The Effects of Labor Market Policies in an Economy with an Informal Sector*

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Abstract

In this paper, we build an equilibrium search and matching model to analyze the effects of labor market policies in an economy with an informal sector. Our model extends Mortensen and Pissarides (1994) by allowing for ex ante worker heterogeneity with respect to formal-sector productivity. We analyze the effects of labor market policy on informal-sector and formal-sector output, on the division of the workforce into unemployment, informal-sector employment and formal-sector employment, and on wages. Finally, our model allows us to examine the distributional implications of labor market policy; specifically, we analyze how labor market policy affects the distributions of wages and productivities across formal-sector matches.

1 Introduction

In this paper we construct a search and matching model that allows us to analyze the effects of labor market policies in an economy with a significant informal sector. What we mean by an informal sector is a sector that is unregulated and hence not directly affected by labor market policies such as severance or payroll taxes. Nonetheless we find that labor market policies in effect only in the formal sector affect the size and the composition of employment in the informal sector. This is important since in many economies, there is substantial economic activity in the informal sector. This is particularly true in developing countries. Estimates for some Latin American countries

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put the informal sector at more than 50 percent of the urban work force.[1] There is also evidence that the informal sector is important in many transition countries as well as in some developed economies.[2]

Although much of the literature treats the informal sector as a disadvantaged sector in a segmented labor market framework, this interpretation is not consistent with recent empirical evidence from Latin America. Under a segmented or dual labor market interpretation, one would expect jobs to be rationed in the primary sector and workers to be in the secondary or informal sector involuntarily. Maloney (2004) presents evidence for Latin American countries that challenges this view and instead interprets the informal sector as an unregulated micro-entrepreneurial sector. Gong and van Soest (2002) analyze Mexican urban labor markets, and their findings also challenge the dual labor market view. Both studies find that employment in the informal sector is a worker's decision determined by his or her level of human capital and potential productivity in the formal sector, which is consistent with the negative association between informal sector employment and education level within countries.[3] This does not mean that workers in the informal sector are as well off as those in the formal sector. As Maloney notes (2004, p.12), "to say that workers are voluntarily informally employed does not imply that they are either happy or well off. It only implies that they would not necessarily be better off in the other sector." To summarize, the evidence suggests that (i) the informal sector is important in many countries, (ii) self employment represents the bulk of informality in many economies, and (iii) a worker's potential productivity, determined by his or her level of human capital, is a major determinant of participation in the informal sector. In addition, there is evidence of significant mobility between the formal and the informal sector, and of large informal sectors in economies with very flexible labor markets.[4] This is the view of the informal sector taken in this paper.

There are other recent papers that analyze the effects of labor market and fiscal policies in models with search unemployment and an informal sector. Most of these adopt the view that the

[1] According to Maloney (2004), the informal sector includes 30 to 70 percent of urban workers in Latin American countries.

[2] Schneider and Enste (2000) give estimates for a wide range of countries. They calculate that the informal sector accounts for 10 to 20 percent of GDP in most OECD countries, 20 to 30 percent in Southern European OECD countries and in Central European transition economies. They calculate that the informal sector accounts for 20 to 40 percent of GDP for the former Soviet Union countries and as much as 70 percent for some developing countries in Africa and Asia.

[3] There is also a negative relationship between average years of education of the population and the size of the informal sector as a percentage of GDP across countries. See Masatlioglu and Rigolini (2005).

[4] Maloney (1999) presents interesting evidence for Mexico, where there is a large informal sector, even though the usual sources of wage rigidity are absent. He notes that in Mexico minimum wages are not binding, unions are more worried about employment preservation than about wage negotiations, and wages have shown downward flexibility.

informal sector is illegal, with tax evasion and noncompliance with legislation as its identifying characteristics. These papers focus on the disutility of participation in the underground economy and analyze the effect of monitoring and punishment on informality.[5] A distinctive aspect of our paper is that, consistent with the evidence in developing countries, we consider an unregulated informal sector, which is not necessarily illegal, but rather the sector in which low-productivity workers decide to work.[6]

The model we construct is a substantial extension of Mortensen and Pissarides (1994), hereafter MP, a standard model for labor market policy analysis in a search and matching framework.[7] This model is particularly attractive for our purposes because it includes endogenous job separations. Specifically, we extend MP by (i) adding an informal sector and (ii) allowing for worker heterogeneity. The second extension is what makes the first one interesting. We allow workers to differ in terms of what they are capable of producing in the formal (regulated) sector. All workers have the option to take up informal sector opportunities as these come along, and all workers are equally productive in that sector, but some workers – those who are most productive in formal-sector employment – will reject informal-sector work in order to wait for a formal-sector job. Similarly, the least productive workers are shut out of the formal sector. Labor market policy, in addition to its direct effects on the formal sector, changes the composition of worker types in the two sectors. A policy change can disqualify some workers from formal-sector employment; similarly, some workers accept informal-sector work who would not have done so earlier. Labor market policy thus affects the mix of worker types in the two sectors. These compositional effects, along with the associated distributional implications, are what our heterogeneous-worker extension of MP buys.

The connection between our assumption about worker heterogeneity and our interest in the informal sector is as follows. We assume that the unemployed encounter informal-sector opportunities at an exogenous Poisson rate α; correspondingly, informal-sector jobs end at exogenous Poisson rate δ. Any informal-sector opportunity, if taken up, produces output at flow rate y_0, all

[5] See, for example, Fugazza and Jacques (2003), Kolm and Larsen (2003), Boeri and Garibaldi (2005), and Bosch (2006).

[6] Dolado, Jansen, and Jimeno (2005) is also related. They construct an MP-style model to analyze the effect of targeted severance taxes. They assume that firms are homogeneous and that vacancies can be filled with either high-skill or low-skill workers, i.e., they assume a two-point distribution of worker types. When a worker and a vacancy meet, an idiosyncratic match productivity is realized. Dolado, et. al (2005) assume that the distribution of match productivity for high-skill workers stochastically dominates the one for low-skill workers.

Our model is also related to the macro literature that introduces home (nonmarket) production into growth models (Parente, Rogerson and Wright, 2000) and RBC models (Benhabib, Rogerson and Wright, 1991) in the sense that our informal sector could be reformulated as a home production sector.

[7] There is a substantial literature that analyzes the equilibrium effects of labor market policies in developed economies using a search and matching framework, e.g., Mortensen and Pissarides (2003).

of which goes to the worker.[8] There is, however, a cost to taking one of these jobs; namely, we assume that informal-sector employment precludes search for a formal-sector job.[9] This opportunity cost is increasing in y, the worker's type. The decision about whether or not to accept an informal-sector job thus depends on a worker's type. Workers with particularly low values of y take informal-sector jobs but do not find it worthwhile to take formal-sector jobs. For these workers, the value of waiting for an informal-sector opportunity exceeds the expected surplus that would be generated by taking a formal-sector job. These "low-productivity" workers are indexed by $0 \leq y < y^*$. Workers with intermediate values of y, "medium-productivity" workers, find it worthwhile to take both informal-sector and formal-sector jobs. These workers are indexed by $y^* \leq y < y^{**}$. Finally, workers with high values of y, "high-productivity" workers, reject informal-sector opportunities in order to continue searching for formal-sector jobs. These workers are indexed by $y^{**} \leq y < 1$. The cutoff values, y^* and y^{**}, are endogenous and are influenced by labor market policy.

