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Trade, Employment and the Informal Sector: An Agent-based Analysis

Bill Gibson

This article discusses a multi-agent model of the informal sector. An analytical model is first developed to explore the possible range of relationships between formal and informal employment. Data from the agent-based model support protecting formal sector jobs with current account restrictions. It is seen that restrictions on outsourcing can have a positive effect on formal sector activity. Offshoring, that is, relocating to another country, is also considered. When restrictions on offshoring are studied, it is seen that formal sector employment growth is less robust. Unrestricted current and capital account activity produces a steady state with near zero informal activity, while restrictions preserve the informal sector indefinitely.

Keywords: *Informal Sector, Employment, Agent-based Models*
JEL Classifications: *O17, E17, D58*

1. Introduction

Trade usually improves growth outcomes by raising productivity in the traded goods sector but, at the same time, lowering productivity in the non-traded goods sector. One of the reasons is that the transition to openness involves a change in the structure of demand for labour, frequently increasing the demand for skilled labour while reducing the demand for unskilled labour. The latter retreat to the informal sector, causing measured productivity of the non-traded goods sector as a whole to plummet. A large productivity gap emerges (McMillan and Rodrik, 2011). Subsequent econometric studies based on aggregate data present an inaccurate picture of the relationship between trade and growth

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because of the presence of the transitionary effect of the informal sector. This article models the relationship between trade and the informal sector using an agent-based model, which permits a low level of aggregation. Two policy options are considered and compared to free markets. It is seen that protection against outsourcing increases the availability of formal sector jobs as do restrictions on offshoring, even though the latter effect is weaker. Unrestricted policies produce a steady state with near zero informal activity, while restrictions on trade and capital movements cause persistent informal activity.

The article is organised as follows. Section two reviews the theory of the informal sector. Section three presents the agent-based model; and the fourth section discusses the results of the simulations. A fifth section concludes.

2. Trade and the Informal Sector

Sinha (2011) notes that since the 1960s, it was generally accepted that economic growth would eventually lead to the disappearance of the informal sector. Since trade is associated with more rapid growth, it follows that trade should accelerate the decline in informality, as in the celebrated model of Lewis (1954). Yet,

> …despite strong global growth that coincided with a massive increase in international trade, many jobs in developing countries remain in the informal economy. The share of employment in the informal economy has been persistent in many developing countries over recent decades and even increased in some regions. On average, 60 per cent of employment in developing countries is in the informal sector…In contrast to developed countries' experiences, the formal sector in developing countries has not been able to absorb informal workers and production processes as expected. In fact, many studies suggest that globalisation and trade reforms lead to competition in the formal sector, which may result in a reduction in formal employment, at least in the short run. (Sinha, 2011, p. 125)

Standard trade models based on the Heckscher–Ohlin–Samuelson (HOS) competitive framework determine the pattern of specialisation in trade by reference to factor endowments. Since factor returns are flexible, there is nothing preventing markets from clearing, and thus full employment is assured. In the real world, sticky wages and prices can impede market clearing, so that labour released from import-competing sectors is not instantaneously absorbed in the expansion of the exporting sector. If the latter is more capital intensive than the former, it may take time for the wage rate to fall sufficiently to bring about the adjustment to full employment.

In developing countries, the full employment wage rate may be close to zero and institutional factors can prevent the market from ever clearing. Jansen and Lee (2007) refer to this process as 'reshuffling' and note that workers laid off from contracting industries in economies without social safety nets may well have to find employment immediately, but the quality of the work could easily deteriorate. If the expanding export sector needs less labour than the contracting sector releases and the real wage does not fall, informal activity will rise (McMillan and Rodrik, 2011). A large productivity gap may occur between the formal and informal sectors.

