati-Bertoldi (2020), who document a reduction in the informality given the Colombian labor reform of 2012, which decreased the payroll tax. On the other hand, the results of Posada & Mejía (2012) and Acosta-Henao (2020), who find that increasing the spending on law enforcement decreases informality, agree with the results in the present paper. Finally, in line with Albrecht et al. (2009), Flórez (2015), Bosch & Esteban-Pretel (2015), and García-Suaza et al. (2021), we model the labor market with search and matching frictions and an informal sector. Nevertheless, to the best of our knowledge, there is no research linking the effect of tax policies on informality in a labor market with micro-founded real wage rigidities, including search and matching frictions with unemployment.

Our theoretical framework accords with the argument of Ulyssea (2020) about the importance of understanding the informality determinants that build decisions from the micro-level to the macro-level. In this regard, a relevant contribution of this paper is to include micro-founded real wage rigidities to understand how these can affect the optimal workers' decisions to enter the formal or informal sector and how these workers' decisions affect the aggregate employment variables in the economy.

Concerning the phenomenon of informality in Colombia, it is notable that despite the different definitions of informality, Colombia has presented high levels of informality over time. The most recent data from National Statistics Department (DANE, for its acronym in Spanish) shows that the informal sector's employment share is around 58% (DANE, 2023a). High levels of unemployment and informality have characterized the

labor market behavior in Colombia, even during economic boom periods. According to DANE, the most recent unemployment figure is 11.4% [1] (DANE, 2023b).

Furthermore, based on the vacancy data provided by Morales & Lobo (2021), it is possible to observe an inverse and non-linear relationship between the vacancy and unemployment rate. This relationship is known as the Beveridge curve, which suggests that unemployment levels will lower as vacancies increase. In this sense, the Beveridge curve allows us to understand unemployment's possible inflows and outflows. The persistence of high levels of informality in the country highlights the relevance of taking into account the informal sector when analyzing the role of vacancies. The theoretical model presented in this paper predicts a convex and negative relationship between formal vacancies and the size of the non-formal sector, defined as the sum of the unemployment and informality rate. Thus, the model presented below deduces a new dualistic Beveridge curve with a dual labor market (formal and informal sectors) that can replicate the empirical relationship of the Beveridge curve with the non-formal sector observed in the data, as shown in Figure 1. The dualistic Beveridge curve facilitates the comprehension of the relationship between exit and entry in the formal sector. This is a crucial element of the model that allows us to understand the ability of the formal sector to absorb the labor force in the face of tax policies that affect workers'employment decisions.

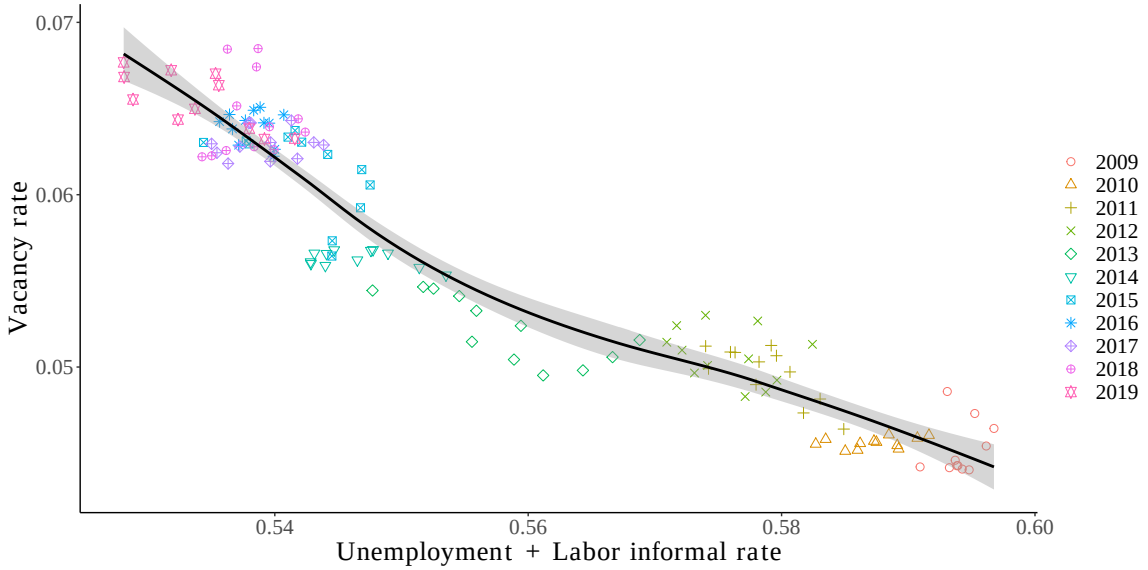

Figure 1: Beveridge curve with non-formal sector (each point is a month).
Source: (Morales & Lobo, 2021) and Colombian Household Surveys (GEIH for its acronym in Spanish) published by the DANE for the 23 main metropolitan areas.

The rest of the paper is organized as follows. Section 2 presents the model, while section

[1] Official data for February 2023

3 provides the calibration details. Section 4 presents the analytical and simulation results, and section 5 concludes.

2 Model

This section presents the analytical framework to analyze the role of taxes and enforcement in developing countries, a general equilibrium model with a dual labor market and three agents: households, firms, and government. The representative household supplies labor own firms and chooses consumption to maximize an intertemporal utility function. The workers in the economy belong to one of three states: informal workers, formal workers, or unemployed. If the worker is employed in the formal sector, she could be a shirking or non-shirking worker.

The firms are formal or informal. Formal firms can hire up to one worker, and these workers could be shirking or non-shirking. Formal firms face a fixed vacancy cost, and wages are determined by the shirking mechanism. On the other hand, informal firms are labor-intensive and have marginal decreasing returns; wages in this sector correspond to workers' marginal productivity.

Finally, the government's primary balance depends on revenue and expenditure. The government revenue comprises formal firms' taxes, households' taxes, and informal firms' fines. In contrast, government expenditure depends on transfers to households, unemployment transfer, enforcement expenditure to capture informal firms, and production of public goods. Government has two principal tax policies to increase the formal sector and government revenue: reduce the formal firms' taxes, and change the enforcement expenditure to increase the probability of auditing and finding an informal firm. Both policies incentivize the transition from the informal to the formal sector, increasing government revenue by increasing the taxable base.

2.1 Households

The representative households derive utility from consumption and from a public good (g_t) according to the following intertemporal utility function:

$$\max_{c_t,b_t} E_0 \sum_{t=0}^{\infty} \left(\frac{1}{1+\rho}\right)^t \Big\{ \mathcal{U}(c_t^{wi} - \chi) l_t^i + \mathcal{U}(c_t^{wns} - \chi - \zeta) l_t^{wns} + \mathcal{U}(c_t^{ws} - \chi) l_t^{ws} + \mathcal{U}(c_t^u) u_t + \mathfrak{U}(g_t) \Big\}, \quad (1)$$

where ρ is the time discount rate, and the variables c_t^{wi}, c_t^{wns}, c_t^{ws}, and c_t^u are per capita consumption for informal, non-shirking, shirking, and unemployed workers, respec-

tively. For simplicity, we assume the functions $\mathcal{U}(\cdot)$ are strictly increasing and strictly concave. Households own firms and labor in the economy, and there is risk-sharing. In each period, the household earns (and consumes) real wages from his work in the formal and informal sectors, defined as w_t^f and w_t^i, respectively.

Formal and informal workers face a disutility equal to χ. An employee in the formal can be a shirking or non-shirking worker. Workers who do not shirk incur a disutility ζ. Furthermore, in each period, the household receives formal firm dividends, Div_t, and an unemployment transfer for the government given by s_t. The household's problem consists of maximizing the intertemporal utility function (1) subject to the following budget constraint:

$$c_t + b_t = (1 + (1 - \tau_t^{\pi})r_{t-1})b_{t-1} + w_t^f l_t^f + w_t^i l_t^i + s_t u_t + (1 - \tau_t^{\pi})Div_t. \tag{2}$$

In equation (2), the household bonds are represented by b_t, and r_{t-1} is the return rate of the bonds. The total household consumption c_t is defined as $c_t = c_t^{wi} l_t^i + c_t^{wns} l_t^{wns} + c_t^{ws} l_t^{ws} + c_t^u u_t$. Additionally, the government tax on the formal profits of the firms is equal to τ_t^{π}. Given the labor market, the total labor force in the economy is divided into non-shirking workers (l_t^{ns}), shirking workers (l_t^s), informal workers (l_t^i), and unemployed (u_t), so in per-capita terms, $1 = l_t^f + l_t^i + u_t$, where $l_t^f = l_t^{ns} + l_t^s$. As a consequence, the first-order conditions from the household maximization problem are given by:

$$\frac{\partial \mathcal{U}(c_t^{wi} - \chi)}{\partial c_t^{wi}} = \frac{\partial \mathcal{U}(c_t^{wns} - \chi - \zeta)}{\partial c_t^{wns}} = \frac{\partial \mathcal{U}(c_t^{ws} - \chi)}{\partial c_t^{ws}} = \frac{\partial \mathcal{U}(c_t^{u})}{\partial c_t^{u}} = \lambda_t, \tag{3}$$

$$\lambda_t = \left(\frac{1}{1+\rho}\right) E_t \lambda_{t+1}(1 + (1 - \tau_{t+1}^{\pi})r_t). \tag{4}$$

From equation (3), it is possible to define the following consumption behavior.

$$c_t^u = c_t^{wi} - \chi = c_t^{wns} - \chi - \zeta = c_t^{ws} - \chi.$$

Combining the equation (3) and (4), we get the following expression:

$$\frac{1}{E_t(1 + (1 - \tau_{t+1}^{\pi})r_t)} = \left(\frac{1}{1+\rho}\right)\frac{\lambda_{t+1}}{\lambda_t} = \left(\frac{1}{1+\rho}\right)\Omega_{t+1}, \tag{5}$$

in which Ω_{t+1} is defined as the ratio of the first-order conditions, $\frac{\lambda_{t+1}}{\lambda_t}$.

2.2 Firms

The firms might be either formal or informal. Formal firms hire up to one formal worker, and informal firms hire up to one informal worker. The formal and informal firms are

homogeneous. In the formal sector, the firms maximize profits and post job vacancies. The shirking mechanism determines the formal wage, creating real wage rigidities. In contrast, informal firms do not face any friction; they only hire non-shirking workers and maximize profit.