We can use our model to analyze the effects of various types of labor market policies in an economy with an informal sector. We choose to focus on the effects of severance taxes and payroll taxes because these are particularly important in developing countries.[10] We do this by solving our model numerically and performing policy experiments. We find that a severance tax reduces the rate at which workers find formal-sector jobs but at the same time increases average employment duration in the formal sector. There are also compositional effects, namely, fewer workers take formal-sector jobs and fewer workers reject informal-sector jobs. The net effect is that unemployment among medium- and high-productivity workers falls, as does aggregate unemployment. A payroll tax has somewhat different effects. It also reduces the rate at which workers find formal-sector jobs, but, unlike a severance tax, it decreases average employment duration in the formal sector. Again, there are compositional effects. As with the severance tax, fewer workers reject the informal sector, and more workers also reject the formal sector. Unemployment among medium- and high-productivity workers increases, as does aggregate unemployment. Even though severance taxation decreases unemployment while payroll taxation increases unemployment in our policy experiments, payroll taxation seems to be the less distorting policy. A severance tax has strong negative effects on productivity because firms keep jobs intact even when productivity is low to avoid paying the tax. On the other hand, payroll taxation has a positive effect on formal-sector productivity. Only high-

[8] We could, of course, endogenize α and/or y_0. For example, if more workers choose to enter the informal sector, this could drive down the arrival rate of informal opportunities and the value of working in that sector.

[9] Alternatively, we could assume that workers in the informal sector can search for formal-sector opportunities but less effectively than if they were unemployed. This would be more realistic but would add algebraic complication without much additional insight.

[10] These policies are particularly relevant for Latin America (see Heckman and Pagés 2004). For the specific case of Colombia, see Kugler (1999) and Kugler and Kugler (2003).

productivity matches are worth sustaining in the presence of a payroll tax. Both policies lead to a fall in net output, but the severance tax has the much stronger effect. Finally, our model generates distributions of productivities and wages. A severance tax leads to more dispersion of formal-sector wages and productivity than a payroll tax does.

In the next section, we describe our model and prove the existence of equilibrium. In Section 3, we work out the implications of the model for the distributions of productivity and wages across workers in formal-sector jobs. Section 4 is devoted to our policy experiments. Our simulations give a qualitative sense for the properties of our model as well as a quantitative sense for the impact of the policies. Finally, Section 5 concludes.

2 The Model

2.1 The Mortensen-Pissarides (1994) Model: Background

The basic 1994 MP model can be summarized as follows. First, there are frictions in the process of matching unemployed workers and vacant jobs. These frictions are modeled using a matching function $m(\theta)$, where $m(\theta)$ is the rate at which the unemployed find work, and θ, which is interpreted as labor market tightness equals v/u (the ratio of vacancies to unemployment). Second, when an unemployed worker and a vacancy meet, they match if and only if the joint surplus from the match exceeds the sum of the values they would get were they to continue unmatched. This joint surplus is then split via Nash bargaining. Third, there is free entry of vacancies, so θ is determined by the condition that the value of maintaining a vacancy equals zero. Fourth – and this is the defining innovation of the 1994 MP paper – the rate of job destruction is endogenous. Specifically, when a worker and a firm start their relationship, match productivity is at its maximum level. Shocks then arrive at an exogenous Poisson rate, and with each arrival of a shock, a new productivity value is drawn from an exogenous distribution (and the wage is renegotiated accordingly). The productivity of a match can go up or down over time, but it can never exceed its initial level. When productivity falls below an endogenous reservation value, R, the match ends. R is determined by the condition that the value of continuing the match equals the sum of values to the two parties of remaining unmatched. Labor market tightness, θ, and the reservation productivity, R, are the key endogenous variables in MP. Firms create more vacancies (θ is higher), the longer matches last on average (the lower is R); and matches break up more quickly (the higher is R), the better are workers' outside options (the higher is θ). Equilibrium, a (θ, R) pair, is determined by the intersection of a job-creation schedule (θ as a decreasing function of R) and a job-destruction schedule (R as an increasing function of θ).

2.2 Our Model

Our innovation is to assume that workers differ in their maximum productivities in formal-sector jobs. In particular, we assume that maximum productivity ("potential") is distributed across a continuum of workers of measure one according to a continuous distribution function $F(y)$, $0 \leq y \leq 1$. Workers with a high value of y start their formal-sector jobs at a high level of match productivity; workers with lower values of y start at lower levels of match productivity. As in MP, job destruction is endogenous in our model. Productivity in each match varies stochastically over time, and eventually the match is no longer worth maintaining. The twist in our model is that different worker types have different reservation productivities; that is, instead of a single reservation productivity, R, to be determined in equilibrium, there is an equilibrium reservation productivity schedule, $R(y)$.[11]

We consider a model in which workers can be in one of three states: (i) unemployed, (ii) employed in the informal sector, or (iii) employed in the formal sector. Unemployment is the residual state in the sense that workers whose employment in either an informal-sector or a formal-sector job ends flow back into unemployment. Unemployed workers receive b, which is interpreted as the flow income equivalent to the value of leisure. The unemployed look for job opportunities. Formal-sector opportunities arrive at endogenous rate $m(\theta)$, and informal-sector opportunities arrive at exogenous rate α. The matching (or meeting) function, $m(\theta)$, has standard properties, namely, (i) $m(\theta)$ is increasing in θ, (ii) $m(\theta)/\theta$ is decreasing in θ, (iii) $\lim_{\theta \to 0} m(\theta) = 0$ and $\lim_{\theta \to \infty} m(\theta) = \infty$, and (iv) $\lim_{\theta \to 0} m(\theta)/\theta = \infty$ and $\lim_{\theta \to \infty} m(\theta)/\theta = 0$.

In the informal sector, a worker receives flow income y_0, where $y_0 > b$. As mentioned above, opportunities to work in the informal sector arrive to the unemployed at Poisson rate α. Employment in this sector ends at Poisson rate δ. We assume that employment in the informal sector precludes search for a formal-sector job; i.e., there are no direct transitions from the informal to the formal sector.

