# Growth and labour markets in developing countries

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**Abstract**

In middle-income countries, the informal sector often accounts for a substantial fraction of urban employment. We develop a general equilibrium model with matching frictions in the urban labour market, the possibility of self-employment in the informal sector, and scope for rural-urban migration. We investigate the effects of different types of growth on wages and the informal sector, and the extent to which labour market institutions can influence aggregate productivity. We quantify these effects by calibrating the model to data for Mexico, a country with a sizeable informal sector and significant labour market rigidities.

**JEL classifications: J40, O10**

**Keywords:** informal sector, urban unemployment, dual economies, matching frictions

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## 1 Introduction

This paper is addressed at a critical question for development economists: how do growth and labour markets interact in poorer countries? At present, we know relatively little about how different types of growth translate into labour market outcomes. We know even less about the effects of labour market institutions on aggregate productivity and sectoral structure. In this paper, we introduce a small-scale general equilibrium model that can be used to address these questions.

The model features an urban manufacturing sector, an urban informal sector, and rural agriculture. Underemployment arises because of matching frictions in the formal sector labour market. In equilibrium, workers not employed in the formal sector can choose between self-employment in the informal sector, and working in the agricultural sector. The model is sufficiently rich to incorporate not only different types of growth, but also important real-world aspects of developing country labour markets, including continual mobility between sectors, employment protection, recruitment costs, and inefficiency in the worker-job matching process and the overall allocation of labour.

We calibrate the model to data for Mexico, a middle-income country often thought to be characterized by inefficient labour markets. Mexico's informal sector is often estimated to represent at least 30% of the urban workforce. We show that this is consistent with the equilibrium of the calibrated model under plausible assumptions about structural parameters. We then use the calibrated model to quantify the effects of different types of productivity growth on wages, underemployment, sectoral structure, urbanization and national income. Unusually, we also consider effects in the other direction, from labour markets to growth: how do labour market institutions influence sectoral structure, labour income and aggregate productivity?

Our paper is motivated by the observation that, in many developing countries, a significant fraction of the urban workforce is engaged in low-wage, low-productivity occupations - the "informal sector" identified by Hart (1973) and the 1972 ILO Employment Mission to Kenya (ILO, 1972). The relevant activities are those for which capital requirements and entry barriers are low, so that self-employment provides an alternative to more conventional employment. The existence of a large informal sector suggests that labour is under-utilized, with implications for aggregate productivity, poverty and inequality. It also raises the possibility that workers in the informal sector will be left behind by economic growth and policy initiatives, which primarily benefit those in the salaried formal sector. With this in mind, the descriptive literature on development policy often calls for "labour-intensive" growth, to draw workers out of the informal sector. Yet too many discussions can seem atheoretical, failing to acknowledge the interdependence of sectors, or to clarify the origins of underemployment.

If we are to address these questions, a general equilibrium analysis is essential.[1] Our multi-

[1]This point has been understood for many years. The potential importance of the informal sector, and the more general "employment problem" in developing countries, was established by a series of ILO country reports

sector model retains several features of the classic analysis due to Harris and Todaro (1970), but allows urban wages to be endogenously determined, along with sectoral structure and the size of the informal sector. As we will see, some predictions of the model are qualitatively similar to those of the Harris-Todaro model, but overall the new model has a richer structure and wider implications.

In the model, the urban informal sector and the rural sector are closely integrated. Workers can move between these sectors, and employment in either is instantly available. In contrast, it takes workers time to find jobs in the urban formal sector: the process by which workers are matched with formal sector firms is imperfect, without any kind of Walrasian auctioneer. This assumption naturally gives rise to a two-tier labour market in the urban sector. Underemployment arises not from an exogenously imposed wage rigidity, but from matching frictions in the urban labour market. This approach seems especially appealing for middle-income countries. Matching frictions and search theory have been successfully applied to the study of developed country labour markets, and there are no obvious reasons why urban labour markets in middle-income countries would have less substantial frictions.[2]

Given our emphasis on matching frictions, a natural starting point is the Mortensen-Pissarides model established in a series of papers, notably Mortensen and Pissarides (1994), and also set out in Pissarides (2000). We embed their approach to matching frictions within a specific factors model with three factors and two commodities: one commodity produced by the urban sector using labour and capital, and the other by rural agriculture using labour and land. In a variant of the basic model, we open the urban sector to international flows of capital, so that the capital stock in this sector is endogenously determined. We also consider two different assumptions about formal sector wage determination. For all versions of the model, we show that the equilibrium is unique and saddle-path stable, and examine the associated comparative statics. We also carry out an efficiency analysis, comparing the decentralized equilibrium with the social planning solution.

As this brief description makes clear, our main contribution is to use matching frictions to explain the importance of the informal sector in developing countries. At first sight, it may seem unlikely that matching frictions will be sufficient, by themselves, to yield a sizeable informal sector as an equilibrium outcome. Why don't formal sector firms create more jobs, and absorb the underemployed? Why don't underemployed urban workers choose to relocate to the rural agricultural sector? With these questions in mind, we explore the quantitative implications of

in the early 1970s. The favourable review of these reports by Thorbecke (1973) drew attention to the need for a general equilibrium approach in future work, but there are relatively few general equilibrium models for developing countries that specify urban labour markets in detail, and even fewer that quantify the relevant effects. We discuss the leading exceptions in section 2 below. An alternative approach to growth and inequality emphasizes the role of financial deepening, as in the work on Thailand of Jeong (2005) and Jeong and Townsend (2003).

[2] Pissarides (2000), Rogerson et al. (2005) and Yashiv (2005) provide recent surveys of search and matching models applied to developed country labour markets.

the matching model in detail, and show that a sizeable informal sector can be an equilibrium outcome under plausible assumptions.

Another attractive feature of the matching model is that workers are continually moving between the informal sector and higher-paid jobs in the formal sector. This is consistent with the high degree of labour market mobility identified by recent empirical studies, notably Maloney (1999, 2002), Gong and van Soest (2002) and Gong et al. (2004), using longitudinal data for Mexico. Their work has emphasized the degree of integration between different labour markets, in contrast to an older view that the formal and informal sectors are rigidly segmented. The extent of mobility between different labour market states appears high even relative to richer countries (Maloney 2002, Gong et al. 2004).

This helps to motivate our emphasis on matching frictions, since one strength of the matching approach is an explicit model for transitions between labour market states. Another strength, relative to other possible models of developing country labour markets, is that many of the relevant parameters and outcomes can be measured in the data. We use microeconometric studies to pin down structural parameters in our calibration exercise, and to obtain estimates of the formal sector wage premium that control for worker characteristics.

We should note some of the limitations of our analysis at the outset. The emphasis on matching frictions, and the stylized way we model the agricultural sector, suggest that our model is most relevant to middle-income countries. In poorer countries, with substantial poverty in rural areas, the effects of growth are likely to depend on the organization and institutions of agriculture.[3] The theoretical and quantitative analysis in this paper does not address these issues. Our modelling choices are more appropriate to middle-income countries, where the rural sector typically accounts for a much lower share of total employment, and where urban labour market frictions are perhaps more likely to resemble those in developed countries.

The modelling of the informal sector is also stylized. In the model, informal sector activity is characterized as a form of self-employment, requiring no capital, while firms in the formal sector use capital and must comply with employment protection legislation (firing costs and severance payments). These assumptions have most in common with the "dualist" view that informal sector activities are marginal, characterized by free entry and incomes that are essentially unrelated to the formal sector.[4] Also as in the dualist view, these activities provide an unofficial safety net in the absence of state-provided unemployment insurance. But the model also characterizes the informal sector as inherently more dynamic than in many dualist accounts. The sector can contribute a substantial share of GDP, and as emphasized above, workers are continually moving between the two tiers of the urban labour market.

[3]The importance of these considerations has been made clear by, for example, empirical research on the effects of technical progress in agriculture (especially the Green Revolution) on rural poverty in India. Basu and Mallick (2005) discuss some of the relevant considerations.

[4]This also means that we are locating the origins of the informal sector in the workings of the urban labour market, rather than in business taxes and regulations. de Soto (1989) and Loayza (1996) emphasize the role of the latter.

The remainder of the paper is organized as follows. Section 2 discusses some of the related literature and the background to this paper. Section 3 describes the model, while section 4 characterizes its steady-state. Section 5 considers the comparative statics. In sections 6 and 7 we first describe the assumptions of the calibration exercise, and then study the calibrated model's responses to changes in structural parameters; it is important to emphasize that we regard this quantitative investigation as a central contribution of the paper. Finally, section 8 concludes.

## 2 Background

A prime motivation for this paper is the lack of research on the interactions between growth and labour markets. Although the main source of income for the poor is labour income, the best-known growth models can rarely accommodate different types of growth, and have little to say on how growth translates into labour income for the poor. For the most part, growth economics and labour economics have proceeded independently of one another. As a result, the effects of growth on labour markets are rarely studied, and the origins of "high-quality" or "pro-poor" growth remain more talked about than understood (Agénor 2005a). Meanwhile, although many developing countries seem to be characterized by inefficient labour market outcomes, we know relatively little about their causes and effects.

In seeking to address these questions, the current paper is related to a number of previous contributions, which we describe in this section. The model we put forward is squarely in the long-standing dual economy tradition, in which an urban, non-agricultural sector coexists with a sizeable agricultural sector.[5] These models can often be seen as specific departures from the standard 2 x 2 or 3 x 2 general equilibrium models of production used in trade theory. As noted in the introduction, our model has the same basic structure as the 3 x 2 model with three factors and two commodities.

One of the most influential dual economy models is that of Harris and Todaro (1970), and there is a sense in which our paper is a response to that classic analysis. It is therefore useful to describe the 2 x 2 version of the Harris-Todaro model introduced by Corden and Findlay (1975). Consider a small open economy with two sectors, in which both goods can be traded internationally at world prices. One sector is urban non-agriculture, and the other rural agriculture. There are two factors, capital and labour, each in fixed supply. There are constant returns to scale and perfect competition in each sector, and factors receive their marginal products. Perfect intersectoral capital mobility means that the returns to capital are equalized between the two sectors.

If labour is also perfectly mobile between sectors and wages in each sector are flexible, we then have the textbook 2 x 2 trade theory model. Instead, the Harris-Todaro model assumes

[5] For surveys of the dual economy literature see Kanbur and McIntosh (1988) and Temple (2005).

that the urban wage is exogenously fixed above the market-clearing level. This generates urban unemployment. If workers are risk neutral, and jobs in the urban sector are allocated by a lottery, the long-run migration equilibrium occurs when expected incomes in the two sectors are equal. Formally, the equilibrium condition is $uz + (1-u)\bar{w}_m = w_a$ where $u$ is the (endogenous) urban unemployment rate, $z \geq 0$ is unemployment income, $\bar{w}_m$ is the fixed urban wage and $w_a$ the market-clearing rural wage.

The Harris-Todaro version of the 2 x 2 model has some interesting properties. It can explain why rural-urban migration persists even in the face of high urban unemployment: workers are willing to bear the risk of urban unemployment, because locating in the city brings with it the possibility of higher wages. Combined with migration, this leads to powerful and sometimes counter-intuitive general equilibrium effects. For example, a productivity improvement in the urban sector can generate extra rural-urban migration and therefore increase the number of unemployed. This is the "Todaro paradox", where urban employment creation is not accompanied by any decline in urban unemployment.

The elegance of the Harris-Todaro model comes at a price. The assumption that the urban wage is exogenously fixed above the market-clearing level is unattractive, especially if we want to study the long-run consequences of productivity growth. It is also intellectually unsatisfying. Given that underemployment seems pervasive in the developing world, appealing to an institutionally determined urban wage is disconcertingly simplistic. Although powerful trade unions or minimum wage legislation may play a role in some poorer countries, this is unlikely to be the case everywhere, and a more general explanation seems desirable.[6]

These points are not new, and papers by Agénor (2004, 2005a, 2005b, 2005c), Bencivenga and Smith (1997), Brueckner and Zenou (1999), Calvo (1978), Krebs and Maloney (1999), Laing et al. (2004), MacLeod and Malcomson (1998), Moene (1988) and Stiglitz (1974, 1976, 1982) all develop models in which the urban wage is endogenously determined. Relative to many of these papers, our analysis is distinctive in its investigation of the quantitative implications of the model, and in offering a unified approach to the analysis of labour market outcomes in developed and developing countries; the developing country case is distinguished mainly by the possibility of rural-urban migration.

We briefly discuss some of these previous contributions. In the Moene (1988) efficiency-wage reformulation of the Harris-Todaro model, the equilibrium urban wage must be above the market-clearing level in order to deter shirking, and this gives rise to equilibrium unemployment. As in our work, a key element of Moene's analysis is a migration equilibrium condition that equates the present value of urban unemployment to the present value of rural wages. Moene's paper derives some simple comparative static results, but does not explore the model's quantitative properties. We will use a similar efficiency wage analysis as one of the mechanisms

[6] For our main focus, Mexico, minimum wages appear to have been too low to be a binding constraint on the formal sector (Bell 1997). This suggests the reasons for Mexico's large informal sector must be sought elsewhere.

for dividing the match surplus that arises in our model.

In the more detailed analysis of Bencivenga and Smith (1997), unemployment arises because of the presence of two types of workers who differ in their productivity, leading to an adverse selection problem in the urban labour market (see also Eicher 1999). Bencivenga and Smith study the effect of capital accumulation within this model, finding similar effects to those in Harris-Todaro: for example, capital accumulation can raise urban unemployment. They emphasize the associated dynamics, and the possibility of multiple equilibria.