Matching Process

The matching function that determines the aggregate hiring in the formal sector is the following:

$$m(u_t, v_t) = k u_t^{\phi} v_t^{1-\phi}, \tag{6}$$

where $m(u_t, v_t)$ is the number of workers hired in the formal sector, u_t is the unemployment rate, and v_t is the formal vacancy rate. Similar to the standard search and matching models literature, the parameters ϕ and k characterize the constant returns of the matching function. Moreover, labor market tightness θ_t is defined as the ratio of the vacancy rate to the unemployment rate, as follows:

$$\theta_t = \frac{v_t}{u_t}, \tag{7}$$

where the higher θ_t, the higher the labor market tightness. In turn, the probability of filling a vacancy in the formal sector, $q(\theta_t)$ is equal to the ratio of the number of workers hired in the formal sector to the vacancy rate, that is:

$$q(\theta_t) = \frac{m(u_t, v_t)}{v_t} = k \left(\frac{1}{\theta_t}\right)^{\phi}. \tag{8}$$

On the other hand, the probability that an unemployed finds a job in the formal sector, $\alpha(\theta_t)$, is defined by the ratio of matching workers in the formal sector to the unemployment rate,

$$\alpha(\theta_t) = \frac{m(u_t, v_t)}{u_t} = k \left(\theta_t\right)^{1-\phi}. \tag{9}$$

In period t, a pool of unemployed workers finds formal work with probability $\alpha(\theta_t)$, and a fraction of non-shirking workers are fired with an exogenous separation rate $\mu \in (0, 1)$. Furthermore, the shirking workers have an additional exogenous probability of being unemployed, defined by d. The formal labor force evolves according to the following equation:

$$l_{t+1}^{f} = (1-\mu) l_t^{ns} + (1-\mu-d) l_t^{s} + \alpha(\theta_t) u_t. \tag{10}$$

The production function of the formal firm depends on worker productivity. For simplicity, if the worker is non-shirking, the production is given by $y_t^f = \psi^f$, where ψ^f is the

formal firm productivity. However, the production is zero if the worker shirks. In addition, the formal firm has a fixed cost η to create a vacancy. Moreover, in each period, the formal firm pays a profit tax defined by τ_t^{π} and pays a payroll tax τ^{w} to hire a worker. Then, the formal firms' net profits for each period t are given by:

$$\Pi_t^f = Div_t\left(1-\tau_t^{\pi}\right) = \left(y_t^f l_t^{ns} - (1+\tau_t^{w}) w_t^f l_t^f - \eta v_t\right)\left(1-\tau_t^{\pi}\right) \tag{11}$$

Therefore, there are three different states of formal firms' profits. The first possible state is represented by the value function of the formal firm to create a vacancy V_t and is defined as follows:

$$V_t = -(1-\tau_t^{\pi})\eta + \left(\frac{1}{1+\rho}\right) E_t\left\{\Omega_{t+1}\left[q(\theta_t)H_{t+1} + (1-q(\theta_t))V_{t+1}\right]\right\}, \tag{12}$$

where $H_{t+1} = J_{t+1}^{ns}$ if the worker chooses not to shirk, and $H_{t+1} = J_{t+1}^{s}$ in the other case. The variable J_t^{ns} represents the value of a filled job with a formal non-shirking worker, and J_t^{s} represents the value of a filled job with a formal shirking worker. Equation (12) represents the Value function of a vacancy. It includes the net cost of posting a vacancy, $(1-\tau_t^{\pi})\eta$, and the expected value function. This value function is a weighted average of the value of filling the vacancy, with probability $q(\theta_t)$, and the value of not filling the vacant, with probability $1-q(\theta_t)$.

At the beginning of the period t, the firm has a net profit given by $(1-\tau_t^{\pi})(y_t^f - w_t^f(1+\tau_t^{w}))$. With an exogenous probability μ, the worker is fired, and the vacancy is open. In contrast, with probability $1-\mu$, the vacancy is still filled by either a shirking or non-shirking worker. Thus, the firm value function of a filled job with a non-shirking worker is:

$$J_t^{ns} = (1-\tau_t^{\pi})(y_t^f - w_t^f(1+\tau_t^{w})) + \left(\frac{1}{1+\rho}\right) E_t\left\{\Omega_{t+1}\left[\mu V_{t+1} + (1-\mu)H_{t+1}\right]\right\}. \tag{13}$$

In contrast, if the vacancy is filled with a shirking worker, the net profit of the firms does not have production and is defined by $-(1-\tau_t^{\pi})(1+\tau_t^{w})w_t^f$. However, the probability of firing a worker and opening a vacancy increase by d. In consequence, with probability $\mu+d$, the vacancy is open. Formally, the firm value function of a filled job with a shirking worker is

$$J_t^{s} = -(1-\tau_t^{\pi})(1+\tau_t^{w})w_t^f + \left(\frac{1}{1+\rho}\right) E_t\left\{\Omega_{t+1}\left[(\mu+d)V_{t+1} + (1-\mu-d)H_{t+1}\right]\right\} \tag{14}$$

Informal Firms

Following Ulyssea (2018), an informal firm's profit function is defined in equation (16). For simplicity, we assume that the production of the informal firm is given by $y_t^i = \psi^i$,

where ψ^i is the productivity of the informal firm, and $\psi^f > \psi^i$. Like Posada & Mejía (2012), Bardey & Mejía (2019), and Acosta-Henao (2020), the informal sector does not have any taxes. Still, it is subject to a probability of being audited, $A(e_t)$, that depends on enforcement expenditure by the government, e_t:

$$A(e_t) = 1 - exp\left\{-\gamma e_t\right\}. \tag{15}$$

We assume that $A(e_t)$ has an exponential distribution probability, where $A_e(\cdot) > 0$, $A_{ee}(\cdot) < 0$, $\lim_{e_t \to \infty} A(e_t) = 1$. An increase in enforcement expenditure increases the probability of auditing an informal firm; in this case, firms lose the whole output. Hence, informal firms'profits are:

$$\Pi^i = y_t^i l_t^i [1 - A(e_t)] - w_t^i l_t^i \tag{16}$$

The informal labor force, l_t^i, follows a law of motion given by:

$$l_{t+1}^i = (1 - \sigma) l_t^i + \xi u_t \tag{17}$$

The probability that an unemployed were employed in the informal sector is exogenous, and it is defined by ξ. On the other hand, with probability σ, the informal worker is fired. Lastly, the marginal productivity in the informal firm gives the expected informal net income and depends on the audited probability.

$$w_t^i = y_t^i (1 - A(e_t)) \tag{18}$$

2.3 Workers

Workers in the model are homogeneous. In the period t, a worker is either employed in the formal or informal sectors or unemployed. However, workers in the formal sector could be employed as shirking workers or non-shirking workers. As a result, the workers' utility has four possible states summarized in the following value function:

$$W_t^{ns} = w_t^f - \chi - \zeta + \left(\frac{1}{1+\rho}\right) E_t \left\{\Omega_{t+1} \left[\mu U_{t+1} + (1-\mu) M_{t+1}\right]\right\} \tag{19}$$

The equation (19) shows the utility when the worker is employed in the formal sector and is non-shirking, where $M_{t+1} = \text{Max}\{W_{t+1}^{ns}, W_{t+1}^{s}\}$. In this case, at the beginning of period t, the worker has a real wage given by w_t^f but suffers a disutility to be non-shirking in terms of the real wage given by ζ and an additional disutility to work χ. The worker is fired from the formal sector and becomes unemployed with probability μ. In contrast, if the worker is shirking, he does not face the disutility ζ, so utility at the beginning of the period t is equal to $w_t^f - \chi$. Nevertheless, the probability of being fired

and becoming unemployed increases and is equal to $\mu + d$. The value function of being employed in the formal sector as a shirking worker is given by:

$$W_t^s = w_t^f - \chi + \left(\frac{1}{1+\rho}\right) E_t \left\{\Omega_{t+1} \left[(\mu + d)U_{t+1} + (1 - \mu - d)M_{t+1}\right]\right\} \tag{20}$$

At the beginning of period t, the worker has a utility of $w_t^i - \chi$ and has an exogenous probability of being fired from the informal work given by σ. The value function of a worker who is employed in the informal sector is defined by the following equation:

$$W_t^i = w_t^i - \chi + \left(\frac{1}{1+\rho}\right) E_t \left\{\Omega_{t+1} \left[\sigma U_{t+1} + (1 - \sigma)W_{t+1}^i\right]\right\} \tag{21}$$

Similarly, the value function of being unemployed is defined as:

$$U_t = s_t + \left(\frac{1}{1+\rho}\right) E_t \left\{\Omega_{t+1} \left[\alpha(\theta_{t+1})M_{t+1} + \xi W_{t+1}^i + (1 - \alpha(\theta_{t+1}) - \xi)U_{t+1}\right]\right\} \tag{22}$$

In this case, the worker receives a government transfer of s_t, with endogenous probability $\alpha(\theta_{t+1})$ he becomes employed in the formal sector. In contrast, the probability of being employed in the informal sector is exogenous and equal to ξ.

2.4 Government

In each period, the government has a balanced budget rule which is represented as follows:

$$g_t + e_t + s_t u_t = \tau_t^w w_t^f l_t^f + y_t^i l_t^i A(e_t) + \tau_t^\pi Div_t. \tag{23}$$

The government expenditures are given by the expenditure in the public good g_t, the enforcement expenditure e_t, and the unemployment transfers $s_t u_t$. The government revenues are defined by payroll taxes from the formal sector $\tau_t^w w_t^f l_t^f$, profit taxes from formal firms $\tau_t^\pi Div_t$, and the output from the informal sector if a firm is audited $y_t^i l_t^i A(e_t)$.

The set of tax policies is represented by all possible combinations of τ_t^w, e_t, and g_t. In the baseline case, we assume that τ_t^w and e_t are exogenous, and the public goods expenditure (g_t) is endogenous. In this case, a particular policy can be described by a pair τ_t^w,e_t. This implies that any change in one of these taxes, provided the other remains the same, leads to a change in the public good expenditure (g_t). That is, $\Delta\tau_t^w \rightarrow \Delta g_t$, $\bar{e}_t$; and, $\Delta e_t \rightarrow \Delta g_t$, $\bar{\tau}_t^w$. Nevertheless, further simulations assume that enforcement expenditure e_t is endogenous. Hence, any change in one of the tax policies, keeping the public good expenditure constant, generates a change in the endogenous tax policy, i.e., $\Delta\tau_t^w \rightarrow \Delta e$, $\bar{g}$.

2.5 Steady State

We perform comparative statics analysis in the steady-state to understand the role of the real wage rigidities given the tax policies that encourage formality in the long run. For this purpose, we present the main equations that are used to compare different scenarios in the long run.