A worker's output in a formal-sector job depends on his or her type. Formal-sector matches initially produce at the worker's maximum potential productivity level y. Thereafter, as in MP, productivity shocks arrive at Poisson rate λ, which change the match productivity. These shocks are *iid* draws from a continuous distribution $G(x)$, where $0 \leq x \leq 1$. There are three possibilities to consider. First, if the realized value of a draw x is sufficiently low, it is in the mutual interest of the worker and the firm to end the match. Here "sufficiently low" is defined in terms of an endogenous reservation productivity, $R(y)$, which depends on the worker's type. Thus, with probability $G(R(y))$, a shock ends the match. Second, if $R(y) \leq x \leq y$, the productivity of the match changes

[11] In Dolado et al. (2005), there are two reservation productivities, one for high-skill workers and one for low-skill workers.

to x. That is, with probability $G(y) - G(R(y))$, the match continues after a shock, but at the new level of productivity. Finally, if the draw is such that $x \geq y$, we assume that the productivity of the match reverts to y. That is, with probability $1 - G(y)$, the match continues after a shock, but the productivity of the match is reset to its maximum value.[12]

The surplus from a formal-sector match is split between the worker and firm using a Nash bargaining rule with an exogenous worker share, β. This surplus depends both on the current productivity of the match, y', and on the worker's type, y. As in MP, we assume the wage, $w(y', y)$, is renegotiated whenever match productivity changes.

Since we are interested in analyzing the effects of severance and payroll taxes, we augment the model to include those policies. The introduction of a payroll tax is straightforward, but the introduction of a severance tax requires us to distinguish between the initial negotiation between a worker and a firm and subsequent negotiations. In the initial negotiation, if the bargaining breaks down, the firm does not have to pay a severance tax; but in subsequent negotiations, the firm's outside option must include the severance tax. This implies that with a severance tax, the initial wage negotiated between the firm and a worker of type y, which we denote by $w(y)$, differs from subsequent wages negotiated between the firm and that worker when the current productivity level is $y' = y$, i.e., $w(y, y)$.[13]

2.3 Value Functions

We can summarize the above discussion of the worker side of the model by the value functions

$$
\begin{aligned}
rU(y) &= b + \alpha \max\left[N_0(y) - U(y), 0\right] + m(\theta) \max\left[N_1(y) - U(y), 0\right] \\
rN_0(y) &= y_0 + \delta\left(U(y) - N_0(y)\right) \\
rN_1(y) &= w(y) + \lambda G(R(y))\left(U(y) - N_1(y)\right) + \lambda \int_{R(y)}^{y} \left(N_1(x, y) - N_1(y)\right) g(x) dx \\
&\quad + \lambda\left(1 - G(y)\right)\left(N_1(y, y) - N_1(y)\right) \\
rN_1(y', y) &= w(y', y) + \lambda G(R(y))\left(U(y) - N_1(y', y)\right) + \lambda \int_{R(y)}^{y} \left(N_1(x, y) - N_1(y', y)\right) g(x) dx \\
&\quad + \lambda\left(1 - G(y)\right)\left(N_1(y, y) - N_1(y', y)\right),
\end{aligned}
$$

[12] Two alternative assumptions are: (i) if a shock is drawn such that $x > y$, the productivity of the match remains where it is rather than reverting to y and (ii) shocks are drawn randomly from $[0, y]$ rather than $[0, 1]$.

[13] See the discussion in Mortensen and Pissarides (1999).

where $U(y)$ is the value of unemployment for a worker of type y, $N_0(y)$ is the value of informal-sector employment for this type of worker, $N_1(y)$ is the initial value of employment for a worker of type y, and $N_1(y', y)$ is the value of employment for a worker of type y in a match that has experienced one or more shocks and has current productivity y'. The final three terms in the expressions for $N_1(y)$ and $N_1(y', y)$ reflect our assumptions about the shock process.

Next, consider the vacancy-creation problem faced by a formal-sector firm. The value functions for a filled job must take into account severance and payroll taxes since we assume these are nominally paid by employers. Let V be the value of creating a formal-sector vacancy, $J(y)$ be the initial value of filling a job with a worker of type y, and $J(y', y)$ be the value of employing a worker of type y in a match with current productivity y'. The latter two values can be written as

$$\begin{aligned} rJ(y) &= y - w(y)(1+\tau) + \lambda G(R(y))(V - J(y) - s) \\ &\quad + \lambda \int_{R(y)}^{y} (J(x,y) - J(y))\, g(x)dx + \lambda(1 - G(y))(J(y,y) - J(y)) \\ rJ(y', y) &= y' - w(y', y)(1+\tau) + \lambda G(R(y))\left(V - J(y', y) - s\right) \\ &\quad + \lambda \int_{R(y)}^{y} \left(J(x,y) - J(y', y)\right) g(x)dx + \lambda(1 - G(y))\left(J(y,y) - J(y', y)\right), \end{aligned}$$

where τ is the payroll tax rate and s is the severance tax. Note that for simplicity, we assume that the tax receipts are "thrown in the ocean," i.e., used for purposes outside the model. A firm that employs a worker of type y initially receives flow output y and pays a wage of $w(y)$. After a shock that moves the match productivity to y', the firm receives flow output y' and pays a wage of $w(y', y)$. The final three terms in these value functions again reflect our assumptions about the shock process. At rate λ, a productivity shock arrives. With probability $G(R(y))$, the job ends, in which case the firm suffers a capital loss of either $V - J(y) - s$ or $V - J(y', y) - s$. If the realized shock x falls in the interval $[R(y), y]$, the value changes to $J(x, y)$. Finally, with probability $1 - G(y)$, the shock resets the value of employing a worker of type y to $J(y, y)$.

The value of a vacancy is defined by

$$rV = -c + \frac{m(\theta)}{\theta} E \max[J(y) - V, 0]. \tag{1}$$

This expression reflects the assumption that match productivity initially equals the worker's type and the E max is taken over the distribution of y among the unemployed. A vacancy does not know in advance what type of worker it will meet. It may, for example, meet a worker of type $y < y^*$, in which case it is not worth forming the match.[14] If the worker is of type $y \geq y^*$, the match

[14] This assumes that workers of type $y < y^*$ search for both types of jobs. Alternatively, we could assume that

forms, but the job's value depends, of course, on the worker's type. Finally, note that in computing the expectation, we need to account for contamination in the unemployment pool. That is, the distribution of y among the unemployed, in general, differs from the corresponding population distribution. We deal with this complication below in the subsection on steady-state conditions.

As usual in this type of model, the fundamental equilibrium condition is the one given by free entry of vacancies, i.e., $V = 0$. Equation (1), with $V = 0$, determines the equilibrium value of labor market tightness. The other endogenous objects of the model, namely, the wage schedules, $w(y)$ and $w(y', y)$, the reservation productivity schedule, $R(y)$, the cutoff values, y^* and y^{**}, and the type-specific unemployment rates, $u(y)$, can all be expressed in terms of θ.

2.4 Wage Determination

We use the Nash bargaining assumption with an exogenous share parameter β to derive the wage functions. Given $V = 0$, the initial wage for a worker of type y solves

$$\max_{w(y)}[N_1(y) - U(y)]^{\beta} J(y)^{1-\beta},$$

One can verify that

$$w(y) = \frac{\beta(y - \lambda s) + (1-\beta)(1+\tau)rU(y)}{1+\tau}.$$

That is, the wage is a weighted sum of the current output minus a term reflecting the severance tax that must eventually be paid and the worker's continuation value.