MacLeod and Malcomson (1997) analyse a two-sector model in which workers can be motivated by either efficiency wages or bonus schemes (performance pay). One sector is relatively labour-intensive, and can be interpreted as a rural agricultural sector. In equilibrium, the two sectors may use different reward schemes, and this generates a rural-urban wage differential. They simulate the response of this economy to a fall in the cost of creating urban sector jobs, and examine the implications for unemployment, total output, wages in the two sectors, and the Gini coefficient. Their model is especially innovative in allowing equilibrium reward schemes to arise endogenously, but their simulations consider fewer experiments, and proceed under simpler assumptions, than those we discuss below.

In purely theoretical terms, the papers closest to ours are Laing et al. (2004) and Zenou (2005). As in our work, these authors consider an urban labour market with matching frictions in the context of a dual economy.[7] The Laing et al. (2004) model is primarily designed to apply to China, and assumes that a fraction of the workforce are legally required to work in rural areas (a form of migration restriction) but may seek urban work illegally. This makes some aspects of the model more complex than ours, but they simplify the analysis by assuming that the average product of labour is fixed in each sector. In our model, these average products are endogenously determined. A more important difference between the papers is that we explore efficiency and the quantitative implications of matching frictions, whereas Laing et al. and Zenou focus on comparative statics, and do not explore the ability of their models to match the data.

Our paper is also related to previous work that embeds search frictions in trade models, as in Davidson et al. (1999) and Waelde and Weiss (2005). These papers concentrate on theoretical results, and especially the extent to which standard trade-theoretic results generalize in the presence of search frictions. Again, they do not consider quantitative implications in detail. Their analyses give less emphasis to the rural-urban distinction, and explicit applications to developing countries, than either our paper or Laing et al. (2004).

When matching models are applied to developing countries, as in Laing et al. (2004), Zenou (2005) and this paper, there will typically be a formal connection with models of developed country labour markets that consider endogenous participation in the labour force. These papers include Garibaldi and Wasmer (2005) and Haefke and Reiter (2005). In our model, workers who

[7]See also Krebs and Maloney (1999), who briefly discuss how their turnover cost model could integrate matching considerations.

choose rural employment behave rather like workers who choose not to participate, at least if the returns to nonparticipation are heterogeneous across individuals (corresponding to variation in rural wages as workers move in and out of the rural sector). Our assumptions on the agricultural technology, by pinning down the response of nonparticipation returns to variation in the size of the rural sector, determine the specific pattern of this heterogeneity. We can also reinterpret any fixed cost associated with moving between participation and nonparticipation as a rural-urban migration cost. The remaining departures in our analysis, beyond the developing country interpretation, are that we allow the urban capital stock to be endogenous, and consider two theories of urban wage determination.

Looking further afield, our work is related to computable general equilibrium models with relatively detailed labour market structures, including Devarajan, Ghanem and Thierfelder (1997, 1999), Maechler and Roland-Holst (1997) and Thierfelder and Shiells (1997). These papers often focus on trade policy issues, rather than seeing the interaction between growth and labour markets as interesting in its own right. Our analysis is also related to calibrations of search and matching models for developed countries, notably Andolfatto (1996), Cole and Rogerson (1999), Den Haan, Haefke and Ramey (2005), Den Haan, Ramey and Watson (2000), Garibaldi and Wasmer (2005), Ljungqvist and Sargent (2004) and Merz (1995). Our calibration draws on some of their assumptions, especially those of Andolfatto (1996), but we do not study the dynamics of adjustment or the propagation of shocks. Instead, we are chiefly interested in whether the steady-state of the model is consistent with a sizeable informal sector, and in the response of equilibrium outcomes to different types of growth. Another key difference from previous research is that we quantify the effect of various labour market parameters, such as the efficiency of the matching process, on sectoral structure and aggregate productivity, questions that are rarely addressed elsewhere.

# 3 The model

As noted in the previous section, our analysis uses a specific factors (3 x 2) model of a small open economy with two sectors, urban and rural, that has been extended to include a more detailed specification of the urban labour market. The outputs of the urban formal sector and the rural agricultural sector can each be traded on world markets at an exogenous relative price. We treat agricultural output as the numeraire, and choose units for urban output such that its price can also be normalized to one. When we analyze the effects of 'growth', we will achieve this by considering a large shock to the level of TFP in either the rural or urban sector.[8]

[8] One possible response is that our model can say little about the effects of growth, because it does not consider a model with a balanced growth path. We think this objection is misplaced. Some important forms of growth - an obvious example would be the Green Revolution in agricultural technologies - will be best studied using step-changes in the level of TFP parameters. See also Solow (2000, p. 100), who argues that the conventional emphasis on steady-state growth is misplaced, and risks falling into a semantic trap.

As is common in the dual economy literature, we model the rural (agricultural) sector as perfectly competitive, and characterized by constant returns to scale and full employment. The structure of the urban sector is more complicated. Urban workers are either employed by a firm in the formal sector, or self-employed in the informal sector. While working in the informal sector, workers can also look for higher-paid jobs in the formal sector, with a variable degree of search effort. Workers and job vacancies are matched as in the standard Mortensen-Pissarides model, incorporating a role for capital in the formal sector.

Once matched, the surplus that arises is divided according to either Nash bargaining or efficiency wage considerations. As well as two different wage setting assumptions, we have two possible assumptions about the capital account. When the capital account is closed, the urban capital stock is treated as exogenously fixed. When the capital account is open, the marginal product of formal sector capital must equal the world real interest rate in equilibrium, and hence the urban capital stock is endogenously determined. The two possible assumptions for both wage setting and capital mobility mean that, throughout the paper, we consider four different versions of the model.

### 3.1 Notation and model structure

The economy is populated by a continuum of identical workers of measure one. Let the two sectors be indexed by $i$ with $i = a$ denoting agriculture and $i = m$ denoting the urban (manufacturing) sector, and let $L_i$, $K_i$ and $k_i$ be the mass of workers, the capital stock and the capital stock per employed worker in sector $i$ respectively. The capital stocks are sector-specific, and so agricultural "capital" can be interpreted as land.

Informal sector workers account for a proportion $u$ of the urban labour force; for simplicity, we call this the urban unemployment rate, and often use the term "unemployment" as a convenient shorthand for the informal sector.[9] Note that $L_a + L_m = 1$, while formal sector employment is given by $(1-u)L_m$. The capital-labour ratios in the two sectors are $k_a = K_a/L_a$ and $k_m = K_m/((1-u)L_m)$ respectively.

All workers are risk neutral. In agriculture, each worker produces $g(k_a)$ where $g(k_a)$ is the agricultural production function in intensive form. The worker is paid a wage $w_a$ and obtains a utility stream $w_a + x_a$ where $x_a > 0$ indicates a preference for living outside the city. Since the agricultural sector is perfectly competitive we can write

$$w_a = g(k_a) - g'(k_a)k_a = w_a\left(\overset{+}{L}_m; \overset{+}{K}_a\right) \quad (1)$$

where $g'(k_a) = r_a$ is the rental cost of the fixed factor in agriculture. The semi-colon in the

[9]This usage is less casual than it may seem. It relates to "productivity definitions" of unemployment in which workers are classed as unemployed when below a threshold level of productivity. This is sometimes a more relevant definition of unemployment for developing countries. The absence of unemployment insurance means that open unemployment is rare and mainly confined to the educated and well-off.

r.h.s. of (1) separates endogenous variables from exogenous variables, and we use this notation throughout the paper.

The urban labour market is modelled along similar lines to Pissarides (2000). Relative to the simplest models he describes, the main complications are that we allow workers to choose to locate in either urban areas or agriculture, include firing costs in the urban formal sector, and that we allow endogenous search intensity on the part of informal sector workers. The motivation for including search intensity is to model discouraged worker effects: as the informal sector becomes large, and job-finding probabilities low, workers may devote relatively little time to active search.

Production in the formal sector is undertaken by one-worker firms. To enter production, a new formal sector firm must post a vacancy. This involves a flow cost $c$ for the duration the vacancy is open. It is important to note that we interpret the act of entry and posting a "vacancy" more broadly than usual. In the developing country context, it may not involve a formal advertisement or use of a labour exchange, but instead the engagement of time and resources in alternative ways of recruiting workers. These could include the use of senior workers or employment brokers to identify employees through social networks, a possibility noted in Collier (1975) and Mazumdar (1983).

Open vacancies are filled at an (endogenous) Poisson rate $q$. Once a vacancy has been filled, the firm agrees a wage $w_m$ with the worker and hires capital $k_m$. The firm's output is given by $A_m f(k_m)$ where $A_m$ is a TFP parameter and $f(k_m)$ is a standard constant returns production function in intensive form. The process of formal sector wage determination will be discussed later.

The firm-employee match continues until its productivity is destroyed by a firm-specific shock, which means that production is no longer profitable. Job destruction occurs at an exogenous Poisson rate $\lambda$. At this point the firm's capital is released for rental by other firms, and the worker moves into the informal sector. The firm incurs a firing cost $F$ and must also make a severance payment $P$ to the departing employee. We include these costs in the model because of their importance for the Mexican labour market, the focus of our calibration exercise in sections 6 and 7 below.

As is standard, our assumptions lead to Bellman equations that define the present value of each possible state. We consider workers first, and then firms. For workers, the present value of working in the informal sector is $U$, while formal sector employment is associated with a present value of $W$. The discount rate is denoted by $r$. We make the standard assumption that workers who migrate from agriculture first enter the informal sector. For now, we will also assume that the city is initially small, so that migration flows from agriculture to the city, denoted $f$, are positive. Migration in either direction involves a cost $B + b\,|f|$, where the parameter $b$ represents a congestion effect in the level of migration. The migration equilibrium condition is that agricultural workers are indifferent between staying in agriculture and migrating:[10]

$$w_a + x_a + r(B + bf) = rU \tag{2}$$

In the formal sector, each worker receives a utility stream equal to her wage $w_m$. In the informal sector, each worker receives a utility stream given by $z - \sigma(s; z, \Pi)$. Here $z$ represents a fixed level of output associated with full-time self-employment, while $\sigma$ is the cost associated with searching for a formal sector job (perhaps foregone output) and $\Pi$ indexes exogenous influences on search costs. These search costs $\sigma(s; z, \Pi)$ and the marginal costs of search $\sigma_s(s; z, \Pi)$ are assumed to be increasing in $s$, $z$ and the shift parameter $\Pi$. There are no entry costs associated with the informal sector, which is consistent with empirical evidence for Mexico in McKenzie and Woodruff (2004).

We consider a symmetric equilibrium where all unemployed workers search at the same intensity $s$ for a formal job, and face the same probability $\bar{q}$ of being matched with a vacancy. The Bellman equations for workers are then:

$$rU = z - \sigma + \bar{q}(W - U) + \dot{U} \tag{3}$$

$$rW = w_m + \lambda(U - W + P) + \dot{W} \tag{4}$$

For firms, we denote the present value of a vacancy by $V$ and the present value of a filled job by $J$. We use $v$ to denote the vacancy rate, which is the ratio of vacancies to the mass of individuals in the urban sector. The Bellman equations for firms are

$$rV = -c + qJ + \dot{V} \tag{5}$$

$$rJ = y(k_m) - w_m - \lambda(J + F + P) + \dot{J} \tag{6}$$

where $y(k_m) = A_m f(k_m) - A_m f'(k_m)k_m$ is the firm's output net of capital costs (or the marginal product of labour).

Given that we assume free, instantaneous entry into the creation of vacancies, the zero-profit condition

$$V = 0 \tag{7}$$

is assumed to hold continuously.

The matching rates $q$ (for a firm filling a vacancy) and $\bar{q}$ (for a worker finding formal sector

[10] When migration costs $B$ are strictly positive, there are multiple equilibria. An equilibrium in which no further migration will take place is given by $w_a + x_a + \chi rB = rU$ where in general $\chi$ can take any value in the interval $[-1, 1]$. For example if agriculture is initially small and workers migrate from the city to agriculture, then migration will cease when $w_a + x_a - rB = rU$, so $\chi = -1$. This does not affect the baseline calibration, where we effectively infer a value for $x_a + \chi rB$, but does affect the comparative statics results and is discussed further where appropriate. Unless otherwise stated, we will either proceed with the assumption that $B = 0$ or describe the equilibrium with $\chi = 1$.

employment) are endogenous. Our treatment of the matching process is again standard. The number of matches at each instant depends on the search efforts of the informal sector workers, and the number of open vacancies. We write the number of matches as an increasing function $m(suL_m, vL_m; M)$ of total search effort by the unemployed. The first argument is the number of unemployed $uL_m$ multiplied by their average search intensity $s$, and the second argument the number of open vacancies $vL_m$. Finally an exogenous shift parameter $M$ is used to index the efficiency of the matching process. In line with empirical work for developed countries, the function $m(.)$ is assumed to have constant returns to scale.[11]

Each firm with an open vacancy faces an identical probability of being matched with a worker, which is

$$q = \frac{1}{vL_m} m\left(suL_m, vL_m\right) = m\left(\frac{su}{v}, 1\right) = q(\overset{-}{\tau}; \overset{+}{M})$$

where the second equality follows from constant returns, and we define $\tau \equiv v/su$ as a measure of labour market "tightness". Note that $q(\tau; M)$ and $\tau q(\tau; M) = m(1, \tau; M)$ are respectively decreasing and increasing in $\tau$, and both increasing in matching efficiency $M$.