Firms

Equations (12) - (18) characterize the steady-state equilibrium of a formal firm. In particular, according to equation (24), the discounted value of a vacancy in the steady-state equilibrium is equal to the expected value that a worker produces. The vacancy is filled with a non-shirking worker with probability $q(\theta)$. The cost of creating a vacancy is affected by a profit tax. As shown below, there are no shirking workers in equilibrium because the firm defines a formal wage level at which the worker is indifferent between being a shirking or non-shirking worker:

$$\rho V = -(1-\tau^{\pi})\eta(1+\rho) + q(\theta)\left(J^{ns} - V\right) \tag{24}$$

In the same way, the formal firm value function of filling a vacancy with non-shirking and shirking workers is defined by the following equations:

$$\rho J^{ns} = (1-\tau^{\pi})(y^{f} - w^{f}(1+\tau^{w}))(1+\rho) + \mu\left(V - J^{ns}\right) \tag{25}$$

$$\rho J^{s} = -(1-\tau^{\pi})(1+\tau^{w})w^{f}(1+\rho) + (\mu+d)\left(V - J^{s}\right) \tag{26}$$

From the perspective of the informal firm, the expected informal net output in the steady-state is given by:

$$w^{i} = y^{i}(1 - A(e)) \tag{27}$$

Workers

The value functions of the workers are summarized in the equations (19) – (22). In particular, formal workers have value functions corresponding to a non-shirking and shirking state. In turn, when the worker is unemployed, we assume that in a steady-state equilibrium, the unemployed become a formal non-shirking worker with probability $\alpha(\theta)$ and informal with probability ξ. Therefore, the value functions for the four possible states are given by:

$$\rho W^{ns} = (w^{f} - \chi - \zeta)(1+\rho) + \mu(U - W^{ns}) \tag{28}$$

$$\rho W^s = (w^f - \chi)(1+\rho) + (\mu + d)(U - W^s) \tag{29}$$

$$\rho W^i = (w^i - \chi)(1+\rho) + \sigma(U - W^i) \tag{30}$$

$$\rho U = s(1+\rho) + \alpha(\theta)(W^{ns} - U) + \xi(W^i - U) \tag{31}$$

Real Wage Rigidities

The shirking mechanism determines the wage in the formal sector. Non-shirking workers face a disutility ζ when employed. If this disutility increase, the workers will have the incentive to shirk. However, formal firms do not want to hire shirking workers. Consequently, the formal firm has the incentive to set a formal wage w^f above the Walrasian equilibrium wage, which makes the real wage rigid.

Following the standard literature of the shirking models, we assume the free entry condition that implies that the value of creating a vacancy is equal to zero. From equation (24) we obtain:

$$J^{ns} = \frac{(1-\tau^{\pi})\eta(1+\rho)}{q(\theta)} \tag{32}$$

And replacing the equation (32) in equation (25) is possible to obtain the job creation curve:

$$w^f = \left(y^f - (\mu+\rho)\left(\frac{\eta}{q(\theta)}\right)\right)\frac{1}{1+\tau^w} \tag{33}$$

Given the formal firm's limited ability to monitor workers, the firm seeks to generate incentives to induce workers' effort. In this sense, the non-shirking condition ensures that the formal wage paid by the firm is high enough to encourage workers to be non-shirking, and consequently, the firm ensures an output different from zero. Hence, using the non-shirking condition $W^{ns} = W^s$, it is found that $W^{ns} - U = \frac{\zeta}{d} > 0$, which implies that formal firms set wages high enough that workers strictly prefer formal employment to unemployment. With the above condition and using the equations (28) – (31), the wage curve can be obtained.

$$w^f = \left(\rho + \mu + \frac{(\rho+\sigma)\alpha(\theta)}{\rho+\sigma+\xi}\right)\frac{\zeta}{d} + \Gamma \tag{34}$$

$$\Gamma = \chi + \zeta + s + \frac{\xi}{\rho + \sigma + \xi}\left(y^i(1 - A(e)) - \chi - s\right)$$

Equation (34) shows that the informal wage affects the formal wage and depends on the probability that an unemployed become employed in the informal sector, ξ. Also, the rigidities in the formal wage are given by the disutility of being a non-shirking worker ζ. This equation is a generalized version of the Shapiro - Stiglitz wage with informality. That is, assuming that there is no informal sector and that the probability of being an informal worker is equal to zero $\xi = 0$ the formal wage is:

$$w^f = (\rho + \mu + \alpha(\theta))\frac{\zeta}{d} + \chi + \zeta + s \tag{35}$$

Beveridge Curve

The classic search and matching model allows obtaining the Beveridge curve that shows the relationship between vacancy and unemployment rates. Considering equations (10) and (17) (laws motion of labor force in the formal and informal sector), and the equation of the total labor force in the steady-state, we have:

$$\begin{aligned} 1 &= l^f + l^i + u && (36)\\ \mu l^f &= \alpha(\theta)u && (37)\\ \sigma l^i &= \xi u && (38) \end{aligned}$$

Thus, the classic Beveridge curve is as follows:

$$u = \frac{\mu}{\alpha(\theta) + \frac{\xi+\sigma}{\sigma}\mu} \tag{39}$$

Equation (39) is a generalized version of the Beveridge curve. Indeed, when there is no informal sector, then $\xi = 0$, and we return the Beveridge curve of the simple search and matching model given by $u = \frac{\mu}{\alpha(\theta)+\mu}$.

Additionally, using the equations (36) – (38), a new version of the Beveridge curve can be obtained that relates the formal vacancy with the non-formal sector (unemployment and informality). That is:

$$u + l^i = \frac{\mu}{\mu + \left(1 - \left(\frac{\xi}{\sigma+\xi}\right)\right)\alpha(\vartheta)} \tag{40}$$

Where $\alpha(\vartheta) = k\left(\frac{v}{u+l^i}\left(\frac{\sigma+\xi}{\sigma}\right)\right)^{1-\phi}$ with $\vartheta = \frac{v}{u+l^i}$. This replicates the stylized fact presented in Figure 1 that shows a non-linear relationship between formal vacancy and non-formal sector. To solve the equilibrium from the Beveridge curve side, I use the equation (40) and the job creation line to obtain the following:

$$v = \theta \frac{\sigma}{\sigma + \xi}(u + l^i) \tag{41}$$

Equilibrium Condition

The labor market equilibrium of the economy is characterized by the equations (33), (34), (40), and (41), which determine the real formal wage of equilibrium w^{f*} and the labor market tightness of equilibrium θ^*. Moreover, in equilibrium, bond tenure is equal to zero $b = 0$. Replacing the informal firm's optimal condition from equation (27) and the steady-state government balance on the steady-state budget balance of the household is possible to find the equilibrium balance defined as follows:

$$GDP = y^f l^f + y^i l^i - \eta v = c + g + e. \tag{42}$$

Figure (2) represents the equilibrium in the economy in which the intersection of curves (33) and (34) returns the formal wage of equilibrium w^{f*} and the labor market tightness of equilibrium θ^*. Also, with the equations (40), (41), and the labor market tightness of equilibrium, it is possible to obtain the formal vacancy rate of equilibrium v^* and the unemployment plus the informal rate of equilibrium $(u + l^i)^*$. The left panel of Figure 2 shows the behavior of the wage curve (positively sloped curve) and the job creation condition curve (negatively sloped curve). The wage and job creation curves replace the Walrasian economy supply and demand curves. The wage curve shows the wage that the formal firm must pay so that workers are non-shirking and have incentives to work in the formal sector.

This implies that, given increases in the labor market tightness and consequently in the probability of finding a formal job, it is easier for the unemployed to find formal employment. Therefore, the cost of being fired as a shirking worker decreases, increasing the formal wage such that shirking is discouraged.

While the job creation curve corresponds to the marginal condition of labor demand, a higher formal wage makes job creation less profitable, which generates a lower demand for workers by formal firms. Therefore, the intersection of the two curves' generates a unique formal wage and labor market tightness of equilibrium (w^{f*}, θ^*)

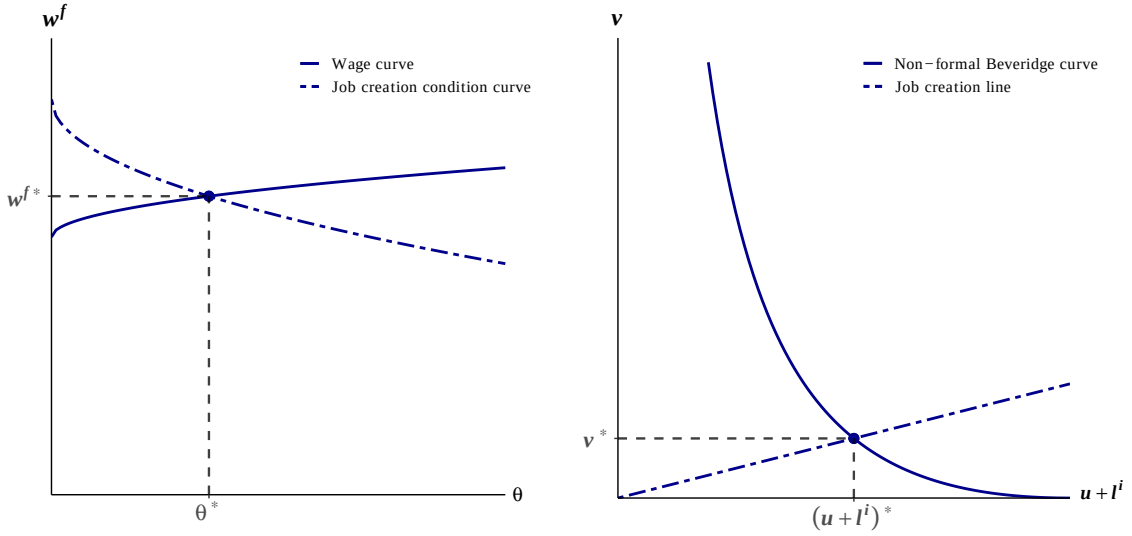

Figure 2: Equilibrium in the economy

The right panel of Figure (2) shows a new version of the Beveridge curve comparing vacancies in the formal sector with the workers in the non-formal sector (unemployment and informality). The convex curve with a negative slope corresponds to the non-formal Beveridge curve. When there are more formal vacancies, unemployment and informality are lower because the probability of finding employment in the formal sector increases. On the other hand, the curve with a positive slope is the job creation line, which shows the ratio between vacancies and the non-formal sector. The intersection of the two curves allows us to find the formal vacancies and the size of the non-formal sector in equilibrium, represented by the sum of unemployment plus informality $(v^*, u^* + (l^i)^*)$.