The wage $w(y', y)$ for a type y worker producing at y' solves

$$\max_{w(y',y)} [N_1(y', y) - U(y)]^{\beta} \left[J(y', y) + s\right]^{1-\beta}.$$

This wage function can be written as

$$w(y', y) = \frac{\beta(y' + rs) + (1-\beta)(1+\tau)rU(y)}{1+\tau}.$$

2.5 Reservation Productivity

Filled formal-sector jobs are destroyed when a sufficiently unfavorable productivity shock is realized. The reservation productivity $R(y)$ is defined by the zero-surplus condition,

$$N_1(R(y), y) - U(y) + J(R(y), y) = -s.$$

these workers do not search for formal sector jobs and redefine unemployment (and thus θ) to only include workers seeking formal-sector employment. This would not affect our qualitative conclusions.

Given the surplus sharing rule, this is equivalent to

$$J\left(R\left(y\right),y\right)=-s.$$

Substitution gives

$$R(y)=(1+\tau)rU\left(y\right)-sr-\frac{\lambda}{r+\lambda}\int_{R(y)}^{y}[1-G(x)]dx. \tag{2}$$

For any fixed value of y, this is analogous to the reservation productivity in MP. Since $U(y)$ is increasing in θ for all workers who take formal-sector jobs, equation (2) defines an upward-sloping "job-destruction" locus in the $(\theta, R\left(y\right))$ plane. This equation makes it clear that s shifts the $R(y)$ schedule down, while τ shifts it up.

An interesting question is how the reservation productivity varies with y. On the one hand, the higher is a worker's maximum potential productivity, the better are her outside options. That is, $U(y)$ is increasing in y. This suggests that $R(y)$ should be increasing in its argument. On the other hand, a "good match gone bad" retains its upside potential. The final term in equation (2), which can be interpreted as a labor-hoarding effect, is decreasing in y. This suggests that $R(y)$ should be decreasing in y. As will be seen below once we solve for $U(y)$, which of these terms dominates depends on parameters.

2.6 Unemployment values and cutoff productivities

Workers with $y<y^*$ work only in the informal sector, workers with $y^*\leq y\leq y^{**}$ accept both informal-sector and formal-sector jobs, and workers with $y>y^{**}$ accept only formal-sector jobs. Thus y^* is defined by the condition that a worker with productivity $y=y^*$ be indifferent between unemployment and a formal-sector offer, and y^{**} is defined by the condition that a worker with productivity $y=y^{**}$ be indifferent between unemployment and an informal-sector offer.

Consider a worker with $y^*\leq y\leq y^{**}$. The value of unemployment for this worker is given by

$$rU\left(y\right)=b+\alpha\left[N_0\left(y\right)-U\left(y\right)\right]+m\left(\theta\right)\left[N_1\left(y\right)-U\left(y\right)\right].$$

The condition that $N_1\left(y^*\right)=U\left(y^*\right)$ then implies

$$rU\left(y^*\right)=b+\alpha\left[N_0\left(y^*\right)-U\left(y^*\right)\right]$$

and substitution gives

$$rU\left(y^*\right)=\frac{b\left(r+\delta\right)+\alpha y_0}{r+\alpha+\delta}.$$

Note that $rU(y)$ takes this value for all $y \leq y^*$ and that $rU(y^*)$ does not depend on θ. A worker who is on the margin between accepting and rejecting formal-sector jobs does not benefit when these jobs become easier to find. Setting $U(y^*)$ equal to $N_1(y^*)$ gives

$$y^* = (1+\tau)\frac{b(r+\delta)+\alpha y_0}{r+\alpha+\delta} + \lambda s - \frac{\lambda}{r+\lambda}\int_{R(y^*)}^{y^*} (1-G(x))\,dx. \tag{3}$$

Note that since $R(y^*)$ does not depend on θ (because $rU(y^*)$ does not depend on θ), neither does y^*.

Similarly, the condition that $N_0(y^{**}) = U(y^{**})$ implies that at $y = y^{**}$

$$rU(y^{**}) = b + m(\theta)\left[N_1(y^{**}) - U(y^{**})\right].$$

Setting $U(y^{**}) = N_0(y^{**})$ implies that $rU(y^{**}) = y_0$ and substitution gives

$$N_1(y^{**}) = \frac{(r+m(\theta))y_0 - rb}{rm(\theta)}.$$

Substituting for $N_1(y^{**})$ and solving gives

$$y^{**} = (1+\tau)\frac{(y_0-b)(r+\lambda)+m(\theta)\beta y_0}{m(\theta)\beta} + \lambda s - \frac{\lambda}{r+\lambda}\int_{R(y^{**})}^{y^{**}} [1-G(x)]dx. \tag{4}$$

Since $U(y)$ is increasing in y for all $y \geq y^*$ and since $rU(y^{**}) > rU(y^*)$, it follows that $y^{**} > y^*$ as we have assumed.

While $rU(y)$ has a simple form that does not depend on y or on taxes when $y \leq y^*$ and $y = y^{**}$, it is more complicated at other values of y. For $y^* \leq y < y^{**}$, we have

$$rU(y) = \frac{[b(r+\delta)+\alpha y_0](r+\lambda) + \frac{(r+\delta)m(\theta)\beta}{1+\tau}\left\{y - \lambda s + \frac{\lambda}{r+\lambda}\int_{R(y)}^{y}[1-G(x)]dx\right\}}{(r+\alpha+\delta)(r+\lambda)+(r+\delta)m(\theta)\beta}$$

and for $y \geq y^{**}$, we have

$$rU(y) = \frac{b(r+\lambda) + \frac{m(\theta)\beta}{1+\tau}\left\{y - \lambda s + \frac{\lambda}{r+\lambda}\int_{R(y)}^{y}[1-G(x)]dx\right\}}{r+\lambda+m(\theta)\beta}.$$

Note that the two expressions would be identical if the informal sector did not exist, that is, were $\alpha = \delta = 0$.

Given the expression for $R(y)$, equation (2), the differing forms for $rU(y)$ mean that the form of $R(y)$ differs for medium- and high-productivity workers. For any fixed value of θ, equation (2) has a unique solution for $R(y)$. One can also check, given a unique schedule $R(y)$, that equations (3) and (4) imply unique solutions for the cutoff values, y^* and y^{**}, respectively.

2.7 Steady-State Conditions

The model's steady-state conditions allow us to solve for the unemployment rates, $u(y)$, for the various worker types. Let $u(y)$ be the fraction of time a worker of type y spends in unemployment, let $n_0(y)$ be the fraction of time that this worker spends in informal-sector employment, and let $n_1(y)$ be the fraction of time that this worker spends in formal-sector employment. Of course, $u(y) + n_0(y) + n_1(y) = 1$.