We now examine the decision problem of informal sector workers, who must decide how actively to search for a formal sector job. Different workers will face different probabilities of being matched with a vacancy, if they search with different levels of intensity. Suppose an informal sector worker indexed by $i$ with a present value of future earnings $U_i$ searches at intensity $s_i$ while all others search at intensity $s$. Her matching rate $\bar{q}_i$ is assumed to be proportional to relative search intensity $(s_i/s)$ so

$$\bar{q}_i = \frac{s_i}{suL_m} m\left(suL_m, vL_m\right) = s_i m(1, \tau; M) = s_i \tau q$$

If we equate this worker's marginal search costs $(\sigma_{s_i})$ and expected benefits $(\frac{d\bar{q}_i}{ds_i}(W - U_i))$ from search, and then impose $U_i = U$ and $s_i = s$ to obtain symmetry, we get the first-order condition for search intensity:

$$\sigma_s(s; z, \Pi) = \tau q(W - U) \tag{8}$$

We also have $\bar{q} = s\tau q$ and so from (3):

$$rU = \zeta + \dot{U} \tag{9}$$

where

$$\zeta(\overset{+}{s}; z, \Pi) = z + (\phi(s; z, \Pi) - 1)\sigma(\overset{+}{s}; \overset{+}{z}, \overset{+}{\Pi})$$

[11] In our calibration we use the standard Cobb-Douglas specification $m(su, v) = M(su)^{\eta} v^{1-\eta}$. The assumption of constant returns is consistent with empirical evidence (Petrongolo and Pissarides 2001) and Cobb-Douglas can elegantly be justified by the theoretical microfoundations given in Stevens (2002).

Here $\phi$ is the elasticity of search costs with respect to $s$. Note that, since the marginal cost of search is increasing in s, the function $\zeta(\overset{+}{s}; z, \Pi)$ is increasing in $s$. We will typically assume that the elasticity $\phi$ is a constant which must then be greater than one.

Finally, we note some useful relationships. From (5) and (7) we have a simple condition for the present value of a filled job:

$$J = \frac{c}{q} \tag{10}$$

Adding (6) to (4) and subtracting (9), while substituting for $J$ from (10), gives:

$$(r+\lambda)\left(\frac{c}{q} + W - U\right) = y(k_m) - \lambda F - \zeta + (\dot{J} + \dot{W} - \dot{U}) \tag{11}$$

To complete the model, we need to specify the determination of the formal sector wage. As in standard models with matching frictions, a match is associated with rents that must be divided between workers and firms, and the formal sector wage determines the allocation of the surplus. We consider two different theories: a Nash bargaining process, and efficiency wages. This will allow us to derive an expression for $W - U$ that holds in and out of steady state.

### 3.2 Wage bargaining

The most common approach in matching models is to assume that rents are divided according to a generalized Nash bargaining solution. Using the parameter $\beta \in (0,1)$ to index worker bargaining power, a wage bargain $i$ in the formal sector leads to a wage $w_{m,i}$ such that

$$w_{m,i} = \arg\max (W_i - U)^{\beta} (J_i - V)^{1-\beta}$$

which since $\frac{\partial W_i}{\partial w_{m,i}} = -\frac{\partial J_i}{\partial w_{m,i}}$ yields the following symmetric outcome

$$(1-\beta)(W - U) = \beta (J - V) \tag{12}$$

Here we assume that the relevant disagreement point, and hence the bargained wage, is independent of firing costs. Implicitly, we are assuming that if workers "walk away" from the bargaining process, the firm is not liable to pay a firing cost. Under this assumption we can allow for firing costs and continuous renegotiation, without the need to distinguish an outside wage, bargained before employment, from an inside wage bargained after employment has begun (for a discussion of this distinction see Pissarides, 2000). The need to allow wages to evolve would make our later calibration unnecessarily complex, and instead we effectively assume that the outside wage always prevails.

### 3.3 Efficiency wages

An alternative way of dividing the surplus is to appeal to efficiency wage considerations. For simplicity, we consider a simple model where the formal sector wage is used to deter shirking, as in Moene (1988). If a formal sector worker shirks he obtains a certain gain $G$ at the risk of being caught and fired with probability $\pi$; if detected, shirking is verifiable and the worker receives no severance pay in this case. We assume that firms will find it optimal to set the wage sufficiently high to deter shirking. Writing down the Bellman equations for shirking and non-shirking workers implies that the wage $w_m$ will have to ensure

$$W - U = \frac{G}{\pi} \equiv X, \text{ say} \tag{13}$$

where we assume that workers who are indifferent do not shirk. Rather than treat $X$ as known, our calibration for the efficiency wage case will back out a value for this parameter. From a theoretical point of view, the key difference from the Nash bargaining case is that $W - U$ is fixed rather than endogenous, with implications for how the economy responds to productivity growth and other parameter changes. In terms of matching the data when we turn to the calibration, the efficiency wage assumption has another consequence: under this assumption, it may be easier to justify workers receiving a large share of the match surplus than when wages are set according to a Nash bargain.

## 4 Steady state

In the Mortensen-Pissarides model the steady-state is unique and saddle-path stable, under standard assumptions. Our specification of the urban labour market follows that model closely, and migrants respond to utility differences between the urban and rural sectors in a way that should be stabilizing. Hence when the fixed cost of migration is zero ($B = 0$) and the equilibrium is unique, we would expect this model to have similar stability properties. Appendix A shows that this is the case for all four variants of the model. When $B > 0$ there is a continuum of equilbria (see footnote 10) and hence perturbations are likely to cause a shift from one equilibrium to another.

We now characterize some properties of the steady-state. Our conditions for a steady state are as follows. We set migration flows $f = 0$ in the migration condition (2) and impose $\dot{U} = \dot{W} = \dot{V} = \dot{J} = 0$ in equations (3) to (6). In the open capital account case, we require the marginal product of capital to be equal to the world interest rate. Finally, we require that in steady state, the inflows and outflows for the informal sector ("unemployment") must balance:

$$\lambda(1 - u) = m(\overset{+}{su}, \overset{+}{v}; \overset{+}{M}) \tag{14}$$

or equivalently,

$$\frac{\lambda(1-u)}{u} = s\tau q(\overset{-}{\tau}, \overset{+}{M}) \tag{15}$$

From (2) and (9), we also have

$$w_a\left(\overset{+}{L}_m; \overset{+}{K}_a\right) + x_a + rB = \zeta(\overset{+}{s}; z, \Pi) \tag{16}$$

We now solve all four possible versions of the model: under Nash bargaining or efficiency wages, and a fixed or endogenous urban capital stock (the latter corresponding to an open capital account). In all cases, the model can be reduced to two equations in two unknowns, which allows a straightforward analysis of the comparative statics in section 5 below.

### 4.1 Wage bargaining

From (7), (8), (10) and (12),

$$\sigma_s(\overset{+}{s}; \overset{+}{z}, \overset{+}{\Pi}) = \tau q(\overset{-}{\tau}; \overset{+}{M})\,(W-U) = \frac{\beta}{1-\beta}\tau q(\overset{-}{\tau}; \overset{+}{M})\,(J-V) = \frac{c\tau\beta}{1-\beta} \tag{17}$$

from which,

$$\tau = \tau\left(\overset{+}{s}; \overset{+}{z}, \overset{+}{\Pi}, \overset{-}{c}, \overset{-}{\beta}\right) \tag{18}$$

Substituting for $W-U$ in the steady state version of (11), we obtain

$$\frac{r+\lambda}{1-\beta}\left(\frac{c}{q(\overset{-}{\tau}; \overset{+}{M})}\right) = y(k_m) - \lambda F - \zeta(\overset{+}{s}; z, \Pi) \tag{19}$$

The behaviour of $k_m$ depends on our assumption regarding the capital account. With an open capital account, the urban capital stock $K_m$ adjusts until the return on capital in the formal sector is equal to the world real interest rate. Given our assumption of constant returns to scale, this implies that the formal sector capital-labour ratio $k_m$ is exogenous. Given (18), the relations (16) and (19) form a system of two equations in two unknowns, $s$ and $L_m$. Given the solutions for search intensity $s$ and "city size" $L_m$ we can then solve the remainder of the system.

With a closed capital account, $K_m$ is assumed exogenous, and the urban capital-labour ratio $k_m$ is given by $k_m = K_m/((1-u)L_m)$. From (15) and (18), $u = u\left(\overset{-}{s}; \overset{+}{\lambda}, \overset{-}{M}, \overset{-}{z}, \overset{+}{c}, \overset{+}{\beta}\right)$. Then we have

$$k_m = \frac{K_m}{(1-u)\,L_m} = k_m\left(\overset{-}{s}, \overset{-}{L}_m; \overset{+}{K}_m, \overset{+}{\lambda}, \overset{-}{M}, \overset{-}{z}, \overset{+}{c}, \overset{+}{\beta}\right) \tag{20}$$

Again, (19) and (16) form a system of two equations in two unknowns, $s$ and $L_m$.

## 4.2 Efficiency wages

From (8), (13), and (15)

$$\sigma_s(\overset{+}{s};\overset{+}{z},\overset{+}{\Pi}) = \tau q(\overset{-}{\tau};\overset{+}{M})\,(W-U) = \tau q(\overset{-}{\tau},\overset{+}{M})X = \frac{\lambda\,(1-u)}{us}X \tag{21}$$

from which, since $\tau q(\overset{-}{\tau};\overset{+}{M})$ is increasing in $\tau$ and $M$,

$$\tau = \tau\left(\overset{+}{s};\overset{+}{z},\overset{+}{\Pi},\overset{-}{X},\overset{-}{M}\right) \tag{22}$$

Substituting for $W-U$ in the steady-state version of (11), we obtain

$$(r+\lambda)\left(\frac{c}{q(\overset{-}{\tau};\overset{+}{M})}+X\right) = y(k_m) - \lambda F - \zeta(\overset{+}{s};z,\Pi) \tag{23}$$

Again, for an open capital account, we treat $k_m$ as exogenous, so using (22), the relations (16) and (23) form a system of two equations in $s$ and $L_m$. For a closed capital account, from (21), we can see that $u = u\left(\overset{-}{s};\overset{+}{\lambda},\overset{+}{X},\overset{-}{z},\overset{-}{\Pi}\right)$, and so:

$$k_m = \frac{K_m}{(1-u)\,L_m} = k_m\left(\overset{-}{s},\overset{-}{L}_m;\overset{+}{K}_m,\overset{+}{\lambda},\overset{+}{X},\overset{-}{z},\overset{-}{\Pi}\right) \tag{24}$$

and (16) and (23) once again form a system of two equations in two unknowns.

One point to note about the systems of equations, in all four cases, is that the solutions for search intensity and city size are independent of the severance payment $P$. The payment is a pure transfer, and so changes in $P$ are exactly offset by a change in the formal sector wage in the opposite direction, with no other effect on equilibrium outcomes. Nevertheless, $P$ will play an important role in the baseline of the calibrated model. In matching differences in formal and informal sector income (and hence utilities) we need to use not only microeconometric estimates of wage differentials, based on hourly earnings, but also expected severance pay. We discuss this in more detail in section 6 below.

## 4.3 Efficiency

As is well known, matching frictions imply the presence of nonpecuniary externalities to decisions by workers and firms, and so the market equilibrium will typically be inefficient. In standard models, the decentralized equilibrium is efficient only under the well-known Hosios (1990) condition, namely that the surplus is allocated so that the worker's share ($\beta$ in the wage bargaining case) is equal to the elasticity of the matching function with respect to $su$. As shown in Appendix B, this condition also ensures efficiency in our model. This is not a surprise given the similarity between our setup and developed country models with endogenous participation, in which efficiency can be established under the same condition (see for example Garibaldi and Wasmer 2005).

In the open capital account case, we also have the standard property that when the Hosios condition is not satisfied, the level of search is too low. From (16), a corollary is that the size of the city will then be too small. This is, however, not the case when the capital account is closed. If formal sector employment rises, the fixed capital stock implies that the capital-labour ratio falls. This exerts a downwards force on formal sector productivity and wages that may offset other effects, reducing efficiency and the welfare of unemployed workers. This feature of the closed capital account case will also be evident in the comparative statics below. It implies that, if the worker receives too much of the surplus, the level of search and consequently the size of the city can be too large, and excess search intensity is associated with an inefficiently high level of employment in the formal sector.

## 5 Comparative statics

The following comparative statics are derived under the assumption that migration is costless ($B = 0$) and the equilibrium is unique. The more general case where $B > 0$, which is slightly more complicated, will be discussed at the end of this section.