3 Calibration

The calibration of the model seeks to adjust to the main characteristics of the Colombian labor market. Parameters are set on a monthly basis. A set of parameters are based on typical values from search and matching models (see Table 1). Following Granda Carvajal & Hamann (2020), we assign the value of the discount rate ρ equal to $\left(\frac{1}{0.972^{1/12}} - 1\right)$. For the parameters describing matching and frictions, we use the standard values in the literature, $\phi = 0.5$, $\eta = 0.5$, and $k = 0.25$ used in Albrecht et al. (2009). The parameters of labor market dynamics are set as follows: for simplicity, it is assumed the unemployment transfer $s = 0$; the formal and informal separation rates are $\mu = 0.0244$ and $\sigma = 0.0235$, given estimations by García-Suaza et al. (2021). Lastly, regarding the

disutility of working, we use the Martin & Wang (2020) value $\chi = 0.62$.

Table 1: Parameter values

Parameter	Description	Source	Value
ρ	Discount rate	Granda Carvajal & Hamann (2020)	0.009
k	Matching process efficiency	Albrecht et al. (2009)	0.25
ϕ	Matching elasticity	Albrecht et al. (2009)	0.5
s	Unemployment transfer	Albrecht et al. (2009)	0
η	Vacancy cost	Albrecht et al. (2009)	0.5
μ	Formal separation rate	García-Suaza et al. (2021)	0.0244
σ	Informal separation rate	García-Suaza et al. (2021)	0.0235
τ^w	Payroll tax	Rincón-Castro (2021)	0.33
τ^π	Income tax	Rincón-Castro (2021)	0.13
e	Enforcement expenditure	Posada & Mejía (2012)	0.007
$A(e)$	Auditing probability	Posada & Mejía (2012)	0.27
χ	Disutility of working	Martin & Wang (2020)	0.62
d	Detection rate	Calibrated	0.96
ζ	Disutility of effort	Calibrated	0.29
ξ	Prob of working informally	Calibrated	0.08
γ	Institutional efficiency	Calibrated	42.44
θ	Labor market tightness	Calibrated	0.17
y^i	Informal production	Calibrated	1
y^f	Formal production	Calibrated	1.37

As for the tax fiscal policy parameters benchmark, we set the value of τ^w and τ^π as 0.33 and 0.13, respectively, following Rincón-Castro (2021). The enforcement expenditure and the probability of being audited are taken from Posada & Mejía (2012), who develop a model with informal sector and enforcement policies, hence $e = 0.007$ and $A(e) = 0.27$

The second set of parameters is calibrated to match the average unemployment and formal and informal labor rates observed in the data from 2008 to 2019, normalizing the informal production $y^i = 1$. Using the equilibrium equations described in the previous section, we select the value of ζ and d to match the unemployment rate $u = 0.112$, the formal rate $l^f = 0.478$, and the informal rate $l^i = 0.410$[2]; the ratio between formal and informal wage observed in the data $\frac{w^f}{w^i} = 1.39$[3].

Finally, the probability of working in the informal sector ξ and labor market tightness θ is derived from the labor market equations (36) – (38). The institutional efficiency γ is

[2]The average rates are calculated based on information from the GEIH (the Colombian Household Survey) published by the DANE for the 23 main metropolitan areas.

[3]The ratio between formal and informal wages was estimated using Mincer equations with GEIH data from 2008 to 2019. Section A presents the estimation results.

obtained using the compliance probability equation (15), and the formal production is derived using the equation (42). The result of the calibrated parameters is presented in Table 1.

4 Counterfactual analysis of policies

This section explores the long-run effect of tax policies, defined as the change in payroll taxes and law enforcement expenditures. In the first part of the analysis, we perform comparative statics to compute the formal wage, vacancy rate, and non-formal sector results, given changes in the tax policies and a reduction in the real wage rigidities.

In the second part, we simulated the model under the tax policies effect in two scenarios: one assuming an endogenous public expenditure and the other considering endogenous law enforcement expenditure. These exercises have two objectives. First, to portray the effect of tax changes on the size of the non-formal sector, the level of public spending, and macroeconomic variables, given the enforcement expenditures. Second, to show the combinations of taxes and enforcement expenditures compatible with a desired level of public expenditures and calculate the levels of the informality rate and macroeconomic variables for each combination.

4.1 Analytical Results

We start assuming a decrease in the payroll taxes τ^w (see Figure 3). Results suggest that a decrease in payroll taxes generates an outward shift of the job creation curve as a consequence of reducing hiring costs, which increases worker demand, given the additional profit of hiring a worker.

The decrease in payroll taxes leads to an increase in the formal wages at which a firm would be willing to hire a formal worker at all productivity levels. This increase in the formal equilibrium wages from w_1^{f*} to w_2^{f*}. Likewise, the job creation curve shift generates an increase in labor market tightness from θ_1^* to θ_2^*. Consequently, there is an increase in the slope of the job creation line. Given the Beveridge curve, the vacancy rate increase to v_2^*, and the equilibrium unemployment plus informality rate decrease to $u_2^* + (I_2^i)^*$.

On the other hand, Figure 4 shows an increase in the law enforcement expenditure e. This policy shifts the wage curve downward due to an increase in the auditing probability, generating a decrease in expected informal net output. The wage curve represents the formal wage that induces workers' effort and compensates for other scenarios, such as working in the informal sector or being unemployed. Therefore, the formal sector's

compensation to induce formal work decreases, given the expected informal net output reduction. In this case, workers are willing to enter the formal sector with a lower wage.

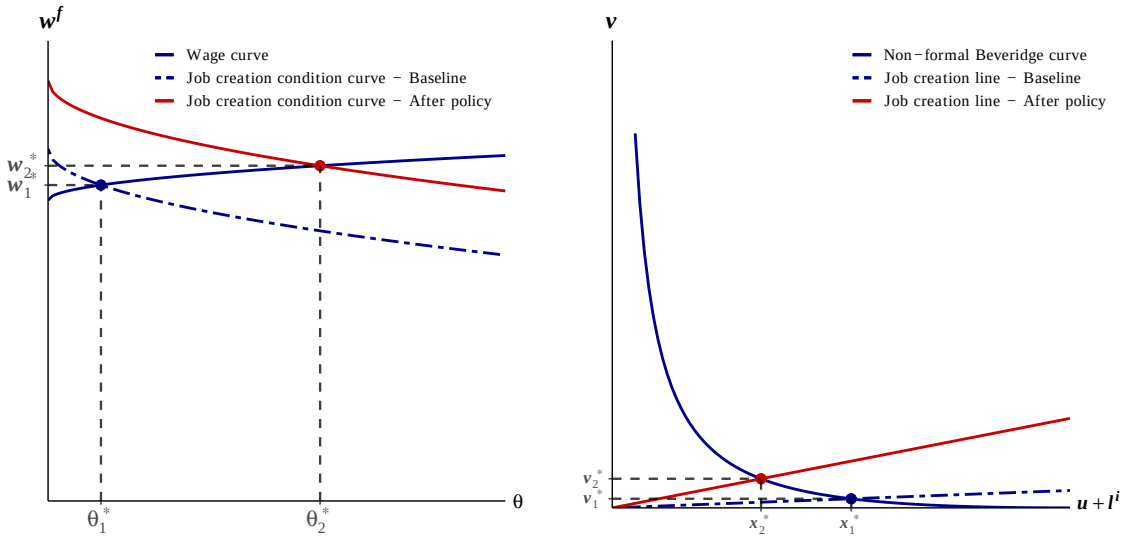

Figure 3: The effects of a decrease in payroll taxes τ^w.
Note: x_j^* refers to $u_j^* + (l_j^i)^*$

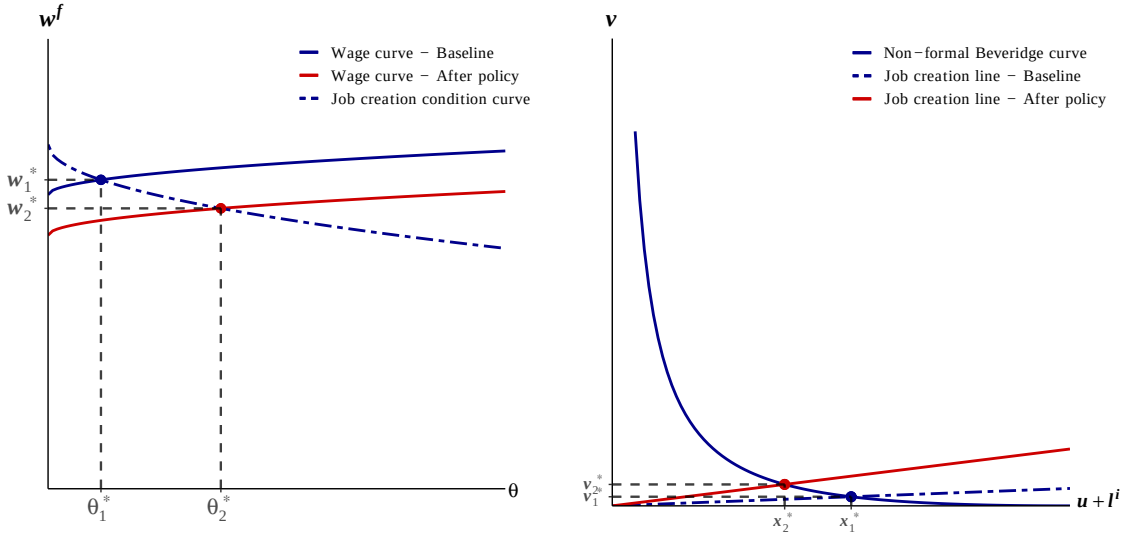

Figure 4: The effects of an increase in law enforcement expenditure e.
Note: x_j^* refers to $u^* + (l_j^i)^*$

The shift of the curve leads to a decrease in the formal equilibrium wage to w_2^{f*} and an

increase in the labor market tightness to θ_2^*. Accordingly, the increase in θ increase in the slope of the job creation line and a decrease in the unemployment and informal rate from $u_1 + (l_1^i)^*$ to $u_2 + (l_2^i)^*$, and an increase in the vacancy rate from v_1^* to v_2^*.

Figure 5 shows that the reduction in real wage rigidities by decreasing the disutility of effort ζ shifts the wage curve downward. The reduction in the disutility of effort causes a decrease in the formal wage needed to induce effort. Therefore, formal wages are close to Walrasian equilibrium wages. Reducing wage rigidities decreases the formal equilibrium wage w^f and raises the labor market tightness θ. As a result, there is a reduction in unemployment and informality $u + l^i$ and increased vacancies v, as shown in the non-formal Beveridge curve. Hence, reducing the rigidity of real wages generates a significant decrease in informality and unemployment and a decrease in formal equilibrium wages. This result shows that the flexibility of the labor market plays a significant role in the determination of informality and unemployment rates.