Not all trade fits this pattern, however. *Intra-sectoral* trade between developed economies, for example, probably has the least impact on employment. A vintner in Italy produces wine and joins his countrymen in consuming all that is produced. Then an opportunity appears to trade some of this wine for German beer, which at least some Italians enjoy. The reverse occurs in Germany and, after some initial adjustment, both Italians and Germans consume both wine and beer with little impact on productivity or employment.[1]

It may well be the case that in both Germany and Italy, small, less productive producers of both wine and beer might exist. According to the classical theory of the informal sector, these producers are price takers, with the returns to capital and labour adjusting endogenously in the model. If as a result of trade, the price of the product produced by the informal producers falls, then the rate of profit on that process also falls. In a perfectly competitive economy, the decline in the profit rate would cause the process to be abandoned. The definition of the informal sector implies that the process will not be abandoned so long as no formal sector employment is available for the informal producers. Even if the profit rate turns negative, such that at the going wage, negative profits are produced, the informal producer will still continue to operate the process in order to survive. No formal sector capitalist would operate the informal process because it would not return the average rate of profit while paying the prevailing wage (Gibson and Kelley, 1994).

2.1 A Simple Dynamic Model

The relationship between trade and informal sector employment can be cast as a relationship between productivity and formal employment. As will be discussed explicitly, trade liberalisation can affect the quantity of labour per unit of capital either by way of changing the pattern of aggregation of production

[1] Transportation and other transaction costs perhaps rise, and are not captured in the model of this article.

processes or through the introduction of technological change or both. If productivity rises with liberalisation in the traded goods sector, it may well fall in the non-traded informal sector.

Thus, there are two fundamental forces structuring the relationship between productivity and employment, working in opposite directions. Any improvement in productivity will *ipso facto* reduce the quantity of labour necessary for the production of a given quantity of output in formal or traded sectors. Thus, a rise in productivity will act to reduce employment initially. At the same time, productivity growth stimulates capital accumulation in that it can raise the profitability and provide incentives to invest. There are, of course, a range of factors that determine the magnitude of the elasticity of investment with respect to productivity, but there is little question about its sign. In this section, we take an agnostic approach to the precise determinants of the relationship and simply assume that higher productivity increases the capital stock by providing a menu of incentives leading to its accumulation. In the following section, we pin down the relationships discussed in this section in a more detailed presentation of the agent-based model.

First, assume that the time derivative of employment, L, and productivity, ρ, can be expressed by the following system of differential equations:

$$\dot{L} = F(L, \rho)$$

$$\dot{\rho} = G(L, \rho)$$

where, F and G are arbitrary functions with the following properties. First, $\frac{\partial F}{\partial L} < 0$ since an increase in L will, holding everything else constant, reduce the rate of growth of employment. This relationship is simply a measure of the tightness of labour markets as the demand for labour approaches available supply. The condition $\frac{\partial F}{\partial \rho} < 0$ holds due to the fact that higher productivity is a drag on employment, as discussed earlier. The sign of the derivative $\frac{\partial G}{\partial \rho}$ is negative simply because productivity cannot continue to increase indefinitely.

The sign of $\frac{\partial G}{\partial L}$ is of fundamental importance in the following discussion. Its sign is less certain and hinges upon a series of factors. First, if labour market tightness causes investment to increase in order to substitute capital for increasingly scarce labour, the sign of this derivative will be positive. On the other hand, if the rising demand for labour causes real wages to increase to the point that further investment is unprofitable, this derivative will be negative. The sign is investigated econometrically later, but for the moment, assume that it is positive. This produces a Jacobian matrix with the pattern:

$$J = \begin{bmatrix} 0\,0 \\ /\,0 \end{bmatrix}$$

Local stability depends on two conditions, first that the trace of the Jacobian is negative; that is, $TrJ = J_{11} + J_{22} < 0$. Under the earlier assumptions, this condition holds. The second condition is that the determinant $J|J| = J_{11}J_{22} - J_{12}J_{21} > 0$, which is also satisfied according to the assumptions. The resulting dynamic system is shown in Figure 1. The slopes of the isoclines