For both the wage bargaining and efficiency wage models, the migration condition (16) and the job creation curve, (19) or (23), describe two curves in ($s$, $L_m$) space. Putting search intensity $s$ on the horizontal axis, the migration condition is upward sloping. The job creation curve is downward sloping with a closed capital account, and vertical with an open capital account. We provide an example in figure 1, for the effects of an increase in urban TFP, under the assumption of Nash bargaining. Many of the comparative static results below are obtained by analysing which way the job creation curves, (19) and (23), and the migration condition (16) move following a parameter change.[12]

In studying effects on the formal sector wage, we use a standard property of matching models with Nash bargaining. The steady-state wage can be written as a weighted average of the marginal product of labour and a worker's outside option (for example, Merz 1995). The wage moves closer to the marginal product of labour as the worker's bargaining strength increases. Here we have,

$$\begin{aligned} w_m + \lambda P &= \beta(MPL - \lambda F) + (1-\beta) rU \\ &= \beta(MPL - \lambda F) + (1-\beta)(w_a + x_a) \end{aligned}$$

[12] In the closed capital account case, it is sometimes also helpful to draw the curves in $(s, k_m)$ space, by inverting (20) or (24) to express $L_m$ as a function of $k_m$, $s$ and parameters.

| Rise in : / Effect on: | $A_a$ | $A_m$ | $M$ | $F$ | $c$ | $\lambda$ | $\Pi$ | $x_a$ |
|---|---|---|---|---|---|---|---|---|
| Migration Condition | $\uparrow$ | $=$ | $=$ | $=$ | $=$ | $=$ | $\downarrow$ | $\uparrow$ |
| Job Creation Curve | $=$ | $\uparrow$ | $?/\uparrow$ | $\downarrow$ | $?/\downarrow$ | $?/\downarrow$ | $\downarrow$ | $=$ |
| $s$ | $+/=$ | $+$ | $?/+$ | $-$ | $?/-$ | $?/-$ | $-$ | $+/=$ |
| $u$ | $-/=$ | $-$ | $-$ | $+$ | $+$ | $+$ | $+$ | $-/=$ |
| $L_m$ | $-$ | $+$ | $?/+$ | $-$ | $?/-$ | $?/-$ | $-$ | $-$ |
| $w_a$ | $+$ | $+$ | $?/+$ | $-$ | $?/-$ | $?/-$ | $-$ | $-$ |
| $w_m$ | $+$ | $+$ | $?/+$ | $-$ | $?/-$ | $?/-$ | $?/-$ | $+$ |
| $(1-u)L_m$ | $-$ | $+$ | $+$ | $-$ | $-$ | $-$ | $-$ | $-$ |

Table 1: Wage bargaining, with a closed/open capital account

where the left-hand side is formal sector labour income including expected severance pay, and $MPL$ denotes the marginal product of labour for a formal sector firm before expected firing costs are taken into account.[13]

Several points are worth briefly noting. (1) The question marks in tables 1 and 2 represent genuine ambiguity, in that the relevant effects may be positive or negative, depending on the parametrization. (2) The results for the change in search costs $\Pi$ are obtained under the assumption that $\phi$, the elasticity of search costs with respect to $s$, is constant. (3) Given that the severance payment $P$ is a pure transfer, influencing only the urban wage $w_m$, we do not include it in the tables. (4) Neither do we study the effect of an increase in self-employment productivity ($z$): this always lowers search intensity and raises the unemployment rate, but other effects are harder to establish.[14]

It is interesting to note how the results in Table 1 and 2 can be used to think about the incidence of poverty. In the model, formal sector workers are better off than those in the informal sector and agriculture (in steady-state, we have $W > U$). If we think of a poverty threshold defined in utility terms to be above $U$ and below $W$, then the number in poverty is $L_a + uL_m = 1 - (1-u)L_m$. On this definition, given a parameter change and holding $x_a$ fixed, sufficient conditions for a reduction in poverty are that formal sector employment $(1-u)L_m$ increases and the rural wage does not fall.

We now discuss some of the comparative statics in more detail. First, we consider the effects of TFP growth in either the agricultural sector (an increase in $A_a$) or the formal sector (an increase in $A_m$). Not surprisingly, agricultural and formal sector wages rise in both cases. The tables show that an improvement in agricultural TFP never raises the urban unemployment rate, and may reduce it. The size of the city ($L_m$) falls, as does formal sector employment and the absolute number of workers in the informal sector. The search intensity ($s$) of those

[13] These expressions follow from (2), (7), (10), the steady-state version of (11) and the bargaining solution (12).

[14] Similarly, it would not be straightforward to derive the effects of changes in commodity prices: monetary quantities such as wages would then need to be deflated by an appropriate price index. Given the 3 x 2 structure of our model, the responses of real wages to price changes are likely to be ambiguous under general assumptions.

| Rise in : Effect on: | $A_a$ | $A_m$ | $M$ | $F$ | $c$ | $\lambda$ | $\Pi$ | $x_a$ |
|---|---|---|---|---|---|---|---|---|
| Migration Condition | $\uparrow$ | $=$ | $=$ | $=$ | $=$ | $=$ | $\downarrow$ | $\uparrow$ |
| Job Creation Curve | $=$ | $\uparrow$ | $\uparrow$ | $\downarrow$ | $\downarrow$ | $?/\downarrow$ | $\downarrow$ | $=$ |
| $s$ | $+/=$ | $+$ | $+$ | $-$ | $-$ | $?/-$ | $-$ | $+/=$ |
| $u$ | $-/=$ | $-$ | $-$ | $+$ | $+$ | $+$ | $+$ | $-/=$ |
| $L_m$ | $-$ | $+$ | $+$ | $-$ | $-$ | $?/-$ | $-$ | $-$ |
| $w_a$ | $+$ | $+$ | $+$ | $-$ | $-$ | $?/-$ | $-$ | $-$ |
| $w_m$ | $+$ | $+$ | $+$ | $-$ | $-$ | $?/-$ | $-$ | $+$ |
| $(1-u)L_m$ | $-$ | $+$ | $+$ | $-$ | $-$ | $-$ | $-$ | $-$ |

Table 2: Efficiency wages, with a closed/open capital account

remaining in the informal sector does not fall, and may rise.

The effects of an increase in formal sector TFP are more complex: although this favourable productivity shock reduces the urban unemployment rate, the improvement in prospects encourages rural-urban migration. The city size increases, and agricultural wages rise, so that the incidence of poverty is reduced; but total unemployment does not necessarily fall, leaving open the Todaro paradox as a possibility. Another effect of increased productivity in the formal sector is that workers in the informal sector search more actively.

Overall, growth tends to reduce or leave unchanged the relative importance of the informal sector in urban employment, but because of the migration response, growth in the formal sector may increase the absolute number of people in the informal sector. These responses are not dissimilar to those in the Harris-Todaro model. Agricultural growth is "labour intensive" but urban growth, potentially, is not.

One strength of our analysis, relative to the Harris-Todaro model, is a more detailed specification of the urban labour market. Turning to some of the relevant parameters, we first consider an improvement in matching efficiency ($M$). In three cases, an improvement in matching efficiency lowers the urban unemployment rate and raises wages, the size of the city, and formal sector employment. These effects might all be regarded as natural consequences of reduced frictions in the urban labour market. But the effects are ambiguous for the case of a closed capital account with wage bargaining. This relates to our earlier discussion in section 4.3. With a fixed capital stock, the increase in formal sector employment will exert downwards pressure on wages, and this effect may be strong enough to reduce the welfare of informal sector workers. Although not inevitable, these counterintuitive results will be encountered in our calibration below.

Increases in the job expiry rate ($\lambda$) or the firing cost parameter ($F$) raise the urban unemployment rate and, in the case of job expiry, also reduce steady-state employment in the formal sector. Again, these are natural results: for example, the increase in the job expiry rate will increase the effective discount rate of workers and firms, reducing entry by firms, all else constant.

Finally, we note that when the fixed migration cost $B$ is strictly positive, there may be no migration flows in response to the parameter changes described above, depending on the size of the shock. For example, suppose we are in an equilibrium where past migration has occurred from agriculture to the city and therefore $w_a + x_a = rU - rB$. A small positive shock to agricultural productivity will not result in any reverse migration, if the increase in the rural wage does not cover the flow value of the migration cost - in other words, if $w_a' + x_a - rB \leq rU$ where $w_a'$ is the new rural wage. Since the urban sector remains the same size, and the shock to agricultural productivity does not otherwise affect the urban labour market, the urban sector and the present value of unemployment remain unaffected. For migration to occur in this example, the agricultural wage would have to rise by a quantity exceeding $2rB$, and then migration would cease when $w_a + x_a - rB = rU$.

# 6 Model parameterization

This section describes the assumptions under which the model is calibrated. We will be interested in whether the calibrated model can match the size of the informal sector seen in the data, even though workers could choose to locate in agriculture, and firms could choose to create new vacancies. This makes the choice of parameters more than usually important. We calibrate the model to match key features of the Mexican economy in 1990. Kose et al. (2004, p. 27-28) argue that Mexico's labour market rigidities have been a significant factor in limiting the size of the formal sector. As we noted in the introduction, one advantage of the Mexican case is that we can use recent microeconometric evidence in selecting structural parameters and constraining equilibrium outcomes.

We will show that the matching model can match a large informal sector (30% of the urban workforce) provided that either workers receive a relatively large share of the match surplus, or that the costs of posting a vacancy are sufficiently high; either of these will be sufficient to limit entry by firms to the required level. In order to see whether the model can match the data under plausible assumptions, we will infer the required allocation of the surplus directly from the baseline of the calibrated model, rather than use the more standard approach in which the division of the match surplus is treated as known.

The calibration is carried out for four cases, corresponding to the two models of formal sector wage determination, and two different assumptions about the capital account (open/closed). Clearly, the model is stylized, and so our calculations are intended as only illustrative. Among the important considerations we abstract from are heterogeneity in worker productivity, female nonparticipation in the labour force, off-farm employment in rural areas, and international emigration.[15] The simplicity of the exercise also has some advantages, however. The assump-

[15] Levy and van Wijnbergen (1994, p. 268) argue that rural-urban migration has been the main driving force

tions and mechanisms are relatively transparent, and we can relate the findings directly to the comparative static results established in section 5 of the paper.

We use microeconometric evidence to select some parameter values, and choose other parameters so that the model's equilibrium outcomes match those seen in the data. In particular we choose some structural parameters so that the model's equilibrium will match the observed size of the informal sector in Mexico, the observed size of the agricultural sector, and estimates of wage differentials from recent microeconometric studies. The calibration assumptions and procedure are described in more detail in a technical appendix, available on request.

The main parameter assumptions are listed in Table 3. We set the annual real interest rate at 4%, a standard choice in calibrating macroeconomic models (for example, Andolfatto 1996). For simplicity, we specialize to Cobb-Douglas technologies in the formal and rural sectors, a Cobb-Douglas matching function, and a simple power function for the costs of search intensity. The matching function is $m(su, v) = M(su)^{\gamma}v^{1-\gamma}$ and we set the elasticity $\gamma$ to 0.50, a common choice in calibrations for developed countries. For search costs, we specialize to

$$\sigma(s, z) = zh(s)$$

This has the following interpretation: $z$ is the income associated with full-time self-employment in the informal sector, but a proportion of a worker's time, $h(s)$, is devoted to searching for a job in the formal sector, and so $zh(s)$ is the income foregone in the process of search. We specify a simple power function $h(s) = \Pi s^{\phi}$ where our calibration will assume $\phi = 2$ based on the empirical analysis in Yashiv (2000). Without loss of generality, we choose units for search intensity $s$ such that its initial level can be normalized to one.

We want the model to yield the informal sector's share of the urban workforce ($u$) as 0.30, based on the estimate of Gong and van Soest (2002) for the early 1990s. We discuss this choice in more detail, later in this section. The agricultural employment share $L_a$ is set to be 0.28, based on ILO data for 1990 extracted from the online LABORSTA database.

The monthly job expiry rate $\lambda$ is set at 0.06, again based on Gong and van Soest (2002). Together $\lambda$ and $u$ pin down steady-state matches $m = \lambda(1 - u)$ as a fraction of the urban workforce. A more difficult choice relates to the duration of vacancies. There is little information on this for developing countries, given data limitations and our necessarily broad interpretation of what is meant by a "vacancy". Here we follow Andolfatto (1996) and Merz (1995) in imposing an average duration of 45 days.[16] This pins down the vacancy rate $v$ and, given knowledge of $m$, $s$ and $u$, this means that we can also pin down the matching efficiency index $M$.

in Mexico's rapid urban growth, with the number of such migrants far in excess of the number emigrating to the USA. It would be straightforward to extend our analysis to consider the impact of emigration on the domestic labour market.

[16] This figure comes from a study of the Dutch economy by van Ours and Ridder (1992). This may be conservative: our broad interpretation of a vacancy might suggest that longer durations are plausible, and we could then match the observed size of the informal sector while assuming smaller flow costs of posting a vacancy.

Another key parameter will be the flow cost of posting a vacancy, $c$. We use an approach similar to Andolfatto (1996) and impose the ratio of recruiting costs to formal sector output in the baseline steady-state ($cv/Y_m$ in our notation). It is important to emphasize that our calibration is quite sensitive to the choice of this ratio. As the size of recruiting costs is progressively reduced, we need workers to receive a larger allocation of the surplus (reducing entry by firms) if we are to continue matching an informal sector employment share of 30%. For our baseline calibration, we set the ratio at 3%, compared to Andolfatto's use of 1% for the US economy. This difference might be justified if recruiting formal sector workers is a costlier process in developing countries than in the US, for example, because systems for transmitting information about labour market opportunities are weaker. Nevertheless, we will examine how our conclusions are modified by the alternative choice of 1%.