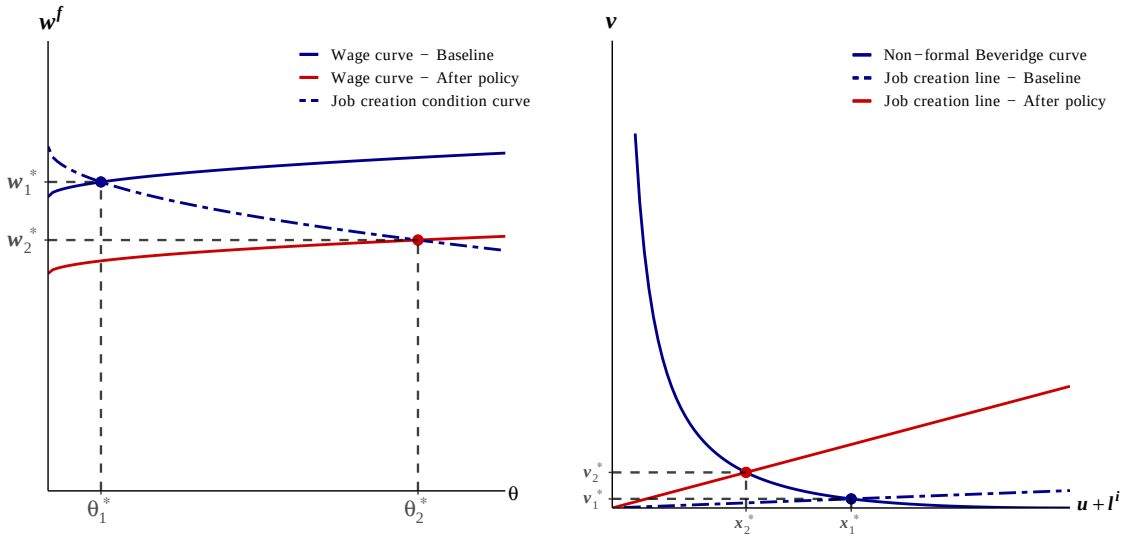

Figure 5: The effects of a decrease in real wage rigidities ζ.
Note: x_j^* refers to $u_j + (l_j^i)^*$

The analytical results suggest that decreasing payroll taxes and increasing law enforcement expenditures reduce informality and unemployment in the long-run. The former policy encourages the formal workers' demand and increases the formal wage in equilibrium. The latter policy reduces the informal worker offer by increasing the formal worker offer leading to a reduction of the formal wage in equilibrium. This suggests that an effective policy to reduce informality is the combination of labor policies and state capacity. Therefore, combining tax policies that increase formal worker demand and reduce the informal worker offer is an effective way to reduce informality and unemployment.

Figure 6 shows the combined effect of tax policy and enforcement. In this scenario, labor market tightness increases from θ_1^* to θ_2^*. Hence, the increase is beyond that observed when only tax policy is implemented (from θ_1^* to θ^{τ^w}). The effect is also higher than the increase in law enforcement expenditure, which increases the labor market tightness (from θ_1^* to θ^e). However, the combined impact of tax policies and enforcement over real formal wages is uncertain. The combination of policies has a more significant impact on reducing unemployment and informality. The unemployment and informality decrease from $u_1^* + (l_1^i)^*$ to $u_2^* + (l_2^i)^*$.

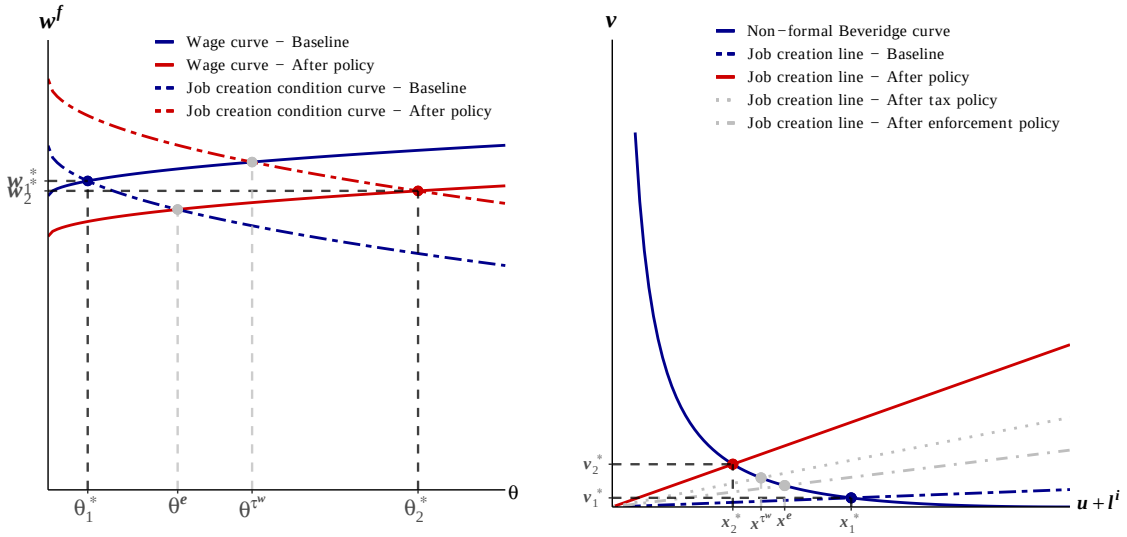

Figure 6: The effects of a decrease in payroll taxes τ^w and increase in law enforcement expenditure e.
Note: x_j^* refers to $u_j^* + (l_j^i)^*$. Baseline scenario (blue), individual policies (gray), the combination of policies (red)

4.2 Simulations

This section presents the results of simulating changes in payroll taxes and law enforcement spending. In addition, we compared two scenarios sensitive to rigidities in real wages. The simulation of the model presents the primary outcome variables in the long-run. Figures 7 and 8 estimate the model with endogenous public good expenditure. Hence, the government expenditure adjusts for payroll tax and law enforcement expenditure changes. In contrast, Figure 9 shows the simulation results when the public good in the economy is constant and the enforcement expenditure is endogenous. Both simulations present the case when the economy faces high real wage rigidities ($\zeta = 0.29$) and low real wage rigidities ($\zeta = 0.14$).

Figure 7 shows the result of the simulations for multiple payroll tax policies. The increase in the payroll taxes leads to an expansion in public goods expenditure, with a decrease in formal employment and an increase in unemployment and informality. Results suggest that when the economy has low real wage rigidities, raising payroll taxes increases informal employment and decreases formal employment more slowly relative to the scenario with higher real wage rigidities. Unemployment and informality follow a similar behavior: they increase slower with low rigidities than with high rigidities.

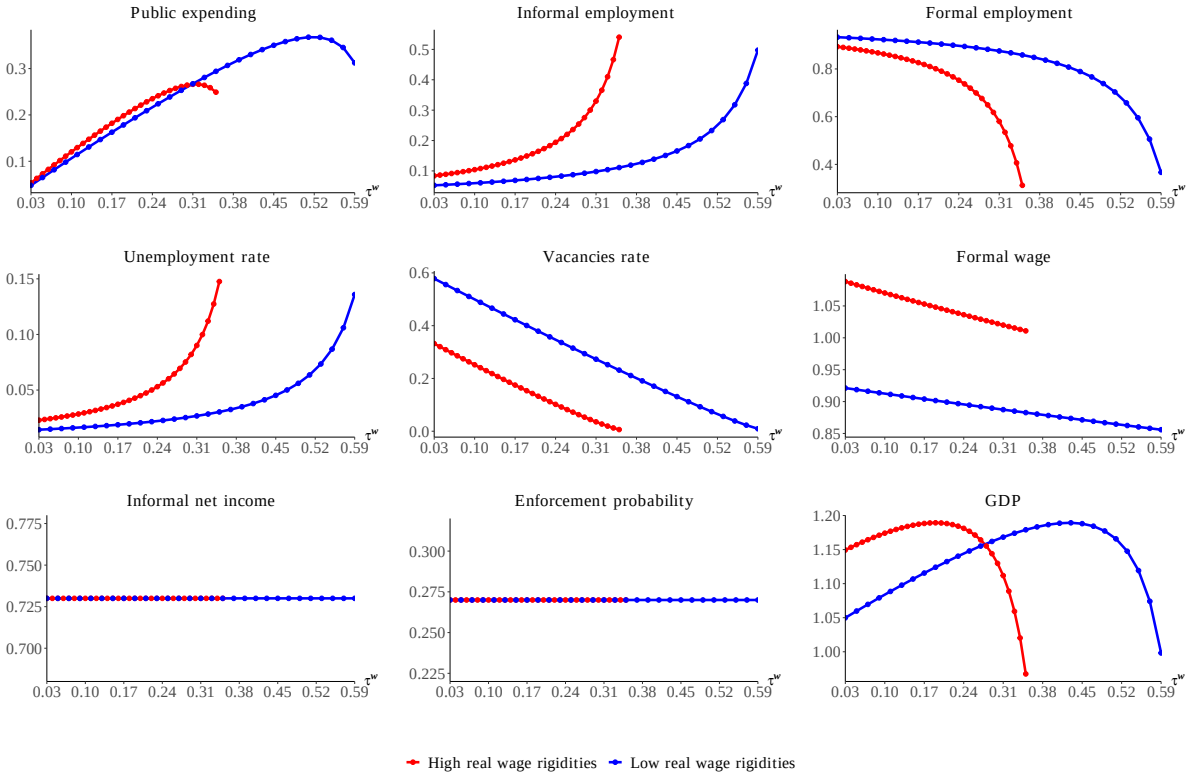

Figure 7: Multiple payroll tax policies with endogenous public expending.
Note: Each point is a steady-state value of the variable given the value of τ^w. High wage rigidities: $\zeta = 0.29$; Low wage rigidities: $\zeta = 0.14$

The figure also shows a Laffer curve of the public goods expenditure: a payroll tax rate exists that maximizes the public goods expenditure. The tax that maximizes the public goods expenditure is a decreasing function of the degree of rigidity of the labor market. Consequently, if the payroll tax rate is very high, it is possible to decrease the payroll taxes while increasing public goods expenses and formal employment, reducing informality and unemployment rates. On the other hand, when the real wage rigidities and taxes are low, it is possible to increase the public good with the increase in payroll taxes, with a low increase in the unemployment and informal rate.

Concerning the law enforcement expenditure policy, Figure 8 shows the results of the simulation. An increase in law enforcement expenditure generates increases in public goods expenditure, with a decrease in unemployment and informal rate and increased formal employment. The results suggest that with high real wage rigidities, there must be a more significant increase in law enforcement expenditure to reduce informal employment and unemployment significantly. In contrast, when the economy has more flexible real wages, a minor increase in law enforcement expenditure is required to reduce informal employment and unemployment.