Workers of type $y < y^*$ flow back and forth between unemployment and informal-sector employment. There is thus only one steady-state condition for these workers, namely, that flows out of and into unemployment must be equal,

$$\alpha u(y) = \delta(1 - u(y)).$$

For $y < y^*$ we thus have

$$\begin{aligned} u(y) &= \frac{\delta}{\delta + \alpha} \\ n_0(y) &= \frac{\alpha}{\delta + \alpha} \\ n_1(y) &= 0. \end{aligned} \tag{5}$$

There are two steady-state conditions for workers with $y^* \leq y \leq y^{**}$, (i) the flow out of unemployment to the informal sector equals the reverse flow and (ii) the flow out of unemployment into the formal sector equals the reverse flow,

$$\begin{aligned} \alpha u(y) &= \delta n_0(y) \\ m(\theta)\, u(y) &= \lambda G(R(y))\,(1 - u(y) - n_0(y))\,. \end{aligned}$$

Combining these conditions gives

$$\begin{aligned} u(y) &= \frac{\delta \lambda G(R(y))}{\lambda(\delta + \alpha)\, G(R(y)) + \delta m(\theta)} \\ n_0(y) &= \frac{\alpha \lambda G(R(y))}{\lambda(\delta + \alpha)\, G(R(y)) + \delta m(\theta)} \\ n_1(y) &= \frac{\delta m(\theta)}{\lambda(\delta + \alpha)\, G(R(y)) + \delta m(\theta)}. \end{aligned} \tag{6}$$

Finally, for workers with $y > y^{**}$ there is again only one steady-state condition, namely, that the flow from unemployment to the formal sector equals the flow back into unemployment,

$$m(\theta)\, u(y) = (1 - u(y))\, \lambda G(R(y))\,.$$

This implies

$$\begin{aligned} u(y) &= \frac{\lambda G(R(y))}{\lambda G(R(y)) + m(\theta)} \\ n_0(y) &= 0 \\ n_1(y) &= \frac{m(\theta)}{\lambda G(R(y)) + m(\theta)}. \end{aligned} \tag{7}$$

Total unemployment is obtained by aggregating across the population,

$$u = \int_0^{y^*} u(y) f(y)dy + \int_{y^*}^{y^{**}} u(y) f(y)dy + \int_{y^{**}}^1 u(y) f(y)dy.$$

2.8 Equilibrium

We use the free-entry condition to close the model and determine equilibrium labor market tightness. Setting $V = 0$ in equation (1) gives

$$c = \frac{m(\theta)}{\theta} E \max[J(y), 0].$$

To determine the expected value of meeting a worker, we need to account for the fact that the density of types among unemployed workers is contaminated. Let $f_u(y)$ denote the density of types among the unemployed. Using Bayes Law,

$$f_u(y) = \frac{u(y)f(y)}{u}.$$

The free-entry condition can thus be rewritten as

$$c = \frac{m(\theta)}{\theta} \int_{y^*}^1 J(y) \frac{u(y)}{u} f(y)dy.$$

After substitution for $J(y)$, this becomes

$$c = \frac{m(\theta)}{\theta} \int_{y^*}^1 (1-\beta) \left(\frac{y - R(y)}{r + \lambda} - \frac{s}{1-\beta} \right) \frac{u(y)}{u} f(y)dy. \tag{8}$$

Equation (8), of course, only makes sense if its right-hand side is positive. Since $J(y^*) = 0$ and $J(y)$ is increasing in y for $y \geq y^*$, a necessary condition for equation (8) to have a solution is $y^* < 1$. From equation (3), a simple sufficient condition for $y^* < 1$ is

$$(1+\tau) \frac{b(r+\delta) + \alpha y_0}{r + \alpha + \delta} + \lambda s < 1. \tag{9}$$

If severance and/or payroll taxes are high enough, no formal-sector matches form. In that case, equation (8) cannot hold, and the only equilibrium is one in which all employment is in the informal sector. Such an equilibrium is not particularly interesting, so henceforth we assume that inequality (9) is satisfied. That is, we consider equilibria with formal-sector employment.

A *steady-state equilibrium with formal-sector employment* is a labor market tightness θ, together with a reservation productivity function $R(y)$, unemployment rates $u(y)$, and cutoff values y^* and y^{**} such that

(i) the value of maintaining a vacancy is zero
(ii) matches are consummated and dissolved if and only if it is in the mutual interest of the worker and firm to do so
(iii) the steady-state conditions hold
(iv) formal-sector matches are not worthwhile for workers of type $y < y^*$
(v) informal-sector matches are not worthwhile for workers of type $y > y^{**}$.

Such an equilibrium exists if there is a θ that solves equation (8), taking into account that $R(y)$, $u(y)$, u and y^{**} are all uniquely determined by θ. A solution to equation (8) exists since the limit of its right-hand side is ∞ as $\theta \to 0$ and is 0 as $\theta \to \infty$. While it is clear that a steady-state equilibrium with formal-sector employment exists, to establish uniqueness requires showing that the right-hand side of equation (8) is monotonically decreasing in θ. Labor market tightness enters into the right-hand side of equation (8) in three ways. First, $m(\theta)/\theta$ is monotonically decreasing in θ by assumption. Second, θ enters $J(y) = (1-\beta)\left(\frac{y - R(y)}{r+\lambda} - \frac{s}{1-\beta}\right)$ through its effect on the reservation productivity schedule. Since $R(y)$ is monotonically increasing in θ for all $y > y^*$, the value of a filled job, $J(y)$ is monotonically decreasing in θ. Finally, θ enters $u(y)/u$ both through $u(y)$ and u. Intuitively, it is clear that $u(y)$ should be decreasing in θ for all $y \geq y^*$. That is, the direct effect of an increase in the job-finding rate for a worker of type y should more than offset any second-order effect via a change in $R(y)$. The issue is that the overall unemployment rate, u, is also decreasing in θ. Further assumptions on $G(x)$ are required to establish that $u(y)/u$ is decreasing in θ for all $y \geq y^*$.[15]

3 Distributional Characteristics of Equilibrium

Given assumed functional forms for the distribution functions, $F(y)$ and $G(x)$, and for the matching function, $m(\theta)$, and given assumed values for the exogenous parameters of the model, equation (8) can be solved numerically for θ. Given θ, we can then recover the other equilibrium objects of the model. In fact, we can do more than this. Once we solve for equilibrium, we can compute

[15] In our simulations, when we assume X is a standard uniform, the equilibria are always unique.

the distributions of productivity and wages in formal-sector employment. We can then use these distributions to evaluate both the aggregate and distributional effects of labor market policy.

To begin, we discuss the computation of the joint distribution of (y', y) across workers employed in the formal sector. Once we compute this joint distribution (and the corresponding marginals), we can find the distribution of wages in the formal sector. To find the distribution of (y', y) across workers employed in the formal sector, we use

$$h(y', y) = h(y'|y)h(y).$$

Here $h(y', y)$ is the joint density, $h(y'|y)$ is the conditional density, and $h(y)$ is the marginal density across workers employed in the formal sector. It is relatively easy to compute $h(y)$. Let E denote "employed in the formal sector." Then by Bayes Law,

$$h(y) = \frac{P[E|y]f(y)}{P[E]} = \frac{n_1(y)f(y)}{\int n_1(y)f(y)dy},$$

where from equations (5) to (7),

$$\begin{aligned} n_1(y) &= 0 && \text{for } y \leq y^* \\ &= \frac{\delta m(\theta)}{\delta m(\theta) + (\alpha + \delta)\lambda G(R(y))} && \text{for } y^* \leq y < y^{**} \\ &= \frac{m(\theta)}{m(\theta) + \lambda G(R(y))} && \text{for } y \geq y^{**}. \end{aligned}$$

Next, we need to find $h(y'|y)$. Consider a worker of type y who is employed in the formal sector. Her match starts at productivity y; later, a shock (or shocks) may change her match productivity. Let N denote the number of shocks this worker has experienced to date (in her current spell of employment in a formal-sector job). Since we are considering a worker who is employed in the formal sector, we know that none of these shocks has resulted in a productivity realization below $R(y)$.