$$\dot{L} = -J_{11}/J_{12} < 0 \tag{1}$$

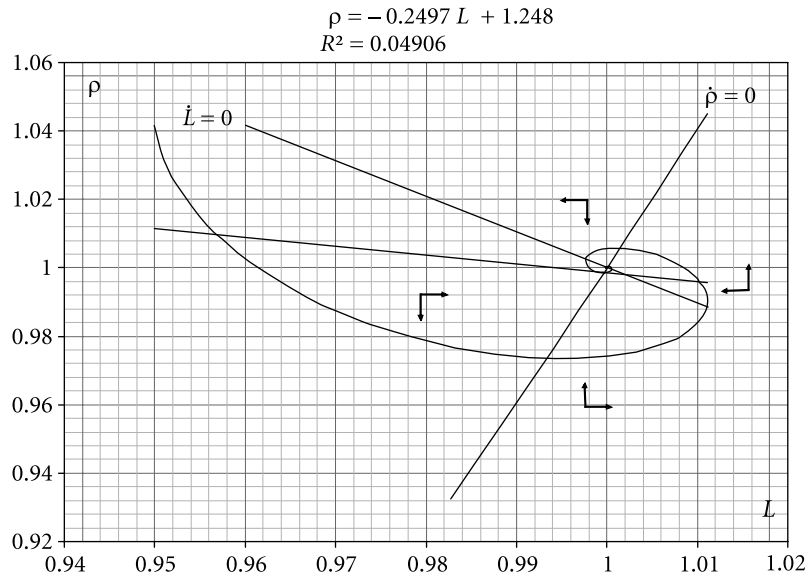
$$\dot{\rho} = -J_{21}/J_{22} > 0 \tag{2}$$

are determined by these same assumptions.

The system converges to a steady state along a sample trajectory as shown in Figure 1, crossing the $\dot{L}$-isocline vertically and the $\dot{\rho}$-isocline horizontally. Depending on the initial conditions, the system may converge to an equilibrium that has higher or lower employment than that with which it began.

Observe that the relationship between productivity and employment is highly variable in this diagram. If the initial conditions (L, ρ) are to the

Figure 1 Phase Diagram

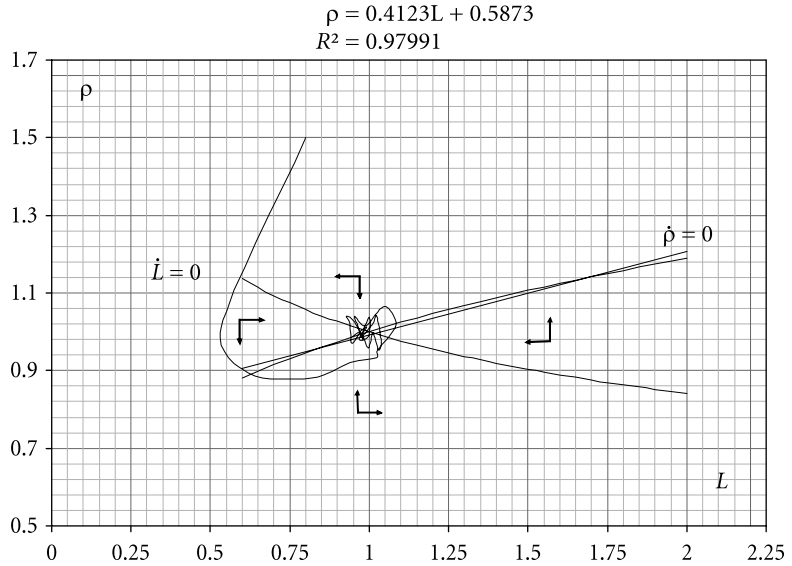


Source: Author's computation.

south-west of the final resting point, employment will initially rise with productivity, but then slow and eventually decline as productivity continues to increase. Eventually, productivity falls and employment begins to increase again. The spiral tightens with each rotation, but the relationship between productivity and employment can be taken to be of either sign depending upon the region in which the economy resides at any given moment along its path. The figure suggests that there is no one-way relationship between the two in theory and thus, one would not expect to uncover a uni-causal relationship in the data. This is a fundamental difficulty with the problem. Figure 1 shows a possible path when the initial conditions are to the north-west of the equilibrium. A linear regression is run through the data to determine the approximate slope of the employment–productivity relationship. Here is the slope seen to be somewhat negative. In Figure 2, however, the regression shows a positive slope. This result hinges on the relative slope of the two isoclines.