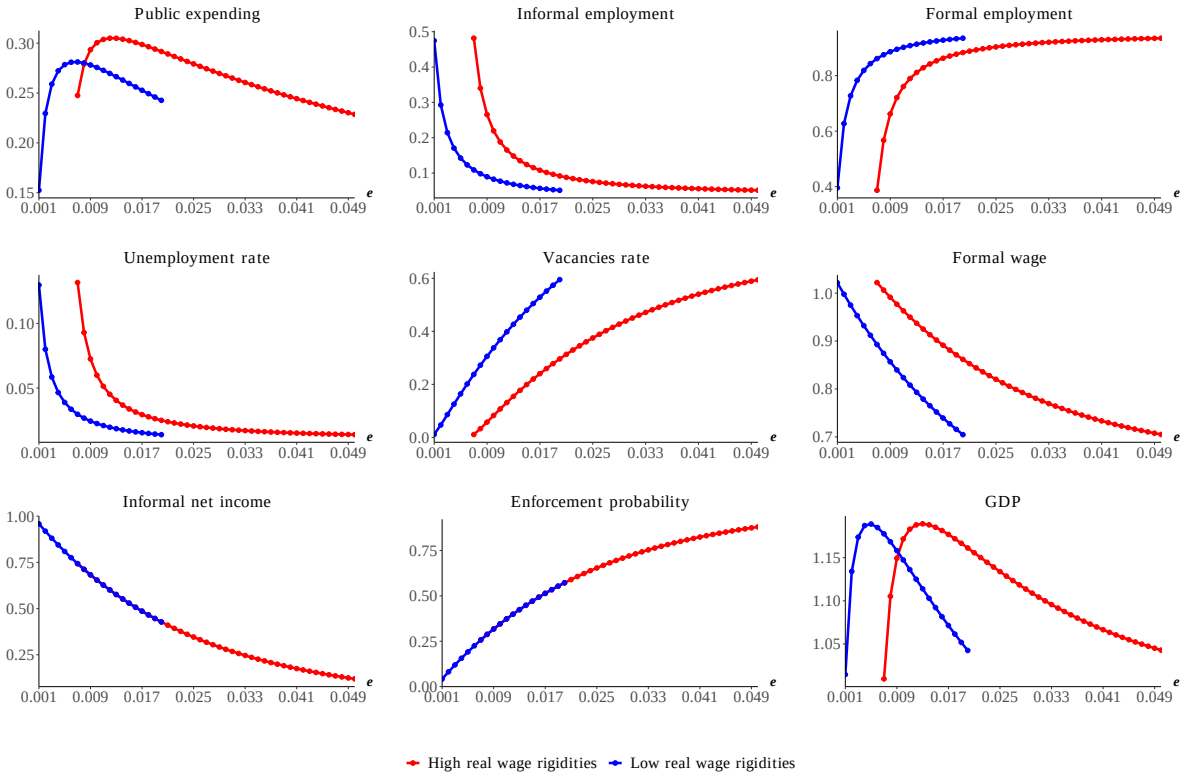

Figure 8: Multiple enforcement expenditure policies with endogenous public expending.
Note: Each point is a steady-state value of the variable given the value of e. High wage rigidities: $\zeta = 0.29$; Low wage rigidities: $\zeta = 0.14$

The results present a public good expenditure Laffer's behavior in both scenarios, with high and low real wage rigidities. In both scenarios, it is possible to find a level of law enforcement expenditure that leads to a peak in public good expenditure with a relevant decrease in unemployment and informality rates and increases in formal employment. With low real wage rigidities, the economy reaches the public good expenditure peak with less law enforcement expenditure. After a certain level of enforcement, the public good present a permanent decrease. However, when the economy faces higher real wage rigidities, increases in law enforcement expenditure tend to increase public spending

more significantly.

Finally, Figure 9 shows the simulation results when the economy has a constant public good expenditure, and the law enforcement expenditure is adjusted for changes in the payroll taxes. This scenario seeks to present a realistic situation from the government's fiscal balance perspective. That is, when a fiscal policy change occurs, the government needs to either offset the negative impacts of the policy or supply other resource needs while maintaining fiscal balance. The law enforcement expenditure has a convex behavior with a minimum point. Hence the increase in the payroll taxes decreases enforcement expenditure when payroll taxes are initially low. However, higher government revenues allow enforcement expenditure to increase when payroll taxes are relatively high.

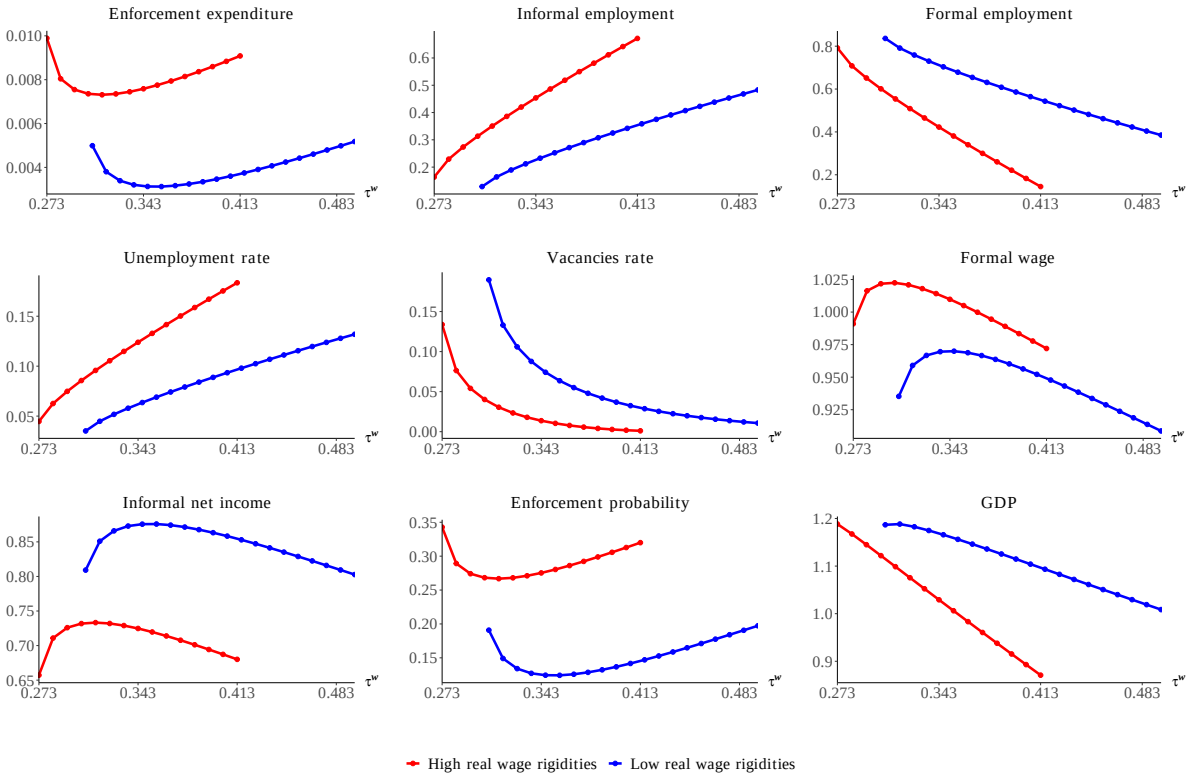

Figure 9: Multiple payroll tax policies with constant public expending.
Note: Each point is a steady-state value of the variable given the value of e. High wage rigidities: $\zeta = 0.29$; Low wage rigidities: $\zeta = 0.14$

The increase in the payroll taxes raises the unemployment and informality rates, no matter the level of law enforcement expenditure. Higher payroll taxes in the economy with high real wage rigidities hurts formal employment more than the economy with low real wage rigidities. Also, law enforcement expenditure is higher in a high real wage rigidities economy than in a low wage rigidities economy. Nevertheless, the simulation

could suggest a combination of tax policies where it is possible to reduce the payroll taxes and increase the law enforcement expenditure to reduce informality significantly.

In this sense, the simulation results agree with the analytical results, where the combination of tax policies, such as decreasing payroll taxes and increasing law enforcement expenditure, significantly reduces unemployment and informality. However, when the economy has high real wage rigidities, law enforcement expenditure will be higher before payroll taxes decrease compared to an economy with low real rigidities.

Therefore, policies making real wages more flexible favor the ability of tax policies to achieve objectives related to informality and unemployment reduction, and increases in government revenues. An economy with low real wage rigidities might increase fiscal revenues and decrease unemployment and informality, with fewer increases in law enforcement expenditure compared to an economy with higher wage rigidities.

Tables 2 through 4 present how labor market and public good expenditure react to payroll taxes reductions under different scenarios of wage rigidities. Simulations were performed assuming an initial value of $\tau^w = 0.33$ and decreasing it up to 25 percentage points (pp), and an initial value of $e = 0.007$ that increases it up to 2.5 pp. Tables 2 and 3 present the impact of tax policies when the economy has endogenous government expenses. In contrast, Table 4 shows the results of a payroll tax change with endogenous law enforcement expenditure.

Table 2 displays the change in the main variables with a decrease in the payroll taxes. When the economy has high real wage rigidities, a decrease of 5 pp leads to a decline in the informality of 0.16 pp. In contrast, the decrease in informality is 0.01 pp when the economy has lower real wage rigidities. If the payroll taxes decreases 25 pp, the reduction in the informality is around 0.31 pp and 0.05 pp for high and low real wage rigidities, respectively. On the other hand, when a decrease of 5 pp, the increase in formal employment is around 0.20 pp for an economy with high real wage rigidities and 0.01 pp for an economy with low real wage rigidities.

Table 2: Effect of decreasing payroll taxes.

Rigidities	Variables	5pp	10pp	15pp	20pp	25pp
High real wage rigidities	public good expenditure	-0.01	-0.04	-0.07	-0.12	-0.16
	Informal employment	-0.16	-0.23	-0.27	-0.29	-0.31
	Formal employment	0.20	0.29	0.34	0.37	0.40
	Unemployment rate	-0.04	-0.06	-0.07	-0.08	-0.09
Low real wage rigidities	public good expenditure	-0.03	-0.07	-0.12	-0.15	-0.18
	Informal employment	-0.01	-0.03	-0.04	-0.04	-0.05
	Formal employment	0.01	0.03	0.04	0.05	0.06
	Unemployment rate	-0.00	-0.01	-0.01	-0.01	-0.01

Note: $\tau^w = 0.33$ is the initial value with endogenous government expenditure. The decrease in τ^w is from 5 pp to 25 pp. Baseline rates. HWR: public good expenditure = 0.26, Informal employment = 0.41, Formal employment = 0.47, Unemployment rate = 0.11. LWR: public good expenditure = 0.28, Informal employment = 0.10, Formal employment = 0.86, Unemployment rate = 0.02.