If $N = 0$, then $y' = y$ with probability 1. If $N > 0$, then $y' = y$ with probability $\frac{1 - G(y)}{1 - G(R(y))}$, i.e., the probability that the productivity shock is greater than or equal to y (conditional on the worker being employed) in which case the productivity reverts to y. Combining these terms, we have that conditional on y, $y' = y$ with probability $P[N = 0] + \frac{1 - G(y)}{1 - G(R(y))}P[N > 0]$. Similarly, the conditional density of y' for $R(y) \leq y' < y$ is

$$h(y'|y) = \frac{g(y')}{1 - G(R(y))}P[N > 0] \text{ for } R(y) \leq y' < y.$$

Thus, we need to find $P[N = 0]$ for a worker of type y who is currently employed in the formal sector.

To do this, we first condition on elapsed duration. Consider a worker of type y whose elapsed duration of employment in her current formal sector job is t. This worker exits formal sector employment at Poisson rate $\lambda G(R(y))$; equivalently, the distribution of completed durations for a worker of type y is exponential with parameter $\lambda G(R(y))$. The exponential has the convenient property that the distributions of completed and elapsed durations are the same.

Let N_t be the number of shocks this worker has realized given elapsed duration t. Shocks arrive at rate λ. However, as the worker is still employed, we know that none of the realizations of these shocks was below $R(y)$. Thus, N_t is Poisson with parameter $\lambda(1-G(R(y))t$, and $P[N_t=0] = \exp\{-\lambda(1-G(R(y))t\}$. Integrating $P[N_t=0]$ against the distribution of elapsed duration gives

$$P[N=0] = \int_0^\infty \exp\{-\lambda(1-G(R(y))t\}\lambda G(R(y))\exp\{-\lambda G(R(y))t\}dt = G(R(y))$$

for a worker of type y.

Thus, the probability that a worker of type y is working to her potential when she is employed in a formal sector job (i.e., that $y'=y$) is

$$P[y'=y|y] = G(R(y)) + \frac{1-G(y)}{1-G(R(y))}(1-G(R(y))) = 1-(G(y)-G(R(y))).$$

The density of y' across all other values that are consistent with continued formal-sector employment for a type y worker is

$$h(y'|y) = \frac{g(y')}{1-G(R(y))}(1-G(R(y))) = g(y') \text{ for } R(y) \leq y' < y.$$

Given the marginal density for y and the conditional density, $h(y'|y)$, we thus have the joint density, $h(y',y)$, which is defined for for $y^* \leq y \leq 1$ and $R(y) \leq y' \leq y$, i.e., for the (y',y) combinations that are consistent with formal-sector employment.

The final steps are to compute the densities of productivity in formal-sector employment (i.e., the marginal density of y') and of formal-sector wages. The density of y' is computed as $h(y') = \int h(y'|y)h(y)dy = \int h(y',y)dy$.

To derive the distribution of wages across formal-sector employment, we use $m(w) = \int m(w|y)h(y)dy$. We thus need the conditional distribution of wages given worker type, i.e., $m(w|y)$. Recall that

$$\begin{aligned} w(y) &= \frac{\beta(y-\lambda s)+(1-\beta)(1+\tau)rU(y)}{1+\tau} \\ w(y',y) &= \frac{\beta(y'+rs)+(1-\beta)(1+\tau)rU(y)}{1+\tau}. \end{aligned}$$

Worker y receives $w(y)$ up to the time that the first shock to match productivity is realized. The probability that worker y receives $w(y)$ is thus $P[N=0] = G(R(y))$. If $N>0$, $y'=y$ with probability $\frac{1-G(y)}{1-G(R(y))}$. Finally, if $N > 0$, the density of y' conditional on y is $\frac{g(y')}{1-G(R(y))}$ for $y' \in [R(y), y)$. Inverting $w(y', y)$ implies that when $N > 0$, the density of w conditional on y is $\left(\frac{1+\tau}{\beta}\right)\frac{g((\frac{1+\tau}{\beta})w - rs - (1-\beta)(1+\tau)rU(y))}{1-G(R(y))}$ for $w \in [w(R(y)), w(y, y))$.

Summarizing, given y we have

$$\begin{aligned} P[w &= w(y)] = G(R(y)) \\ P[w &= w(y,y)] = 1 - G(y) \\ m(w|y) &= (\frac{1+\tau}{\beta})g((\frac{1+\tau}{\beta})w - rs - (1-\beta)(1+\tau)rU(y)) \text{ for } w \in [w(R(y)), w(y,y)). \end{aligned}$$

There are thus two mass points in the conditional distribution of wages given worker type. The final step is to carry out the integration, $m(w) = \int m(w|y)h(y)dy$.

4 Numerical Simulations

We now present our numerical analysis of the model and examine the effects of labor market policy. Specifically, we look at a severance tax and a payroll tax. For all our simulations, we assume the following functional forms and parameter values. First, we assume that the distribution of worker types, i.e., y, is uniform over $[0, 1]$ and that the productivity shock, i.e., x, is likewise drawn from a standard uniform distribution. We assume the standard uniform for computational convenience, but it is not appreciably more difficult to solve the model using flexible parametric distributions, e.g., betas, for $F(y)$ and/or $G(x)$. Second, we assume a Cobb-Douglas matching function, namely, $m(\theta) = 4\theta^{1/2}$. Third, we chose our parameter values with a year as the implicit unit of time. We set $r = 0.05$ as the discount rate. We normalize the flow income equivalent of leisure to $b = 0$. The parameters for the informal sector are $y_0 = 0.35$, $\alpha = 5$ and $\delta = 0.5$, and the formal-sector parameters are $c = 0.3$, $\beta = 0.5$, and $\lambda = 1$. Note that the share parameter, β, equals the elasticity of the matching function with respect to labor market tightness. Our parameter values were chosen to produce plausible results for our baseline case in which there is no severance tax or payroll tax.