Consider several cases. Case I: The isocline slopes are relatively flat. In this case, the denominators in equations (1) and (2) are large relative to their numerators. Is this likely in reality? It was just noted earlier that in the equation for the slope of the labour isocline, there are opposing forces in the determination of the numerator that may cancel each other out. Yet, in the denominator, only one force is active, that of rising productivity slowing employment growth. Thus, it

Figure 2 Phase Diagram with Noise



Source: Author's computation.

would be reasonable to think that the slope of the employment isocline is indeed small. With regard to the productivity isocline, the effect of ρ on productivity growth, J_{22}, would seem to be relatively large, while the effect of employment on employment growth would only be large near full employment. At levels of unemployment observed in most developing economies, the effect of an increase in employment is not likely to have much of an impact on the growth of employment. Hence, it might be reasonable to assume that the slope of the second isocline is also relatively flat.

The assumptions of Case I suggest that the effect of productivity is larger on both employment and further productivity growth than is the level of employment. The assumptions imply that the north and south phase regions are relatively large, while the east and west are small. There will then be a large number of observations in the north and south quadrants and few in the east and west. When most of the observations are in the north and south regions, employment and productivity are positively related. Only in the east and west regions are they negatively related.

Case II: For the employment isocline to be steep, the effect of employment on productivity must be strongly positive, again presumably the result of higher investment to offset labour scarcity. Similarly, for the $\dot{\rho}$-isocline, the effect of employment on productivity growth must be large, a Verdoon effect. In other words, when the isoclines are relatively steep, it must be the case that labour markets are tight and that investment is very responsive to labour market tightness. If the latter is the result of rapid growth in aggregate demand, productivity growth is pro-cyclical. Neither of these conditions necessarily holds in developing economies.

In Case II, the east and west regions of the phase plane are just as prominent as the north and south. Periods in which productivity and employment move in opposite directions are more balanced with periods in which they move together. Figure 2 adds an additional complication: there is noise in the data as the differential equations are stochastic and so the adjustment process takes a random error into account. In the parallelogram defined by the intersection of 2-*sd* errors (not shown), the trajectories can move randomly and more randomly the closer they get to the origin. This puts more weight on the outer observations in determining the slope of the regression line. Even so, note that the flatness of the isoclines produces a positive coefficient with large R^2.

2.2. Informal Sector

Now when we introduce the informal sector into the model, things change. The negative relationship between productivity and employment becomes much

stronger. Investment raises the productivity of the modern sector but, at the same instance, disgorges the least skilled workers onto the unskilled labour market. If formal jobs cannot be found, these workers take up informal sector activities, processes with characteristically low labour productivity. A productivity wedge appears, with ever-higher productivity formal sector labour working alongside ever-lower productivity informal sector workers.

The main hypothesis that emerges from this simple analytical model is that the presence of the informal sector increases the absolute value of $J_{12} = \left|\frac{\partial F}{\partial \rho}\right|$. A rise in foreign investment with its associated rapid growth in productivity has a *stronger* negative effect on employment when an informal sector is present.

At the same time, the increase in productivity has a *weaker* effect on total productivity growth, since productivity-enhancing investment in the formal sector at the same time lowers the productivity in the informal sector. Overall, productivity does not advance as quickly. More importantly, the rise in productivity in the formal sector sets the stage for more productivity-enhancing investment in the future. This can occur in the informal sector itself as startups graduate to formality. A larger informal pool of labour may serve to attract foreign capital, as well thereby accelerating productivity growth. The point made here is simply that the informal sector can embody *potential* productivity growth, potential that is not present in societies in which all labour is formal. In general, this will tend to steepen the $\dot{\rho}$-isocline, but its effect may be limited.

Finally, the magnitude of $\frac{\partial G}{\partial L}$, the effect of employment on productivity growth, is much lower in the presence of an informal sector. Higher rates of employment could send firms in search of ways to substitute capital for ever-more scarce labour. With a replete informal sector, there is less necessity to invent one's way out of the labour shortage since none effectively exists. A low value of this partial derivative reduces the slope of the $\dot{\rho}$-isocline, strengthening the one-way relationship between productivity and employment.