The model includes a role for firing costs, $F$. These represent a direct resource cost to the firm associated with job expiry. We set these costs at twice the monthly wage at baseline, so that it will have a similar order of magnitude to severance pay. We set the severance pay parameter $P$ to be four times the monthly wage. This is motivated by Mexico's labour market regulations: in essence, a firm that dismisses a worker without just cause must pay the worker three' months salary plus twenty days of salary for each year worked (for example, Capelleja 1997). Our estimate of the monthly job expiry rate implies an average job duration of almost 17 months in the formal sector, so that setting $P$ at four times the monthly wage is a reasonable approximation.[17]

As discussed earlier, assumptions about formal sector severance pay have some relevance for our calibration. In fitting Mexican data, an attractive aspect of our model is that workers will strictly prefer the formal sector even when there is no formal sector wage premium, because formal sector labour income includes expected severance pay as well as hourly wages. Microeconometric estimates of the wage premium in the Mexican formal sector, relative to the informal sector, suggest that it is low after controlling for worker characteristics, at least for unskilled workers. With this in mind, we set the formal sector wage premium at 10%.[18]

Using labour force survey data for 1991, extracted from the ILO LABORSTA database, we find that the formal sector wage is roughly 80% higher than the rural wage. This assumption is broadly in line with the computable general equilibrium model of Mexico due to Venables and van Wijnbergen (1993), who assumed that the marginal product for unskilled labour in urban areas was twice that in rural areas.

[17] Given that severance payments are always proportional to salaries, the lump-sum $P$ is forced to rise or fall in proportion to the formal sector wage when studying how the economy responds to a parameter change.

[18] Marcouiller et al. (1997) find that, if anything, there is a wage premium associated with the *informal* sector in Mexico. Our model can accommodate this possibility, given severance pay. Gong and van Soest (2002) find very low formal sector wage premia for individuals with low or intermediate levels of education, and significantly larger premia for those with a high level of education. The latter account for 19% of the men and 7% of the women in their sample. In principle, allowing for this heterogeneity would be desirable, but it would complicate the model and the comparative statics.

With the formal sector-rural wage premium at 80% and the estimated formal-informal premium of just 10%, even the informal sector wage is greater than the rural wage. This is consistent with the observations of Gregory (1980) and Mazumdar (1976) that productivity and/or wages in the informal sector may often exceed those in agriculture. In order to match the rural population observed in Mexico, our calibration then requires migration costs $B$ and the direct utility cost of living in the city $x_a$ to be sufficiently high to deter migration. A necessary condition is that $x_a + \chi r B > 0$ where the parameter $\chi$ is described in footnote 10. We infer the value of $x_a + \chi r B$ in the calibration exercise but cannot separately identify the values of $B$ and $x_a$. Later in the calibration, we will allow the preference parameter $x_a$ to be heterogeneous.

Finally, we need to specify the technologies in the formal and rural sectors. We choose both to be Cobb-Douglas for simplicity. We impose the elasticities of output with respect to labour for the formal sector and the agricultural sector. Here we face a problem common to other modellers of the Mexican economy, namely that the aggregate capital share provided in the national accounts seems too high at around 70% (for discussion of this, see Kehoe and Kehoe 1994). This is also true of UNIDO data on the capital share for the Mexican manufacturing sector, which makes a rigorous choice of technology parameters difficult. Rather than choose the relevant parameters freely, we use the same choices as Imam and Whalley (1985), a calibration of the Harris-Todaro model using Mexican data.[19]

We choose units for agricultural output so that we can normalize the agricultural TFP parameter to unity. Without loss of generality, we also normalize to unity the initial stocks of capital and land, and then infer the level of TFP in the formal sector that is needed for the equilibrium of the model to replicate the observed sectoral employment structure.[20] We do not seek to match agriculture's share of GDP. In calibrating the model, we typically find that it significantly over-predicts the share of agriculture in GDP for Mexico relative to national accounts data. This might be explained in terms of home production or subsistence agriculture, the output of which is not fully captured in the national accounts. Moreover, the data on employment allocations may overstate the proportion of effective labour allocated to agriculture. These and other relevant considerations are discussed in Gollin et al. (2004), Parente et al. (2000) and Schmitt (1989).

Our parameter choices have an important implication. Given the rapid turnover between the informal sector and the formal sector observed in Mexico, and a low discount rate, the utility levels of formal sector and informal sector workers are similar at the baseline steady-state. The

[19] The current model does not have a one-to-one correspondence between the formal sector's input elasticities and its factor shares, given that formal sector labour does not receive its marginal product; we briefly discuss this issue in our technical appendix (available on request).

[20] Strictly speaking, we infer urban TFP multiplied by the relative price of formal sector output. In the calibration, this quantity has to move to offset any change to the levels of land and urban capital, given that we constrain the model's equilibrium to match the observed sectoral structure. This means that equilibrium outcomes such as relative wages are independent of the scale of the fixed factors: any change in scaling only affects the absolute level of wages and output.

formal sector "utility premium" $(W-U)/U$ is very small, 0.75% at baseline. Hence the informal sector, although less productive, yields lifetime utility similar to that obtained in the formal sector. This result is not inconsistent with some of the available evidence for Mexico, which suggests that the different urban sectors are well integrated and not fundamentally distinct in terms of their desirability (for example, Bosch and Maloney 2005).

The similarity in lifetime utility indicates that, at least for the specific case of Mexico, informality is less interesting as a cause of poverty, and more as a cause of low productivity.[21] With this in mind, our calibration emphasizes the effects of parameter changes on productivity and labour income. The relative size of the formal sector is also of interest from a welfare point of view. An expansion in the formal sector could have beneficial effects beyond those we consider here, including better opportunities for specialization and training, and greater income security, as discussed in a *World Development Report* (World Bank, 1995, p.18).

In the experiments we carry out, the productivity effects are driven by reallocations of employment across sectors. These reallocations can have sizeable effects, because our baseline implies that the marginal product of labour in the formal sector is roughly 1.6 times that in the informal sector and 2.6 times that in agriculture. (The presence of matching frictions means that workers in the formal sector receive only about 70% of their marginal product in the baseline equilibrium.) Reallocating labour from sectors where its marginal product is relatively low will usually raise aggregate output and total factor productivity. Whenever the Hosios condition is not met, this has the potential to raise social welfare.

The preceding discussion points to a shortcoming of our model, at least in its application to Mexico. One view of developing country labour markets distinguishes between two tiers of self-employment (Fields 1990). The lower tier is a staging post for salaried work in the formal sector (as in our paper) and the upper tier corresponds to forms of self-employment that may be actively preferred to the formal sector (which we do not explicitly model). For example, some individuals may accumulate capital and human capital while working in the formal sector, and then quit voluntarily to set up their own business. Fields (1990) calls this 'restricted-entry self-employment' and Maloney (1998, 1999, 2002) emphasizes the relevance of the upper tier to understanding the Mexican informal sector. In contrast, McKenzie and Woodruff (2004) use a detailed survey of micro-enterprises in Mexico to show that the capital requirements for entry are low in many sectors, suggesting that entry into any upper tier must be restricted in other ways.

Nevertheless, in calibrating the model, we should be careful to avoid identifying the informal sector with all forms of self-employment. As discussed above, our baseline calibration assumes

[21] Sethuraman (1976) pointed out that the consequences of the informal sector for overall resource allocation and productivity were too often overlooked. Looking across countries, Maloney (1998, 2002) shows that there is a strong inverse association between industrial labour productivity and the extent of self-employment. This suggests that labour markets, sectoral structure and productivity are tightly connected, even though the direction of causality remains unclear.

that the informal sector represents 30% of the urban workforce. This figure corresponds to the job-type definition of informality used by Gong and van Soest (2002), in which the self-employed are classified as informal sector workers only if their firm has no employees. Any entrepreneur with at least one employee is placed in the formal sector category. This yields a smaller informal sector than the combined share of self-employment and employment in micro-enterprises, which is reported by Maloney (2002) to be close to 50% for Mexico; hence, the difference between the two could partly reflect an upper tier to the informal sector. Our model is effectively aggregating salaried employees and business owners into one formal, capital-intensive sector, while the informal sector continues to represent a low-productivity staging post, and accounts for a smaller share of the urban workforce than the combined share of self-employment and micro-enterprises.[22] This is an imperfect solution, but defining the upper tier of the informal sector as part of the formal sector is in line with most previous work, and simplifies the analysis throughout the paper.[23]

Given our focus on productivity effects, we end this section by briefly noting how we measure output (net of recruitment costs) and factor incomes. For the formal sector, there is a distinction between gross output and factor incomes, because of recruitment and firing costs. For this sector, our model implies:

$$Y_m - \frac{r+\lambda}{\lambda} cvL_m - \lambda F(1-u)L_m = r_m K_m + (w_m + \lambda P)(1-u)L_m$$

This says that formal sector output net of recruitment and firing costs (the left-hand-side) is equal to factor incomes (the right-hand-side). When this quantity is added to agricultural output and informal sector output, we have a measure of domestic output (GDP).

When the capital account is open, it is essential to distinguish between GDP and GNP. The response of domestic output to a parameter change will usually differ from the response of domestic factor incomes. Although labour income and land rentals may change, capital income for domestic residents is fixed: their capital income is simply equal to their holdings of capital multiplied by the world return. Any increase in capital income will accrue to foreign owners of capital. This means we can easily compute changes in national income (GNP) for parameter experiments with an open capital account: to calculate the new value of GNP, we hold the capital income accruing to domestic residents at its initial level, and then add the new value of labour income. To allow simple presentation of the results in terms of percentage changes, we assume that GDP equals GNP at baseline (net foreign assets are initially zero, and there are

[22] This is also relevant to the idea that many self-employed entrepreneurs in the informal sector arrive by voluntary quits (Cunningham and Maloney 2001). If some of these entrepreneurs are using capital-intensive technologies then, in our model, we can interpret their movements as job-to-job transitions within the formal sector.

[23] Fields (1990) noted that constructing a model with several tiers to the informal sector, and the possibility of capital accumulation prior to entering the upper tier, is a formidable task. One of his suggestions, to use Markov chains to link the sectors, could be seen as a reduced-form for the explicit modelling of transitions that we adopt in this paper. See also Krebs and Maloney (1999).

no cross-border labour services).

## 7 Calibration

The first question of interest is whether the model can explain an informal sector employment share of 30% and an agricultural employment share of 28% under reasonable assumptions. We can achieve this, under two conditions: first, there must be a significant migration cost or urban disutility; and second, either the flow costs of worker recruitment must be high, or workers must receive a relatively large share of the match surplus. Taking these conditions in turn, at baseline, our assumptions imply that the disutility cost of urban living, together with the migration cost, is equivalent to 95% of the rural wage. This is required to ensure that a substantial fraction of the population remains in agriculture, despite the higher wage available in the urban informal sector.

In the Nash bargaining model, the baseline equilibrium requires worker bargaining strength ($\beta$) to be 0.67, higher than the 0.50 value which is the norm in calibrations for developed countries. In the efficiency wage case, the required division of the surplus may seem more reasonable. For example, if we assume a monthly detection probability of 5%, the same division of the surplus can be achieved with a gain from shirking that is just 12% of the formal sector wage at the baseline equilibrium.

Our baseline assumptions imply that the flow cost of posting a vacancy is high, at 62% of the formal sector wage: this confirms the potential importance of interpreting a "vacancy" broadly, so that recruitment costs extend beyond an advertisement. Recall that the vacancy cost figure is derived by constraining the steady-state ratio of recruitment costs to formal sector output to 3%. If we lower this ratio to the 1% figure used by Andolfatto (1996) for the USA, the required vacancy cost falls to 20% of the formal sector wage. This change has a significant drawback, however. To continue explaining the large size of the informal sector, we then need formal sector workers to receive a higher share of the match surplus. In the Nash bargaining case, we need $\beta$ to be as high as 0.86. The experiments we describe below are all for the alternative case in which the recruitment costs ratio is 3% and the division of the surplus corresponds to a $\beta$ of two-thirds.

Our experiments will consider how changes in key parameters affect the labour market equilibrium, wage differentials and search intensity, the sectoral structure of output and employment, and total output. When the capital account is open, aspects of the model economy such as domestic output can respond dramatically to parameter changes. As noted in the previous section, it is important to focus on changes in GNP rather than GDP in this case.

The first experiment we consider is a 20% increase in agricultural TFP (rural growth). The results are shown in Table 4. As expected (given fixed commodity prices) agricultural employment and output increases substantially, but there is some reduction in the output of the formal and informal sectors. With an open capital account, the city is simply scaled down in size, with the urban unemployment rate, matching rate, and wage premia all independent of rural TFP. For the closed account case, the urban unemployment rate decreases and the informal sector contracts, while aggregate output rises by approximately 2.6%. However, looking across the table, rural growth is potentially "immiserizing". Workers are left worse off in the open capital account case: although all wage rates remain unchanged in the new equilibrium, total labour income declines, because fewer workers are employed in the relatively well-paid jobs in the formal sector.

In the second experiment, reported in Table 5, urban TFP rises by 20% (urban growth). Importantly, the urban unemployment rate falls sharply. Agricultural and informal sector employment contract, while employment and output in the formal sector expand: at least in this calibration, urban growth is labour-intensive, pulling workers out of the informal sector. Wages and labour income rise dramatically in the open capital account case. This is because the direct effect of the increase in urban TFP is amplified by capital inflows: the formal sector capital-labour ratio must rise until the return on capital is back at its baseline value, the world real interest rate.[24] When the capital account is open, GDP roughly doubles in response to the 20% increase in urban TFP, but most of this increase in GDP is returned to foreign owners of capital. GNP rises by roughly 30%.