Formal employment increased by 0.40 pp and 0.06 pp with a decrease in payroll taxes of 25 pp in an economy with high and low real wage rigidities. With decreases in payroll taxes, unemployment has a reduction but with a low magnitude than the reduction of informality. Given the above, the economy with high real wage rigidities has a higher reduction in informality and unemployment and relevant increases in formality with a decrease in payroll taxes than the economy with low real wage rigidities.

Table 3 shows the results related to the increase in law enforcement expenditure with endogenous government expenditure for both scenarios of real wage rigidities. First, with high real wage rigidities, the increase of 0.5 pp in the enforcement expenditure reduces informal employment by 0.32 pp and unemployment by 0.09 pp and increases formal employment by 0.40 pp. Second, the low real wage rigidities case shows that the increase in enforcement expenditure of 0.5 pp causes a reduction in informality close to 0.04 pp and unemployment close to 0.01 pp. In comparison, the increase in formal employment is 0.05 pp. Based on the above, the increase in law enforcement expenditure is a policy with relevant results in the informal employment reduction, which effect is greater when the economy is in front of high real wage rigidities than in the economy with low real wage rigidities.

Table 3: Effect of increasing law enforcement expenditure.

Rigidities	Variables	0.5pp	1pp	1.5pp	2pp	2.5pp
High real wage rigidities	public good expenditure	0.06	0.05	0.04	0.03	0.02
	Informal employment	-0.32	-0.37	-0.40	-0.41	-0.42
	Formal employment	0.40	0.48	0.51	0.52	0.53
	Unemployment rate	-0.09	-0.10	-0.11	-0.11	-0.11
Low real wage rigidities	public goods expenditure	-0.01	-0.03	-0.04		
	Informal employment	-0.04	-0.05	-0.06		
	Formal employment	0.05	0.07	0.07		
	Unemployment rate	-0.01	-0.01	-0.02		

Note: $e = 0.007$ is the initial value with endogenous government expenditure. The increase in e is from 0.5 pp to 2.5 pp. Baseline rates. HWR: public goods expenditure = 0.24, Informal employment = 0.48, Formal employment = 0.38, Unemployment rate = 0.13. LWR: public goods expenditure = 0.28, Informal employment = 0.10, Formal employment = 0.86, Unemployment rate = 0.02.

Finally, Table 4 shows the results of a reduction in payroll taxes when the economy has endogenous enforcement expenditure and constant government expenditure. In the scenario with high real wage rigidities, a decrease of 5 pp returns a reduction in informal employment of around 0.03 pp, a decrease in unemployment of 0.009 pp, and an increase in formal employment of around 0.04 pp. With low real wage rigidities, the reduced payroll tax of 5 pp declines informal employment and unemployment by 0.02 pp and 0.006 pp, respectively. At the same time, the increase in formal employment is close to 0.02 pp. Also, the effect on enforcement expenditure is relatively lower in both rigidities scenarios.

Table 4: Effect of decreasing payroll taxes with endogenous enforcement.

Rigidities	Variables	5pp	10pp	15pp	20pp	25pp
High real wage rigidities	Enforcement expenditure	-0.00004	0.000005	0.0001	0.0006	0.002
	Informal employment	-0.03	-0.07	-0.11	-0.15	-0.22
	Formal employment	0.04	0.09	0.14	0.19	0.28
	Unemployment rate	-0.009	-0.01	-0.03	-0.04	-0.06
Low real wage rigidities	Enforcement expenditure	0.0001	0.0005	0.001		
	Informal employment	-0.02	-0.04	-0.08		
	Formal employment	0.02	0.06	0.10		
	Unemployment rate	-0.006	-0.01	-0.02		

Note: $\tau^w = 0.33$ is the initial value. The decrease in τ^w is from 5 pp to 25 pp. Baseline rates. HWR: Enforcement expenditure = 0.007, Informal employment = 0.38, Formal employment = 0.50, Unemployment rate = 0.10. LWR: Enforcement expenditure = 0.003, Informal employment = 0.21, Formal employment = 0.73, Unemployment rate = 0.05.

The simulation results reveal the relevance of the tax policy changes that affect the prin-

cipal labor market variables of the economy. Also, highlight the role of the real wage rigidities in the magnitude effect of these policies. The results pretend to understand the effect of tax policies and the combination of these policies as an alternative to reduce informal employment and unemployment and increase formal employment.

When the economy has high real wage rigidities, the tax policies have a more significant impact on reducing informal employment and the increase in formal employment. Also, a fixed government expenditure with an endogenous law enforcement expenditure highlights the case in which it is the government desires to maintain government spending and selects the combination of tax policies that reduce the informality. In addition, the economy with low real wage rigidities has lower levels of informality and a wider margin of action in the tax policies that do not negatively affect formal employment and increase government income. Hence, a relevant policy to reduce informality is a flexibilization of real wage rigidities. Besides the above, the results highlight that the tax policies are effective in the case of low real wage rigidities to encourage formal employment.

5 Conclusion

This article has developed a dynamic general equilibrium model with search and matching frictions and rigidities of real wages through shirking mechanisms based on Martin & Wang (2020). It includes a government and an informal labor market. The simulation results suggest that the rigidities of the real wage in the economy are a relevant determinant of the magnitude of the tax policies that seek to reduce informality.

The model highlights the tax policies combination as a relevant instrument to reduce informal employment and increase formal employment. In this respect, the paper shows the importance of labor policies and state capacity in reducing informality and the government income increase. First, the analytical results show that a decrease in payroll taxes increases the formal employment demand, and an increase in enforcement expenditure decreases the informal employment offer.

Hence, both policies significantly impact the reduction of informality and unemployment and the increase in formal employment. Based on the above, the tax policies combination has a most significant impact on the reduction of informality and unemployment because it affects the demand and supply side of the economy. Also, a policy associated with flexibilization in the real wage rigidities decreases informal employment and unemployment.

The above is coherent with the simulation results. The decrease in payroll taxes and increase in law enforcement impact the informal employment reduction for high and low real wage rigidities. The model shows that for both wage rigidities scenarios, there is a

Laffer curve that explains the possibility of reducing the informality rate and increasing the government income simultaneously by reducing payroll taxes.

Also, there is a case in which the increase in law enforcement expenditure leads to a peak in public spending with low levels of informal employment. However, the simulations exhibit the relevance of wage flexibility as a policy that could impact the reduction of informality and increase fiscal revenues.

Additionally, with an endogenous law enforcement expenditure and a constant government expenditure, there is a case in which it is possible to reduce informal employment and unemployment with a decrease in payroll taxes and an increase in enforcement expenditure. The above is coherent with the counterfactual analysis in which the tax policies combination has a greater impact on informality reduction.

In addition to the above, the impact of the policy on the informal employment reduction depends on the initial value of the tax policies. Although, the results suggest that tax policies could have a greater impact on the reduction of informality when the economy has high real wage rigidities relative to the economy with low real wage rigidities. Also, the tax policy effect has a bigger impact on informality reduction than unemployment reduction. Notwithstanding the previous, the tax policies have a greater effect on reducing informal employment in an economy with high and low real wage rigidities.

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6 Appendix

A Mincer Regressions

We estimate the wage gap between the formal and informal sectors using a Mincerian regression model; Table A1 presents the results. In this way, we used the information available in the Colombian Household Surveys (GEIH for its acronym in Spanish) from 2008 to 2019 for the 23 main metropolitan areas. The dependent variable is the logarithm of the monthly hourly income (w_h) reported by workers in the economy.

Among the explanatory variables used in the estimation, the informality dummy variable takes the value of 1 if the person is informal and 0 if he/she is formal; the variable was constructed based on the DANE (2009) informality definition, which classifies a worker as informal if he/she meets at least one of the following criteria: employees of a private company with five or fewer workers, domestic employees, self-employed workers who work in establishments with up to five people, family workers, unpaid workers, day laborers, or employer in a company with five or fewer workers.

The model considers variables such as age, years of schooling, and sex defined as a dichotomous variable that takes the value of 1 if a worker is a man and 0 if the worker is a woman. In addition to the above, the estimations were made, including fixed effects by metropolitan areas and by year. On the other hand, we exclude the three percent observations from the tail distributions to clean the data.

Table A1: Mincerian regression models.

Variables	$\log(w_h)$	$\log(w_h)$	$\log(w_h)$	$\log(w_h)$
Informal DANE	-0.625***	-0.354***	-0.342***	-0.339***
	(0.000765)	(0.000760)	(0.000769)	(0.000748)
Age		0.0331***	0.0336***	0.0350***
		(0.000158)	(0.000157)	(0.000154)
Age^2		-0.000310***	-0.000314***	-0.000339***
		(1.93e-06)	(1.93e-06)	(1.90e-06)
Schooling		-0.0145***	-0.0157***	-0.0228***
		(0.000350)	(0.000353)	(0.000348)
$Schooling^2$		0.00442***	0.00451***	0.00476***
		(1.78e-05)	(1.80e-05)	(1.78e-05)
Man		0.175***	0.178***	0.180***
		(0.000699)	(0.000695)	(0.000678)
Constant	8.386***	6.996***	7.048***	6.870***
	(0.000543)	(0.00356)	(0.00374)	(0.00397)
23 main metropolitan areas FE	No	No	Yes	Yes
Time FE per year	No	No	No	Yes
N. of obs	2,766,183	2,654,843	2,654,843	2,654,843
R^2	0.191	0.376	0.386	0.416

Note: The wage gap is the exponential of the Informal DANE coefficient with both fixed effects. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

B Sensitivity Analysis

Given the relevance of parameter d on the effect of real wage rigidities, Figures A1 – A3 show the results of the simulations presented earlier in the paper, assuming values of the detection rate between 0.2 and 0.95.

Figure A1 shows the simulation results for multiple payroll tax policies, given different detection rate values. The main results are the same as presented previously in the paper; the increase in payroll tax can lead to an increase in the public good expenditure until a given level of τ^w, with a formal employment decrease and an increase in informality and unemployment.

However, the principal difference in the results is the magnitude of the effects. With low values in the detection rate, the increase in informal employment, given increases in payroll taxes, is higher than the scenario with high values of detection rate for both real wage rigidities cases. The above pattern is equal for formal and unemployment. Also, the increase in the public good expenditure whit low values of detection rates tends to be lower than the scenario with high values of detection rate for high and low real wage rigidities.