Consider first the baseline case given in row 1 of Table 1. With no severance payment or payroll taxation, our baseline generates a labor market tightness of $\theta = 1.21$. More than 30 percent of the labor force works only in the informal sector, while about 60 percent of the labor force works only in the formal sector. The remaining 10 percent would work in either sector. The reservation productivity for the worker who is just on the margin of working in the formal sector ($y = y^*$) is the same as that worker's type. With no severance payment, it is worthwhile employing this worker even though the match would end were its productivity to go even a bit below its maximum level. Next, note that $R(y^{**}) < R(y^*)$. As we discussed earlier, there are two effects of y on the reservation productivity. First, more productive workers have greater "upside potential"; on the other hand, more productive workers have better outside options. The first effect dominates among medium-productivity workers for this parameterization, however, the first panel of Figure 1 shows that $R(y)$ is increasing for $y \geq y^{**}$, i.e., for high-productivity workers. The next three columns in Table 1 give average unemployment rates. The average unemployment rate for the baseline case is 8.6 percent. Among low-productivity workers, the unemployment rate is $\delta/(\alpha + \delta) = 9.1$ percent (not shown). The average unemployment rate for medium-productivity workers is much lower, reflecting the fact that these workers take both informal- and formal-sector jobs. Finally, the average unemployment rate for high-productivity workers is 9.1 percent. This reflects the fact that these workers do not take up informal-sector opportunities. Next, we present average productivity for workers in the formal sector, which is 0.639, and the average wage paid to formal-sector workers, which is 0.579. The final two columns give net total output (Y), i.e., the sum of outputs from the informal and formal sectors net of vacancy creation costs ($c\theta u$), and the tax revenues generated by the severance and payroll tax policies (zero in the baseline case).

The next four rows of Table 1 show the effect of raising the severance tax, s. Since the severance tax makes vacancy creation less attractive, labor market tightness decreases. The severance tax shifts the reservation productivity schedule down. This is because the tax makes it more costly to end matches. In addition, the severance tax affects the composition of the sectors. The two cutoff values y^* and y^{**} increase with s; that is, formal-sector employment is less attractive to the previously marginal workers. The reason is that although jobs last longer when the severance tax is higher, the expected formal-sector wage decreases with s. The unemployment rates for medium- and high-productivity workers fall significantly. The effect of increasing job duration outweighs the reduction in the job arrival rate. Since the reduction in unemployment associated with formal-sector jobs outweighs the effect of the increase in the number of workers in the high-unemployment informal sector, the overall unemployment rate falls. While the unemployment effects of the severance tax make it seem attractive, this policy has strong negative effects on productivity. The large downward shift in the $R(y)$ schedule (see Figure 1) implies that jobs last longer, leading to a reduction in average productivity ($\overline{y}'$) in the formal sector. Wages in the formal sector fall, as does net output. Tax receipts are increasing in s but at a decreasing rate. There are two reasons for this – as the severance tax goes up, (i) workers exit the formal sector and (ii) worker-firm matches are of increasingly longer duration and thus less productive on average conditional on worker type.

Table 2 presents the effects of varying the payroll tax, τ, holding the severance tax at zero. We consider payroll taxes ranging from zero to 20 percent. A payroll tax of $\tau = 0.1$ raises a bit more tax revenue than a severance tax of $s = 0.2$. As shown in Table 2, increasing the payroll tax reduces θ since it makes formal-sector vacancy creation less attractive. In contrast to the effect of the severance tax, a payroll tax decreases job duration by shifting up the reservation productivity schedule, as can be seen in Figure 1. The payroll tax also has compositional effects. The fraction of workers who never take formal-sector jobs ($y < y^*$) increases substantially with τ, and the fraction who only take formal-sector jobs ($y > y^{**}$) decreases substantially with τ. Given that a payroll tax has a stronger effect on the unemployment value of high-productivity workers than on that of medium-productivity workers, y^{**} increases by more than y^* with τ. This means that the fraction of workers who would take any job increases with τ. The fact that both labor market tightness and expected formal-sector job duration decrease implies that unemployment increases among high-productivity workers. The effect on overall unemployment, however, is mitigated to some extent by the compositional changes. Consistent with the compositional change and the shift in the reservation productivity schedule, average formal-sector productivity rises. Formal sector wages fall, as does net output. Tax receipts increase with τ at slightly less than linear rate. There are fewer matches to tax as τ increases, but this effect is offset to some extent by the fact that the matches that are taxed are increasingly more productive.

The final table examines the effects of increasing s and τ simultaneously to $s = \tau = 0.1$. Since both of these taxes make vacancy creation less attractive, labor market tightness falls. Employment duration in the formal sector increases, i.e., the severance tax effect dominates, as can be seen in Figure 1. On net, there is a slight decrease in the average unemployment rate among high-productivity workers, which leads to a corresponding fall in the aggregate rate. Average productivity in the formal sector falls as a result of the decrease in the reservation productivity, the average formal-sector wage decreases, and net output falls.

Figures 2 and 3 illustrate the effects of s and τ on the distribution of types (y), current productivities (y') and wages in the formal sector. The density of y is the contaminated one; i.e., it incorporates the different job-finding and job-losing experiences of the various worker types. Since no worker's current productivity can exceed his or her type, the distribution of y necessarily first-order stochastically dominates that of y'. Figure 2 shows how the severance tax and the payroll tax compress the distribution of types in the formal sector. The severance tax shifts the density of current productivity to the left, reflecting the decrease in reservation productivities. The payroll tax shifts the density of y' to the right, reflecting the upward shift in the reservation productivity schedule. Regarding wages (Figure 3), both taxes compress the wage distribution, although the effect of the payroll tax is greater. Finally, while Figures 2 and 3 suggest that the distributional effects of the payroll tax are more pronounced, when analyzing the two policies together the severance tax effects dominate.

5 Conclusions

In this paper, we build a search and matching model to analyze the effect of labor market policies in an economy with a significant informal sector. In light of the empirical evidence for many developing countries, we model an economy where workers operate as self employed in the informal sector. Additionally, depending on their productivity levels, some workers only work in the formal sector, others only work in the informal sector, and an intermediate group of workers goes back and forth between the formal and the informal sectors.

We solve our model numerically and analyze the effects of two labor market policies, a severance tax and a payroll tax. Despite the fact that both policies reduce the rate at which workers find formal-sector jobs, their effects on unemployment duration, unemployment rates and the distribution of workers across the sectors are different. A severance tax greatly increases average employment duration in the formal sector, reduces overall unemployment, reduces the number of formal-sector workers, and reduces the number of workers who accept any type of offer (formal or informal). In contrast, a payroll tax reduces average employment duration in the formal sector, greatly reduces the number of formal-sector workers, and significantly increases the size of the informal sector and the number of workers accepting any type of offer. Total unemployment rises. The two policies also have different effects on the distributions of productivity and wages in the formal sector. The severance tax decreases average productivity, while the payroll tax increases it, but under both policies, net output falls.