We now consider the effects of varying some of the key labour market parameters. We first look at an increase in matching efficiency (the shift parameter $M$ in the matching function) of 20%. To what extent is better matching associated with improved outcomes in the urban and rural labour markets? Table 6 quantifies the reduction in the urban unemployment rate, while formal sector output and employment expands. Our earlier comparative statics indicated that the effect on wages is ambiguous in one case, that of Nash bargaining with a closed capital account. We find an example of this counter-intuitive result here: better matching increases formal sector employment, but this reduces the capital-labour ratio sufficiently that wages fall. In the other three cases, wages rise. In all four cases, aggregate output and national income increase. With an open capital account, the effect of better matching on labour income is substantial: labour income rises by 4.6% under bargaining, and by 5.4% under efficiency wages. This partly reflects a general equilibrium effect in that rural wages rise by 5%-7%.

Our baseline includes relatively modest firing costs in the formal sector, equivalent to two months' wages. If these firing costs are halved, we get the results shown in Table 7, including an expansion in formal sector output and employment, a reduction in the urban unemployment rate, and an increase in aggregate output and national income. Wages rise in the formal sector (by 1.4% to 4.4%, depending on the model) and in the agricultural sector (by 3.1% to 8.9%). Again we see that, in general equilibrium, labour market institutions in the urban sector

[24]With Cobb-Douglas technologies, this effect will be especially powerful when the urban capital exponent $\theta$ is high, because the factor increase in the capital-labour ratio is equal to the factor increase in urban TFP raised to the power $1/(1-\theta)$.

influence the standard of living in rural areas.

Our final experiment is a 20% increase in the job expiry rate, from a monthly Poisson rate of 0.06, to one of 0.072. This increase may appear modest, but it has sizeable effects. Output and employment in the formal sector falls, and total labour income falls by as much as 8.5% in the open capital account case. The informal sector expands in relative and absolute terms, rising from 30% of the urban workforce to somewhere between 34% and 43% depending on the model. Wages fall in both agriculture and the formal sector. In this model, even quite modest increases in the job expiry rate have a significant effect on the labour market equilibrium, and on aggregate output and national income.

Finally, given the strong response of "city size" in some of the experiments, we briefly discuss the possibility that location preferences (captured in $x_a$) may be heterogeneous across the population of workers. This is a straightforward extension of our analysis. Assume that $x_a$ has a distribution function $F(x_a)$ which is continuous and strictly increasing over its entire support. Let $x_a^*$ be the preference parameter of the agricultural worker who is indifferent about migrating. All workers with $x_a < x_a^*$ will live in the city, while those with $x_a \geq x_a^*$ will live in rural areas, so

$$F(x_a^*) = L_m$$

Given our assumptions about $F(.)$ then $x_a^*$ can be expressed as a continuous function of $L_m$, $x_a^*(L_m)$. We can then replace $x_a$ with $x_a^*$ throughout the previous analysis. In describing the steady-state, the only change to the analysis in section 5 is that the migration condition becomes:

$$w_a\left(\overset{+}{L}_m; \overset{+}{K}_a\right) + x_a^*(L_m) + rB = \zeta(\overset{+}{s}; \overset{+}{z}, \overset{+}{\Pi}) \tag{25}$$

To implement this idea in the calibration, we need to specify a distribution for $F(x_a)$. We have experimented with a normal distribution in which the variance is imposed, while the mean is treated as an unknown parameter that can be inferred from the observed size of the city. When we introduce heterogeneity in this way and study the effects of parameter changes, the responsiveness of city size is altered (as expected) but the effects on outcomes within the urban labour market, such as the relative size of the informal sector, appear modest.

# 8 Conclusions

Agénor (1996, 2004, 2005a), Fields (1984) and Freeman (1992) have argued strongly that too little attention has been paid to the interactions between labour markets and aggregate development. In this paper, we have described a simple general equilibrium framework in which an urban labour market with matching frictions is embedded in a 3 x 2 specific factors model, with an urban sector and a rural agricultural sector. Ths specification of the urban labour market provides a unified approach to the analysis of labour markets and underemployment for developed and developing countries, and allows us to draw on recent microeconometric studies of labour market transitions and wage differentials.

For middle-income countries, at least, matching frictions in the urban labour market can help to explain the existence of a sizeable informal sector. Taking the example of Mexico, informal sector employment is often estimated to account for as much as 30% of the urban workforce. Our calibration shows that this can be explained solely in terms of matching frictions, provided either that workers receive a relatively large share of the match surplus, or that recruitment costs are significant: 3% of formal sector output in our main calibration.

The model allows us to consider a range of questions of central importance to development economics, while acknowledging the interdependence of sectors. These questions include the effects of different types of growth on employment, the informal sector, sectoral structure, urbanization, labour income and total output. We have also studied the effects of labour market parameters on equilibrium outcomes, to see whether labour market institutions are an important determinant of sectoral structure and overall productivity. Even relatively modest changes in labour market parameters can have sizeable effects, especially for total labour income.

It would be straightforward to adapt our model to consider distributional issues, including the effects of growth on inequality. More ambitiously, further work could significantly improve on our analysis by developing a richer model of the informal sector, perhaps incorporating several tiers to self-employment, and the role of business regulation. Finally, since our analysis suggests that labour market institutions can have significant effects on aggregate outcomes, there is a case for examining the same effects for poorer economies. That might well require a more complex approach to the urban labour market and the rural sector than we have developed here.

# A Stability

This Appendix establishes that the equilibrium is saddle-path stable when $B = 0$. Then a natural assumption is that the instantaneous change in the urban labour force is given by

$$\dot{L}_m = \theta \left( rU - (w_a + x_a) \right) \tag{26}$$

which might follow if the parameter $b$ (introduced in the discussion preceeding equation 2) is strictly positive. Note that our results on stability do not rely on the linearity in (26). It is also important to note that $U$ in equation (26) represents the welfare of a worker in urban unemployment who does not migrate, so that (3) continues to describe the evolution of $U$.

In equation (11), $y(k_m)$ is output per filled job less the rental cost of capital; this can also be interpreted as the marginal product of labour. With an open capital account $k_m$ and hence $y(k_m)$ will be exogenously determined by the world real interest rate. With a closed capital account, since $y(k_m)$ is an increasing function of capital per employed worker and the urban capital stock is fixed, it can also be expressed as a decreasing function of formal sector employment $E_m = (1-u)L_m$. We use $y(\underset{-}{E_m})$ to denote this decreasing function.

From standard properties of the matching function, $q(\tau)$ and $\tau q(\tau)$ are respectively decreasing and increasing in $\tau$. From (8), we can show that search intensity $s$, and therefore $s\tau q(\tau)$, are increasing functions of $\tau$; this argument uses the efficiency wage condition (13), or the Nash wage bargain combined with the fact that $J = c/q(\tau)$, as appropriate.

With a closed capital account, we then have

$$(r+\lambda)(J+W-U) = y(\underset{-}{E_m}) - z - \zeta(\underset{+}{\tau}) + (\dot{J}+\dot{W}-\dot{U}) \tag{27}$$

In the case of Nash wage bargaining this becomes

$$\frac{r+\lambda}{1-\beta}J = y(\underset{-}{E_m}) - z - \zeta(\underset{+}{\tau}) + \frac{1}{1-\beta}\dot{J} \tag{28}$$

while with efficiency wages we have

$$(r+\lambda)(J+X) = y(\underset{-}{E_m}) - z - \zeta(\underset{+}{\tau}) + \dot{J} \tag{29}$$

In either case, it follows from (10) and either (28) or (29), that $\dot{\tau}$ is an increasing function of $\tau$ and a decreasing function of $E_m$. With an open capital account, since $y(k_m)$ is exogenous, $\dot{\tau}$ is just an increasing function of $\tau$. We also note that from (9), $\dot{U}$ is an increasing function of $U$ and $\tau$.

The evolution of formal sector employment is given by

$$\dot{E}_m = mL_m - \lambda E_m = s\tau q(\tau)(L_m - E_m) - \lambda E_m \tag{30}$$

Finally we consider the instantaneous change in the size of the city, $\dot{L}_m$. The two endogenous variables that determine this are (positively) the present value of urban unemployment $U$ and (negatively) the agricultural wage, where the latter is an increasing function of city size $L_m$.

These arguments combine so that, after taking a first order linear approximation around the steady state, we obtain a system of the following sign pattern in the variables $\tau, U$, $L_m$ and $E_m$:

$$\begin{pmatrix} \dot{\tau} \\ \dot{U} \\ \dot{L}_m \\ \dot{E}_m \end{pmatrix} = A \begin{pmatrix} \tau \\ U \\ L_m \\ E_m \end{pmatrix} \quad \text{where } A = \begin{pmatrix} + & 0 & 0 & A_{41} \geqslant 0 \\ - & + & 0 & 0 \\ 0 & + & - & 0 \\ + & 0 & + & - \end{pmatrix}$$

where $A_{41} = 0$ when the capital account is open, and $A_{41} > 0$ when it is closed.

We want to show that there are two eigenvalues with negative real part corresponding to the two predetermined variables $L_m$ and $E_m$, and two eigenvalues with positive real part corresponding to the jump variables $\tau$ and $U$, so that the system is saddle-path stable and determinate. This is clear by inspection for the open capital account case, where $A_{41} = 0$ and $A$ is triangular, so the eigenvalues are just the diagonal elements of $A$.

With a closed capital account where $A_{41} > 0$, the proof is slightly more involved. The result follows because the sign pattern implies the following two statements: (i) $\det(A) > 0$ (ii) $f'\left(\frac{A_{11}+A_{22}}{2}\right) < 0 < f'\left(\frac{A_{33}+A_{44}}{2}\right)$, noting that $\frac{A_{33}+A_{44}}{2} < 0 < \frac{A_{11}+A_{22}}{2}$, where $f(\lambda) \equiv \det(A - \lambda I)$ is the characteristic polynomial.

# B Efficiency

It is useful to review how the decentralized equilibrium depends on intial conditions. If the city is initially small, workers will migrate from agriculture to the city until we have

$$w_a\left(\overset{+}{L}_m; \overset{+}{K}_a\right) + x_a + rB = \zeta(\overset{+}{s}; z, \Pi) \tag{31}$$

and conversely if the city is initially large, equilibrium requires

$$w_a\left(\overset{+}{L}_m; \overset{+}{K}_a\right) + x_a - rB = \zeta(\overset{+}{s}; z, \Pi) \tag{32}$$

There is also an intermediate case where no migration occurs, where the urban labour market is in equilibrium and

$$w_a\left(\overset{+}{L}_m; \overset{+}{K}_a\right) + x_a - rB < \zeta(\overset{+}{s}; z, \Pi) < w_a\left(\overset{+}{L}_m; \overset{+}{K}_a\right) + x_a + rB.$$

In our efficiency analysis, we assume that the social planner can engineer a flow of workers $f$ from agriculture to the city, with associated costs of migration. We first consider the case where the city is initially small and so $f > 0$; we consider other cases later. The stock variables (here both unemployment and the size of the city) are the state variables, and the social planner's control variables are search intensity $s$, vacancy creation, which can be seen as choosing $\tau$, and the number of migrants $f$.

We make the standard assumption that the social planner maximises the present discounted value of the total income of domestic factors of production:

$$Y = \int_0^\infty \left[Y_a(L_a) + L_a x_a - Bf - bf^2 + (1 - L_a)\left\{1 - u)y_m^X + u\left(z - \sigma(s, z)\right) - cv - \lambda(1 - u)F\right\}\right] e^{-rt} dt \tag{33}$$

Here $Y_a(a)$ is agricultural production, and $L_a x_a$ is the utility benefit of living in rural areas, which we interpret as income for simplicity. The quantity

$$y_m^X = A_m \left( f(k_m) - X f'(k_m) k_m \right)$$

is formal sector output per worker in the closed capital account case ($X = 0$) and the marginal product of labour in the open capital account case ($X = 1$). The quantity $y_m^X$ will be the aspect of formal sector output that a social planner seeks to influence. When the capital account is open, domestic allocations do not affect the capital income that accrues to domestic residents. Hence, the social planner can disregard capital income in solving for the optimum allocation. With a closed capital account, the social planner cares about the entirety of formal sector output, given that capital is domestically owned and the return on this capital may vary.

Noting that $k_m$ is exogenous (endogenous) when $X = 1$ ($X = 0$), it is straightforward to show that

$$\frac{\partial}{\partial u} \left\{ (1-u) y_m^X \right\} = -y(k_m) \tag{34}$$

$$\frac{\partial}{\partial L_a} \left\{ (1-L_a) y_m^X \right\} = -y(k_m) \tag{35}$$

for $X = 0, 1$ where (as in the main text) $y(k_m) = A_m f(k_m) - A_m f'(k_m) k_m$ or the marginal product of labour.

The social planner's control variables are $f$, $s$ and $\tau$, and the state variables are $u$ and $L_a$. The constraints are given by

$$\dot{L}_a = -f \tag{36}$$

and

$$\frac{d}{dt} \left\{ (1-u) L_a \right\} = \lambda (1-u) - m + f$$

which gives

$$\dot{u} = \lambda(1-u) - su\tau q(\tau) + \frac{1-u}{1-L_a} f \tag{37}$$

Hence the aim of the social planner is to maximize the welfare criterion (33) subject to the constraints (36) and (37), which capture the inertia in the size of the city and the urban unemployment rate.