For the above, under increases in probability detection rate, the results in the reduction of informality and unemployment due to decreases in payroll taxes tend to be a higher

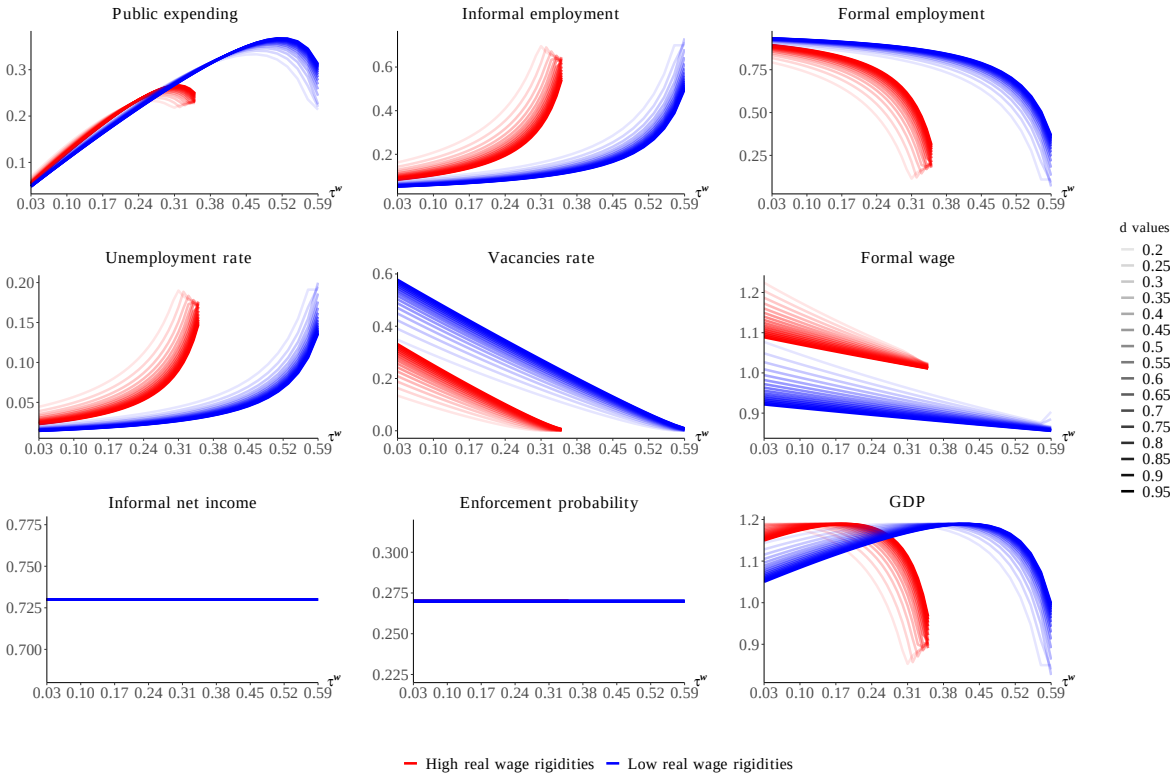

Figure A1: Multiple payroll tax policies with constant enforcement expenditure.
Note: Each point is a steady-state value of the variable given the value of τ^w.

magnitude for both real wage rigidities scenarios. Also, the public good Laffer curve suggests that the decrease in payroll taxes could increase the public good expenditure with a high detection rate compared to the case of a low detection rate.

Similarly, Figure A2 shows the simulation results given the increases in the enforcement expenditure for the principal economic variables. With increases in law enforcement expenditure, the simulations suggest that an economy with high detection rate values tends to lower informality and unemployment levels more than an economy with low detection rate values for high and low real wage rigidities.

The results differ from the simulation in Figure A1 regarding the public good expenditure. There are scenarios in which increases in enforcement expenditure with low values of detection rate could lead to high levels of public good expenditure for low and high real wage rigidities. The above is the consequence of the existence of high levels of informality with low levels of detection rates. The probability of auditing increases, given the increase in law enforcement expenditure. Consequently, there is an increase in the informal sector fines that increase the public good expenditure.

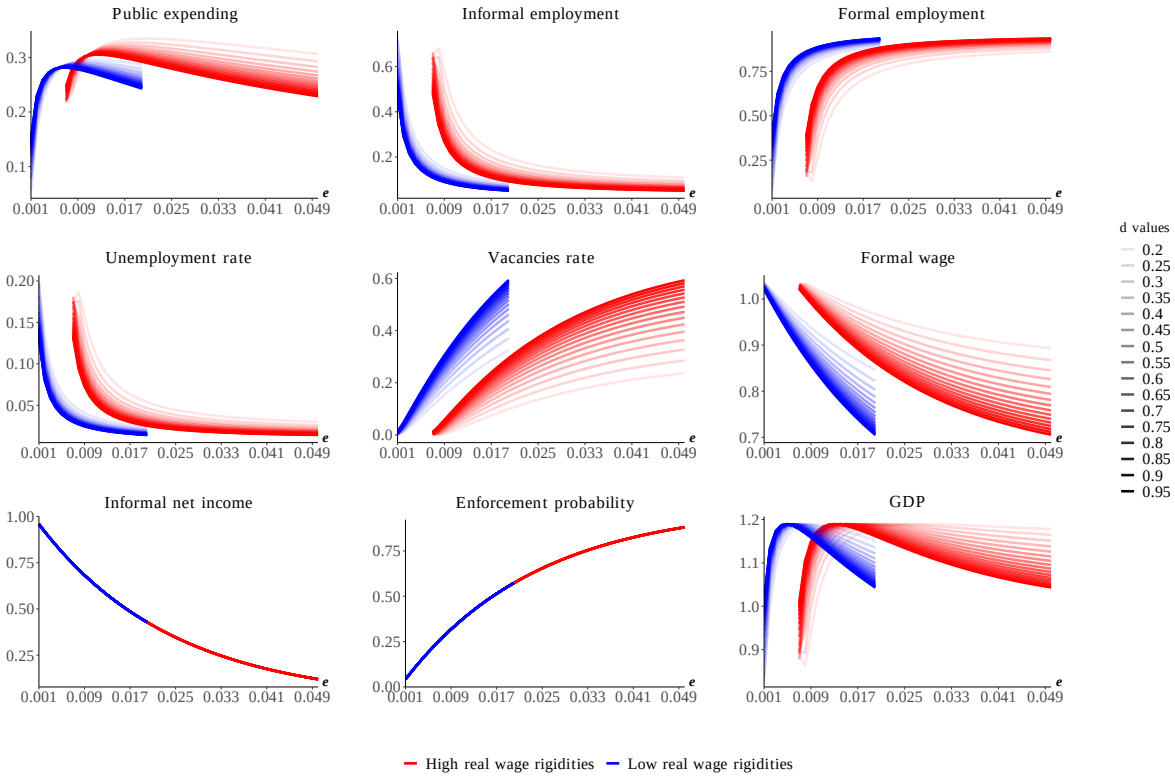

Figure A2: Multiple enforcement expenditure policies with constant enforcement expenditure
Note: Each point is a steady-state value of the variable given the value of e.

Finally, Figure A3 shows the simulation results given the change in payroll taxes with endogenous enforcement expenditure and different values of the detection rate probability. Similarly, the simulations are consistent with the main results in the paper. There is a scenario in which a decrease in payroll tax could increase enforcement expenditure, reduce informality and unemployment levels significantly, and increase formal employment.

Nevertheless, the payroll tax magnitude effect change given the detection rate values. With high detection rate values, the level of informality and unemployment reduction is higher with the decrease in payroll taxes than in the scenario with low values of detection rate. The above is satisfied for both cases of real wage rigidities. In addition, with low detection rate values, enforcement expenditure levels tend to be higher when the d value is lower. The above suggests that the enforcement expenditure effort is inversely related to the detection rate probability for high and low-wage rigidities.

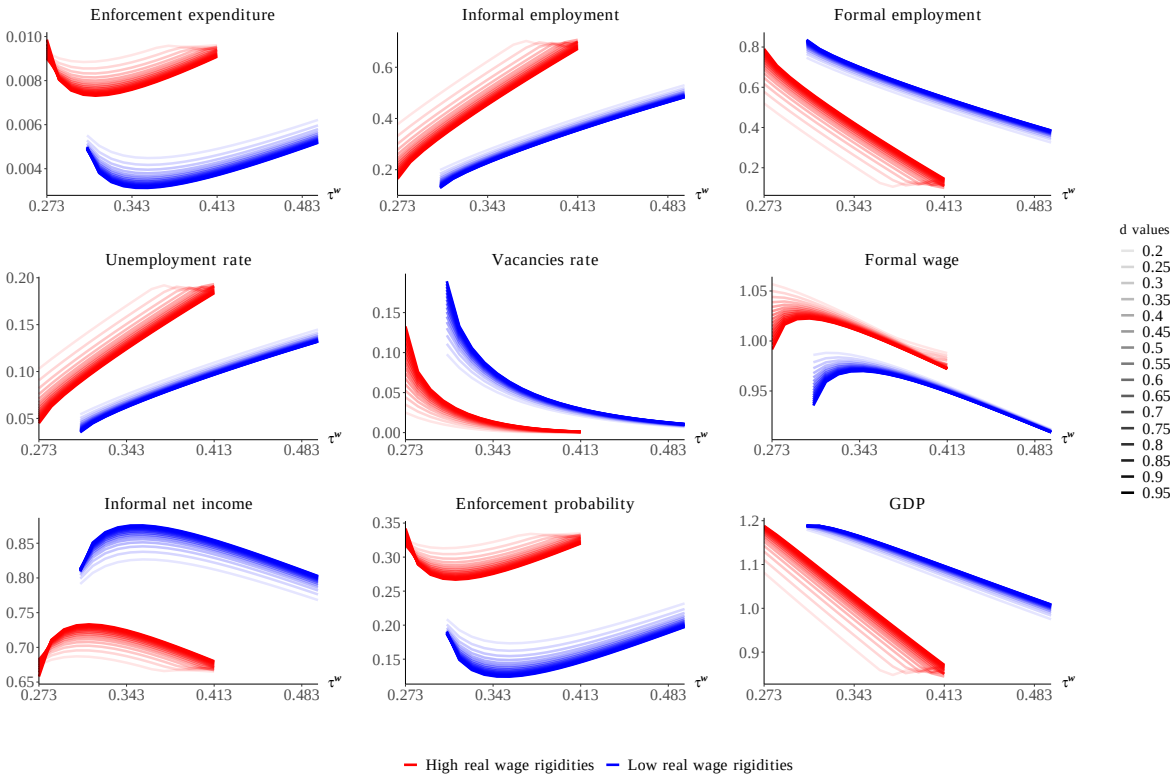

Figure A3: Multiple payroll tax policies with constant public good expenditure.
Note: Each point is a steady-state value of the variable given the value of e.