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Table 1: Effects of Varying s with $\tau = 0$

						u rates by type			formal		output	tax
s	θ	y^*	y^{**}	$R(y^*)$	$R(y^{**})$	med	high	total	$\overline{y}'$	$\overline{w}$	Y	revenue
0	1.21	0.315	0.410	0.315	0.243	0.037	0.091	0.086	0.639	0.579	0.459	0
.05	1.12	0.331	0.425	0.278	0.200	0.035	0.085	0.082	0.631	0.562	0.458	0.011
.1	1.03	0.345	0.439	0.240	0.153	0.031	0.079	0.078	0.617	0.544	0.453	0.019
.15	0.94	0.357	0.451	0.200	0.104	0.027	0.071	0.074	0.601	0.528	0.448	0.024
.2	0.85	0.368	0.458	0.158	0.049	0.021	0.061	0.068	0.578	0.510	0.440	0.028

Table 2: Effects of Varying τ with $s = 0$

						u rates by type			formal		output	tax
τ	θ	y^*	y^{**}	$R(y^*)$	$R(y^{**})$	med	high	total	$\overline{y}'$	$\overline{w}$	Y	revenue
0	1.21	0.315	0.410	0.315	0.243	0.037	0.091	0.086	0.639	0.579	0.459	0
0.05	1.19	0.331	0.434	0.331	0.257	0.039	0.093	0.087	0.647	0.560	0.459	0.016
0.1	1.17	0.347	0.459	0.347	0.272	0.040	0.095	0.088	0.656	0.540	0.458	0.030
0.15	1.15	0.363	0.484	0.363	0.287	0.041	0.098	0.088	0.665	0.524	0.456	0.042
0.2	1.12	0.378	0.511	0.378	0.302	0.043	0.100	0.089	0.675	0.509	0.455	0.052

Table 3: Results with $s = \tau = 0$ and $s = \tau = 0.1$

					u rates by type			formal		output	tax
θ	y^*	y^{**}	$R(y^*)$	$R(y^{**})$	med	high	total	$\overline{y}'$	$\overline{w}$	Y	revenue
1.21	0.315	0.410	0.315	0.243	0.037	0.091	0.086	0.639	0.579	0.459	0
0.98	0.380	0.495	0.275	0.186	0.035	0.084	0.081	0.636	0.509	0.451	0.046

Figure 1: $R(y)$ for Various (s, τ) Combinations

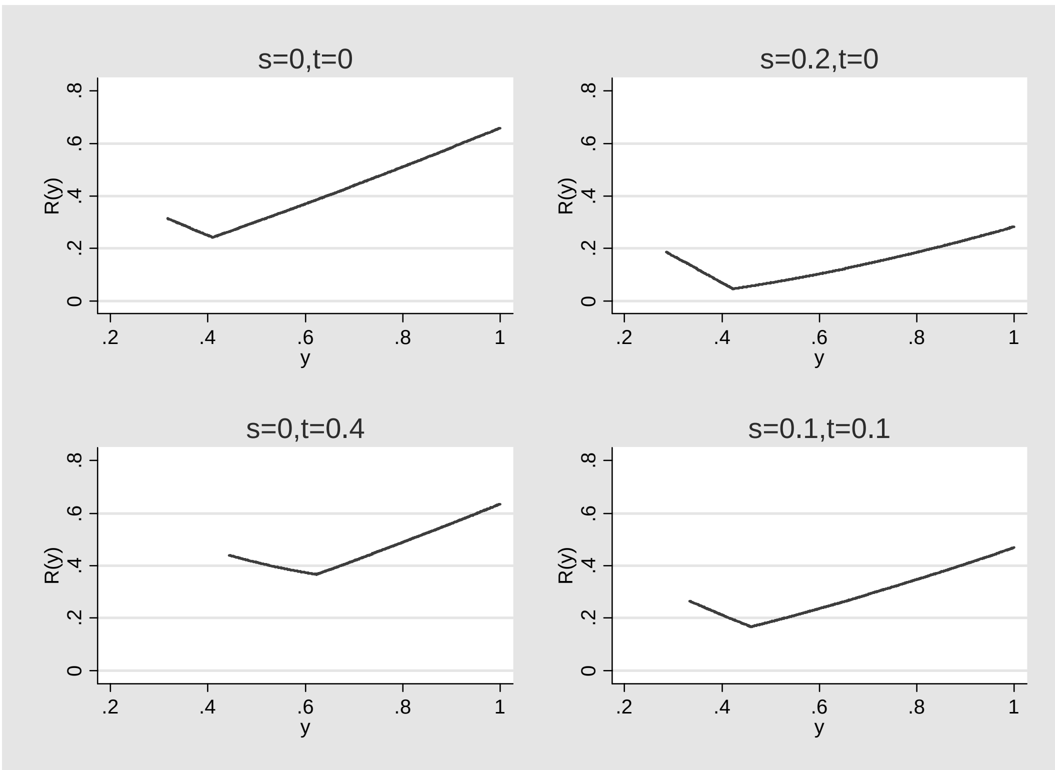

Figure 2: Densities of y and y' for Various (s, τ) Combinations

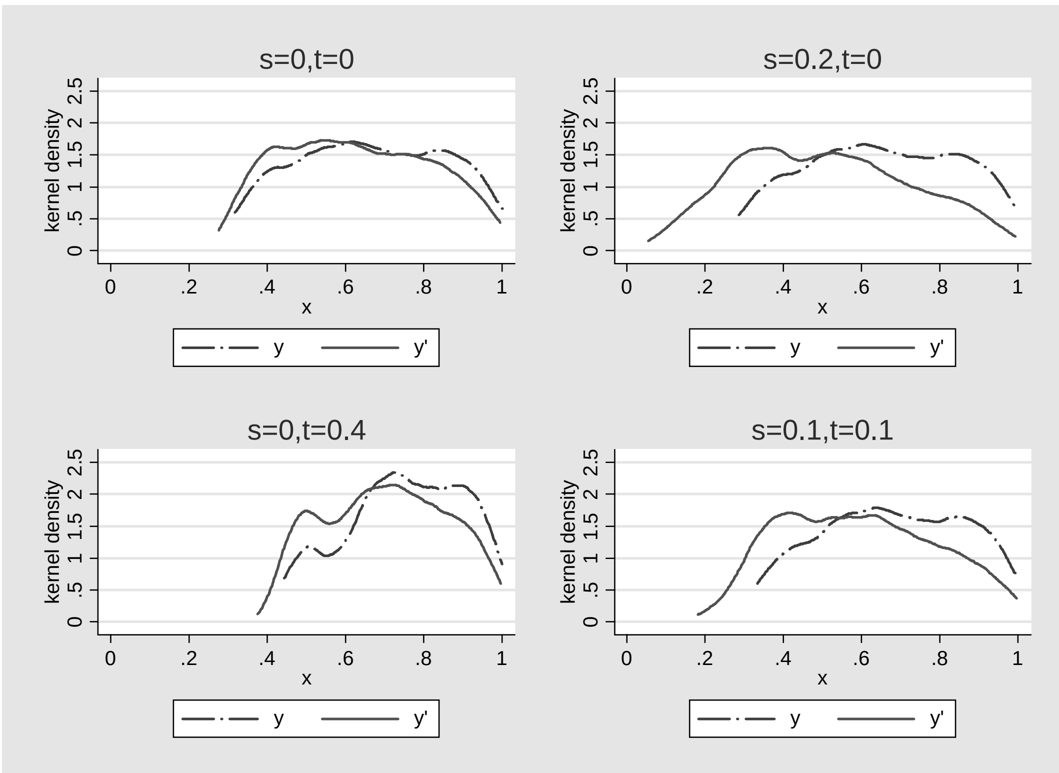

Figure 3: Densities of y' and w for Various (s, τ) Combinations