Writing $\psi e^{-rt}$ as the costate variable for $L_a$ and $\mu e^{-rt}$ as the costate variable for $u$, the current value Hamiltonian is:

$$H = Y_a(L_a) + L_a x_a - Bf - bf^2 \tag{38}$$

$$+ (1-L_a) \left[ (1-u)\, y_m^X + u\, (z - \sigma(s;z)) - csu\tau - \lambda(1-u) F \right] \tag{39}$$

$$+ \mu \left[ \lambda(1-u) - su\tau q(\tau) + \frac{1-u}{1-L_a} f \right] - \psi f \tag{40}$$

Using $\eta$ to denote the elasticity of the matching function with respect to search effort $su$ (which is the negative of the elasticity of $q$ with respect to $\tau$) the maximum principle gives the following first order conditions:

$\frac{\partial H}{\partial \tau} = 0:$

$$(1 - L_a)\, c = -\mu q(\tau)(1 - \eta) \tag{41}$$

$\frac{\partial H}{\partial s} = 0:$

$$(1 - L_a)[\sigma_s(s; z) + c\tau] = -\mu\tau q(\tau) \tag{42}$$

$\frac{\partial H}{\partial f} = 0:$

$$\psi + B + 2bf = \frac{1 - u}{1 - L_a}\mu \tag{43}$$

$\frac{\partial H}{\partial u} = r\mu - \dot{\mu}$, using (34):

$$(1 - L_a)\,[-y(k_m) + z - \sigma(s; z) - cs\tau + \lambda F] = \mu(r + \lambda + s\tau q(\tau) + \frac{f}{1 - L_a}) - \dot{\mu} \tag{44}$$

$\frac{\partial H}{\partial L_a} = r\psi - \dot{\psi}$, using (35):

$$w_a(L_a) + x_a - \{(1 - u)\, y(k_m) + u\,(z - \sigma(s; z)) - csu\tau - \lambda(1 - u)F\} - \mu f \frac{(1 - u)}{(1 - L_a)^2} = r\psi - \dot{\psi} \tag{45}$$

From (41) and (42),

$$\sigma_s(s; z) = \frac{\eta c\tau}{1 - \eta} \tag{46}$$

In steady state $\dot{\tau} = 0$, $\dot{u} = 0$ and $f = \dot{L}_a = 0$. This implies $\dot{\mu} = 0$ from (41) and $\dot{\psi} = 0$ from (43). Also, from (37)

$$\lambda(1 - u) = su\tau q(\tau) = m \tag{47}$$

and from (41) and (44),

$$\frac{r + \lambda}{1 - \eta}\frac{c}{q(\tau)} = y(k_m) - \lambda F - \left(z - \sigma(s; z) + \frac{\eta cs\tau}{1 - \eta}\right) \tag{48}$$

The steady state version of (45) is given by

$$w_a(L_a) + x_a = (1 - u)\, y(k_m) + u\,(z - \sigma(s; z)) - csu\tau - \lambda(1 - u)F - (1 - u)\frac{r}{1 - \eta}\frac{c}{q(\tau)} \tag{49}$$

Substituting for $y(k_m)$ in (49) from (48), we get

$$w_a(L_a) + x_a + rB = \frac{\lambda(1-u)}{1-\eta}\frac{c}{q(\tau)} + (1-u)\left(z - \sigma(s;z) + \frac{\eta c s \tau}{1-\eta}\right) + u\left(z - \sigma(s;z)\right) - csu\tau$$

From (47), we then have

$$\begin{aligned} w_a(L_a) + x_a + rB &= \frac{csu\tau}{1-\eta} + (1-u)\left(\frac{\eta c s \tau}{1-\eta}\right) + z - \sigma(s;z) - csu\tau \\ &= z - \sigma(s;z) + \frac{\eta c s \tau}{1-\eta} \end{aligned} \tag{50}$$

When the capital account is open, $k_m$ is exogenous and equations (46), (47), (48) and (50) yield the efficient values of $s, u$, $\tau$ and $L_a$ which we denote $s^*$, $u^*$, $\tau^*$ and $L_a^*$. With a closed capital account, we also have the identity for $k_m$, which of course also applies in the decentralized equilibrium:

$$k_m \equiv \frac{K_m}{(1-L_a)(1-u)} \tag{51}$$

which together with equations (46), (47), (48) and (50) yields the efficient values $s^*$, $u^*$, $\tau^*$, $L_a^*$ and $k_m^*$.

We will now show that the decentralized outcome is efficient if and only if the Hosios condition (52) holds. By comparing equations (46), (47), (48) and (50) with equations (17), (15), (19) and (31), we can see that for both cases that the steady state decentralized values $s^{dec}$, $u^{dec}$, $\tau^{dec}$ and $L_a^{dec}$ equal the efficient values if and only if the surplus in the decentralized equilibrium is shared according to the Hosios condition,

$$(1-\eta)(W-U) = \eta (J-V) \tag{52}$$

In the efficiency wage case, this occurs iff $X$ is at the appropriate value. With wage bargaining it occurs iff we have the well-known Hosios (1990) condition that $\beta = \eta$.

We now consider the case where the size of the city is initially large relative to the equilibrium. For the social planner, $f$ is now negative and we replace the migration costs term $-Bf$ in equations (33) and (38) with $+Bf$. This results in a migration condition for the social planner that is

$$w_a(L_a) + x_a - rB = z - \sigma(s;z) + \frac{\eta c s \tau}{1-\eta}$$

Again the decentralized equilibrium, now given by equations (17), (15), (19) and (32), is efficient if and only if the Hosios condition holds. A similar argument can be made for the intermediate case; whatever the initial conditions, the decentralized equilibrium will replicate the social planner's outcome if and only if the Hosios condition holds. Finally, we note that it is straightforward to show that this remains the case when $x_a$ is heterogeneous across the population.

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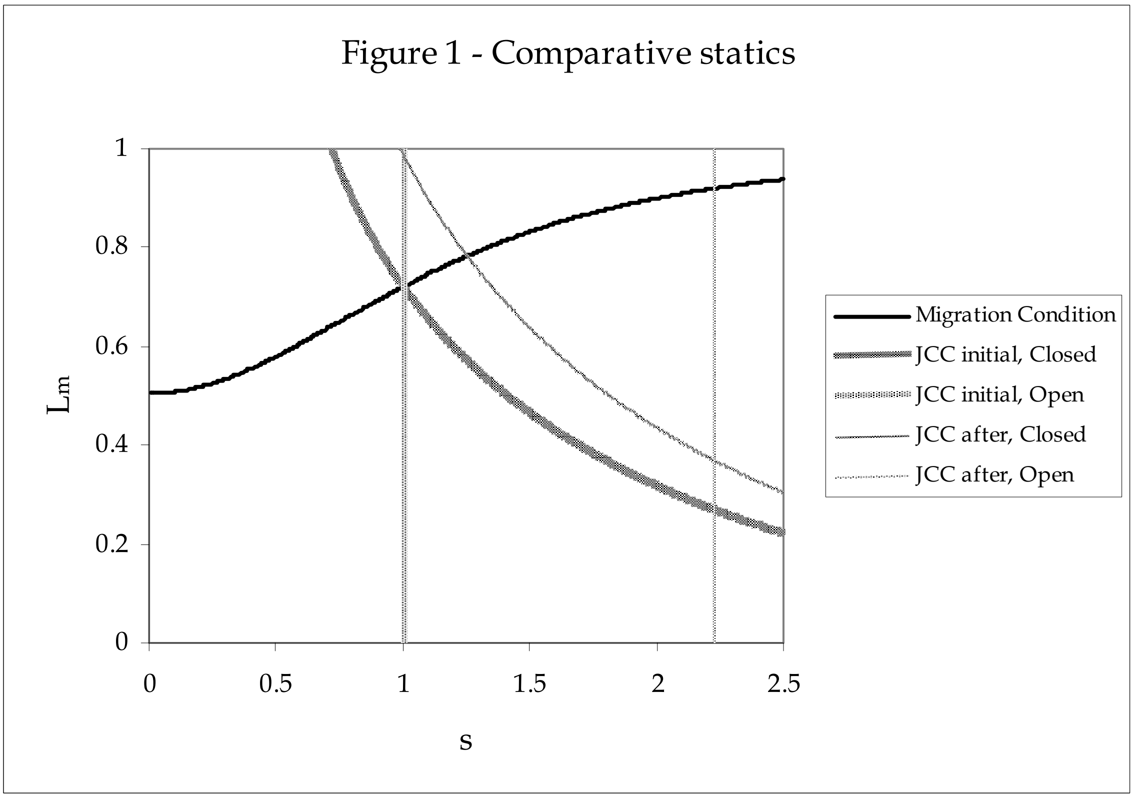


Figure 1 - Comparative statics

*Notes*

This figure illustrates the comparative static results associated with a 20% increase in TFP in the urban sector, for the Nash Bargaining case, with either a closed or open capital account. The upward sloping line corresponds to the migration condition. It is the same for both the open and closed capital account, and does not move in response to the shock. The job creation curve (JCC) is downward sloping (closed capital account) or vertical (open capital account) and moves in the indicated direction in response to the increase in urban TFP.

## Table 3. The assumptions used in the calibration

| Constrained parameters/baseline outcomes | Value | Source |
| --- | --- | --- |
| Exponent on labour (agriculture) | 0.37 | Imam and Whalley (1985) |
| Exponent on labour (formal sector) | 0.42 | Imam and Whalley (1985) |
| Agricultural employment share (La) | 0.28 | ILO LABORSTA, 1990 |
| Informal sector share of urban labour (u) | 0.30 | Gong and van Soest (2002) |
| Annual interest rate (r) | 0.04 | Standard |
| Matching function elasticity ($\gamma$) | 0.50 | Standard |
| Monthly job separation rate ($\lambda$) | 0.06 | Gong and van Soest (2002) |
| Monthly vacancy fill rate (ratio of matches to vacancies) | 0.50 | Andolfatto (1996, p. 121) |
| Recruitment costs/formal sector output | 0.03 | See text |
| Firing costs/formal sector wage | 2.00 | See text |
| Severance pay/formal sector wage | 4.00 | Capelleja (1997) – see text |
| Search cost elasticity ($\varphi$) | 2.00 | Yashiv (2000, p. 1311) |
| Formal sector wage/rural wage | 1.80 | ILO LABORSTA, 1991 |
| Formal sector wage/informal sector wage | 1.10 | See text |

**Table 4. The effects of raising agricultural TFP by 20%**

| | | Closed capital account | | Open capital account | |
|---|---|---|---|---|---|
| | Baseline | New (NB) | New (EW) | New (NB) | New (EW) |
| Urban unemployment rate | 0.30 | 0.27 | 0.27 | 0.30 | 0.30 |
| Vacancy rate | 0.08 | 0.09 | 0.10 | 0.08 | 0.08 |
| Matching rate | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 |
| Formal-informal wage ratio | 1.10 | 1.14 | 1.13 | 1.10 | 1.10 |
| Urban-rural wage ratio | 1.80 | 1.75 | 1.75 | 1.80 | 1.80 |
| Search (% of time, informal sector) | 0.19 | 0.23 | 0.23 | 0.19 | 0.19 |
| Agricultural labour (% of total) | 0.28 | 0.34 | 0.34 | 0.37 | 0.37 |
| Formal sector (% of total) | 0.50 | 0.48 | 0.48 | 0.44 | 0.44 |
| Informal sector (% of total) | 0.22 | 0.18 | 0.18 | 0.19 | 0.19 |
| Agricultural wages (% increase) | | 5.95 | 5.61 | 0.00 | 0.00 |
| Formal sector wages (% increase) | | 3.23 | 2.51 | 0.00 | 0.00 |
| Total labour income (% increase) | | 0.08 | -0.24 | -5.33 | -5.33 |
| Agricultural output (% increase) | | 29.10 | 29.35 | 33.56 | 33.56 |
| Formal sector output (% increase) | | -2.14 | -1.86 | -13.05 | -13.05 |
| Informal sector output (% increase) | | -20.39 | -22.35 | -13.05 | -13.05 |
| GDP (% increase) | | 2.56 | 2.58 | -4.16 | -4.16 |
| GNP (% increase) | | 2.56 | 2.58 | 1.76 | 1.76 |

**Table 5. The effects of raising TFP in the formal sector by 20%**

| | | Closed capital account | | Open capital account | |
|---|---|---|---|---|---|
| | Baseline | New (NB) | New (EW) | New (NB) | New (EW) |
| Urban unemployment rate | 0.30 | 0.24 | 0.22 | 0.12 | 0.08 |
| Vacancy rate | 0.08 | 0.10 | 0.12 | 0.16 | 0.25 |
| Matching rate | 0.04 | 0.05 | 0.05 | 0.05 | 0.06 |
| Formal-informal wage ratio | 1.10 | 1.20 | 1.18 | 1.76 | 1.71 |
| Urban-rural wage ratio | 1.80 | 1.68 | 1.66 | 1.31 | 1.25 |
| Search (% of time, informal sector) | 0.19 | 0.30 | 0.29 | 0.93 | 0.95 |
| Agricultural labour (% of total) | 0.28 | 0.22 | 0.22 | 0.08 | 0.08 |
| Formal sector (% of total) | 0.50 | 0.60 | 0.61 | 0.81 | 0.85 |
| Informal sector (% of total) | 0.22 | 0.18 | 0.17 | 0.11 | 0.07 |
| Agricultural wages (% increase) | | 17.35 | 16.34 | 120.24 | 123.51 |
| Formal sector wages (% increase) | | 9.25 | 7.32 | 60.00 | 55.34 |
| Total labour income (% increase) | | 13.93 | 13.11 | 82.95 | 84.68 |
| Agricultural output (% increase) | | -8.97 | -8.50 | -37.10 | -37.65 |
| Formal sector output (% increase) | | 28.99 | 29.88 | 149.08 | 159.83 |
| Informal sector output (% increase) | | -25.88 | -30.48 | -95.48 | -97.73 |
| GDP (% increase) | | 18.01 | 18.13 | 98.54 | 104.10 |
| GNP (% increase) | | 18.01 | 18.13 | 30.88 | 31.55 |

**Table 6. The effects of raising the matching efficiency index M by 20%**

| | | Closed capital account | | Open capital account | |
|---|---|---|---|---|---|
| | Baseline | New (NB) | New (EW) | New (NB) | New (EW) |
| Urban unemployment rate | 0.30 | 0.26 | 0.29 | 0.24 | 0.26 |
| Vacancy rate | 0.08 | 0.07 | 0.06 | 0.08 | 0.05 |
| Matching rate | 0.04 | 0.04 | 0.04 | 0.05 | 0.04 |
| Formal-informal wage ratio | 1.10 | 1.08 | 1.11 | 1.11 | 1.13 |
| Urban-rural wage ratio | 1.80 | 1.76 | 1.79 | 1.72 | 1.74 |
| Search (% of time, informal sector) | 0.19 | 0.19 | 0.20 | 0.23 | 0.23 |
| Agricultural labour (% of total) | 0.28 | 0.28 | 0.27 | 0.26 | 0.25 |
| Formal sector (% of total) | 0.50 | 0.53 | 0.51 | 0.56 | 0.55 |
| Informal sector (% of total) | 0.22 | 0.19 | 0.21 | 0.18 | 0.20 |
| Agricultural wages (% increase) | | -0.17 | 1.25 | 5.58 | 6.57 |
| Formal sector wages (% increase) | | -2.20 | 0.56 | 0.83 | 2.94 |
| Total labour income (% increase) | | -0.20 | 1.05 | 4.58 | 5.44 |
| Agricultural output (% increase) | | 0.10 | -0.72 | -3.14 | -3.67 |
| Formal sector output (% increase) | | 2.09 | 0.81 | 12.06 | 9.43 |
| Informal sector output (% increase) | | -11.99 | -2.90 | -20.91 | -14.05 |
| GDP (% increase) | | 0.87 | 0.73 | 7.05 | 6.16 |
| GNP (% increase) | | 0.87 | 0.73 | 1.58 | 1.88 |

**Table 7. The effects of halving the lump-sum firing cost, initially twice the monthly wage in formal sector**

| | | Closed capital account | | Open capital account | |
|---|---|---|---|---|---|
| | Baseline | New (NB) | New (EW) | New (NB) | New (EW) |
| Urban unemployment rate | 0.30 | 0.28 | 0.28 | 0.26 | 0.25 |
| Vacancy rate | 0.08 | 0.09 | 0.09 | 0.09 | 0.10 |
| Matching rate | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 |
| Formal-informal wage ratio | 1.10 | 1.12 | 1.12 | 1.15 | 1.14 |
| Urban-rural wage ratio | 1.80 | 1.77 | 1.77 | 1.74 | 1.72 |
| Search (% of time, informal sector) | 0.19 | 0.21 | 0.21 | 0.24 | 0.25 |
| Agricultural labour (% of total) | 0.28 | 0.27 | 0.27 | 0.25 | 0.24 |
| Formal sector (% of total) | 0.50 | 0.53 | 0.53 | 0.55 | 0.57 |
| Informal sector (% of total) | 0.22 | 0.21 | 0.21 | 0.20 | 0.19 |
| Agricultural wages (% increase) | | 3.40 | 3.18 | 8.25 | 8.92 |
| Formal sector wages (% increase) | | 1.85 | 1.42 | 4.46 | 4.00 |
| Total labour income (% increase) | | 2.85 | 2.66 | 6.81 | 7.33 |
| Agricultural output (% increase) | | -1.94 | -1.82 | -4.55 | -4.90 |
| Formal sector output (% increase) | | 1.80 | 1.98 | 9.91 | 12.42 |
| Informal sector output (% increase) | | -5.91 | -7.17 | -13.54 | -18.43 |
| GDP (% increase) | | 1.80 | 1.82 | 6.85 | 8.17 |
| GNP (% increase) | | 1.80 | 1.82 | 2.35 | 2.53 |

**Table 8. The effects of increasing the job expiry rate by 20%, from 0.06 to 0.072 per month**

| | | Closed capital account | | Open capital account | |
|---|---|---|---|---|---|
| | Baseline | New (NB) | New (EW) | New (NB) | New (EW) |
| Urban unemployment rate | 0.30 | 0.34 | 0.35 | 0.39 | 0.43 |
| Vacancy rate | 0.08 | 0.09 | 0.09 | 0.08 | 0.07 |
| Matching rate | 0.04 | 0.05 | 0.05 | 0.04 | 0.04 |
| Formal-informal wage ratio | 1.10 | 1.08 | 1.08 | 1.03 | 1.04 |
| Urban-rural wage ratio | 1.80 | 1.78 | 1.78 | 1.85 | 1.88 |
| Search (% of time, informal sector) | 0.19 | 0.19 | 0.19 | 0.14 | 0.13 |
| Agricultural labour (% of total) | 0.28 | 0.28 | 0.28 | 0.32 | 0.33 |
| Formal sector (% of total) | 0.50 | 0.47 | 0.47 | 0.41 | 0.39 |
| Informal sector (% of total) | 0.22 | 0.25 | 0.25 | 0.27 | 0.29 |
| Agricultural wages (% increase) | | -0.94 | -0.87 | -8.51 | -9.56 |
| Formal sector wages (% increase) | | -1.93 | -1.79 | -6.19 | -5.54 |
| Total labour income (% increase) | | -0.82 | -0.76 | -7.52 | -8.48 |
| Agricultural output (% increase) | | 0.55 | 0.51 | 5.36 | 6.08 |
| Formal sector output (% increase) | | -2.98 | -3.03 | -18.64 | -23.45 |
| Informal sector output (% increase) | | 15.05 | 15.44 | 31.82 | 41.85 |
| GDP (% increase) | | -1.64 | -1.64 | -11.02 | -13.52 |
| GNP (% increase) | | -1.64 | -1.64 | -2.56 | -2.88 |

**Technical appendix on the calibration (not for publication)**

**Parameter assumptions (details)**

**1. Technology parameters**

The figure for the labour exponent in the agricultural production function we take as 37%, based on Imam and Whalley (1985), which in turn is based on Kehoe and Serra-Puche (1983). This figure corresponds quite well to those in Taylor (2002). He reports labour shares of 40% for basic grains, 35% for modern grains, 60% for labour-intensive cash crops, 32% for capital-intensive cash crops, and 10% for livestock rearing. Without detailed information on the respective importance of these crops, we regard 37% as a representative figure.

The figure for the labour exponent in the formal sector production function we set at 43%, again following Imam and Whalley (1985). UNIDO data on the labour share for manufacturing suggest a lower value, 22% for 1991, but we choose a higher figure on the basis that the non-agricultural sector includes services (with a high labour share) as well as manufacturing. Note that otherwise, if we took the UNIDO share at face value and combined it with our choice of the labour share for agriculture, this would imply a very low aggregate labour share (labour income as a fraction of GDP).

The Kehoe-Serra-Puche figures are a useful starting point but should not be taken too literally. First, they are based on relatively old data, requiring strong assumptions about parameter constancy over time. Second, they are not obtained by direct measurement, but by requiring that the observed sectoral structure is consistent with the equilibrium of a CGE model for Mexico. Nevertheless, given that these estimates have been used in several previous calibrations of dual economy models for Mexico (Imam and Whalley 1985, Bhatia 2002) they form a natural starting point for our own analysis, and are less arbitrary than other potential choices.

**2. Agricultural employment share**

The agricultural employment share “La” is set to be 28%, based on ILO data for 1990 extracted from the LABORSTA database. The exact figure is obtained as the economically active population in agriculture divided by the economically active population in agriculture, industry and services (both sexes). Our calculation assumes that informal sector workers are classed as economically active in industry and services; were this not the case, and hence informal sector workers were omitted from the denominator, the calculated employment share would have to be adjusted downwards to correspond to the variable “La” in the model. For example, with an informal sector employment share (“u”) of 30%, the value of “La” would be 21% rather than 28%.

**3. Informal sector as a share of urban workforce**

We require the baseline equilibrium of the model to match the informal sector's share of the urban workforce (“u”) as 30%, based on the estimate of Gong and van Soest (2002, p. 519).

**4. Interest rate**

We set the annual interest rate at 4%, a figure often used in calibrations of macroeconomic models for developed countries (for example, Andolfatto 1996).

**5. Matching function elasticity**

We set this elasticity to 0.5, a standard choice in the literature on search and matching for developed countries.

**6. Monthly job separation rate**

The monthly job expiry rate $\lambda$ is set at 6%. This is based on a quarterly figure reported by Gong and van Soest (2002), and assuming that the probability of job loss and re-employment within a quarter is at its steady-state value. Note that given "u" this pins down steady-state matches $m=\lambda(1-u)$ as a fraction of the urban workforce.

**7. Monthly vacancy fill rate**

In calibrating the vacancy fill rate, the inverse of the duration of vacancies, we have little information for developing countries, given data limitations and our relatively broad interpretation of what is meant by a "vacancy". Here we follow Andolfatto (1996) and Merz (1995) in imposing an average duration of 45 days. Assuming that a vacancy may be filled on each day of a 30-day month, this implies that in monthly terms the ratio m/v – the rate at which vacancies are filled – is equal to 1-(44/45)^30 or approximately 0.50. Since "m" is known (see section 6 above) this pins down the vacancy rate v and, given knowledge of m, s and u, this means that we can also pin down the matching efficiency index M.

The figure of 45 days comes from a study of the Dutch economy by van Ours and Ridder (1992). We are being conservative here: our broad interpretation of a vacancy would suggest longer durations are plausible, and we could then match the observed size of the informal sector while assuming smaller flow costs of posting a vacancy.

**8. Recruitment costs**

A key parameter is the flow cost of posting a vacancy, c. To select a value for this parameter, we follow the approach of Andolfatto (1996) and impose the ratio of recruiting costs to formal sector output in the baseline steady-state. It is important to emphasize that our calibration is quite sensitive to the choice of this ratio. As the size of recruiting costs is progressively reduced, we need workers to receive a larger allocation of the surplus (reducing returns to firms, and hence entry) if we are to continue matching an informal sector employment share of 30%. For our baseline calibration, we set the ratio at 3%, compared to Andolfatto's use of 1% for the US economy. This difference might be justified if the recruitment of formal sector workers is a costlier process in developing countries than in the US, for example, because systems for transmitting information about labour market opportunities are weaker. The paper briefly examines how our conclusions are modified by the alternative choice of 1%, used in Andolfatto (1996, p. 120).

**9. Firing costs and severance pay**

The model includes a role for firing costs, F. In the model these firing costs represent a resource cost to the firm of job expiry. We set these costs at twice the monthly wage at baseline, so that it will have a similar order of magnitude to severance pay.

We set the severance pay parameter P to be four times the monthly wage. This is motivated by Mexico's labour market regulations: in essence, a firm that dismisses a worker must pay the worker three' months salary plus twenty days of salary for each year worked (for example, Capelleja 1997).

Our estimate of the monthly job expiry rate implies an average job duration of almost 17 months in the formal sector, so that setting P at four times the monthly wage is a reasonable approximation. In the calibration, given that severance payments are always proportional to salaries, the lump-sum P is adjusted so that it rises or falls in proportion to the formal sector wage when a new equilibrium is derived.

**10. Elasticity of search costs**

For the elasticity of search costs with respect to search intensity, see Yashiv (2000). Using microeconomic data, a quadratic function emerges as his preferred specification. As in our calibrated model, he assumes search costs are proportional to unemployment income - in our model, the informal sector wage.

**11. Wage differentials**

The ratio of the formal sector wage to the agricultural wage we set at 1.80. This figure is based on the ratio of manufacturing earnings per month to those in agriculture for men in 1991, using ILO LABORSTA data (originally from a labour force survey). This figure should be seen as an upper bound on the true differential, because manufacturing workers are likely to be more skilled on average than agricultural workers. For women the manufacturing earnings per month are slightly below those in agriculture but this appears to be due to differences in working hours. When figures on earnings per hour become available, in 1998, the ratio of the manufacturing wage to the agricultural wage is around 2.00 for men and women combined, and around 1.50 for women. Venables and van Wijnbergen (1993) assumed that the urban marginal product for unskilled labour in Mexico was twice that in rural areas.

The ratio of the formal sector wage to the informal sector wage is harder to calibrate, given our assumption that workers are homogenous. This is because Gong and van Soest (2002) find that their estimated wage differentials, corrected for selection effects, differ across subgroups of the population. For men and women with low or intermediate education, there is no formal sector wage premium, or even a small premium for the informal sector (their Table 5). For the highly educated, who comprise 19% of the men and 7% of the women in their sample, there is a substantial formal sector premium of around 45%, correcting for selection effects. Given the relatively small proportion of individuals who are highly educated, and the uncertainties inherent in estimating wage differentials, we set the formal-informal sector wage premium at a low value, namely 10%.

**Model solution**

We reduce each model to 3 nonlinear simultaneous equations and then solve them numerically to obtain unconstrained parameters and outcomes at the baseline equilibrium. We then use a similar procedure to solve for the new equilibrium in response to a parameter change. At each stage we check that the key equations for the steady-state of the model are satisfied by the derived equilibrium.

More details can be made available on request.

**References in addition to the main paper**

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