The working hypothesis is, then, that the combined effect of the presence of the informal sector is most likely to flatten both isoclines, lowering the probability that a rise in productivity will, on balance, diminish employment growth. Most paths will then look like that illustrated in Figure 2, with employment and productivity rising together towards the steady state.

2.3 Econometric Estimates

Might it be possible to determine empirically the slope of the relationship between employment and productivity? In regressions of employment on output per worker, greater productivity can cause higher employment as easily as higher employment causes higher productivity. Recent attempts to solve this

problem have instrumented employment by changes in labour taxes since the latter should be unaffected by changes in productivity. Several authors have found a strong *negative* relationship between productivity and employment, for example, Beaudry and Collard (2002), among others. This effort would suggest that protection is the right way to save jobs since protection reduces productivity and therefore increases employment. In this view, the phase plane geometry of Figure 1 is correct and one cannot rely on trade to spur employment growth or the demise of the informal sector. We return to this issue later.

A casual conversation with the data does not lead to the same conclusion. Since reliable data for world employment are not readily available, a work-around is necessary. One approach is to replace employment with the labour force, a variable widely reported, under the assumption that there is no trend in unemployment rates over time.[2] To counteract spurious correlation, the regressions use time fixed effects. Country fixed effects partially compensate for the endogeneity, since what would be a large error associated with a large value of the independent variable ρ is absorbed into the dummy variable. The results of the regression are presented in Table 1.

In Table 1, equation 1 includes only *country* fixed effects, while the rest have two-way fixed effects, *country* and *time.* In all equations, the coefficient on the measure of productivity (in log form in the equations) is positive and significant. Moreover, the results are stable whether the data is weighted or whether time fixed effects are included. The significance and positive sign of the coefficient on the *productivity* variable continues to hold for equation 4, which uses two-way fixed effects and includes the variable *trade* to measure openness in the economy (the ratio of the sum of imports and exports to gross domestic product [GDP]). Including *trade* in the model reduces slightly the coefficient on the *productivity* variable but it remains significant at the 1 per cent level. The coefficient on the *trade* variable itself is also positive and significant.

These simple regressions can only be suggestive, but they lend support to the notion that there is a positive relationship of labour productivity and trade with employment, and thus the disappearance of the informal sector. The estimates are also relatively robust to the structure of the regression. On the other hand, the simultaneity discussed in this section will play an important role in the behaviour of agents in the multi-agent systems model discussed next.

[2] This proxy certainly reduces the variability of the dependent variable and leads to inflated *t*-stats, as will be reported. Whether the resulting upward bias in reported *t*-ratios is sufficient to create a false impression of significance is a judgement left to the reader.

Table 1 Dependent Variable: Natural Log of the Labour Force

Equation	*1*	*2*	*3*	*4*	*5*
Productivity[2]	0.300***	0.307***	0.300***	0.307***	0.285***
	(0.047)	(0.046)	(0.047)	(0.046)	(0.063)
Trade					0.001*
					(0.001)
Constant	12.549***	11.707***	12.549***	11.707***	11.779***
	(0.416)	(0.452)	(0.416)	(0.452)	(0.601)
R^2-adjusted	0.063	0.127	0.063	0.127	0.123
Observations *n*	–	4568	–	4568	3536
F-stat	41	44.8	41.1	44.9	17.1
Time fixed effects	no	yes	yes	yes	yes
County fixed effects	yes	yes	yes	yes	yes
Population weights	yes	no	yes	no	no

Source: Author's computations based on World Bank (2009).
Notes: (a) Standard errors in parentheses.
(b) ***p < 0.01; **p < 0.05; *p < 0.1.
1. The dependent variable is the log of the labour force.
2. The variable *productivity* is the log of income per capita.
3. The variable *trade* is the sum of exports and imports divided by gross domestic product.

3. An Agent-based Model

The theoretical analysis of the previous section suggests that economies with informal sectors are more likely to benefit from job-creating investment. The empirical literature is ambiguous but slightly favours a positive relationship between informality and employment growth in the long run. The problem may also be addressed from the perspective of the agents themselves in a multi-agent model, the subject of this section.

3.1 Agent-based Models and the Informal Sector

The agent-based approach to the evaluation of the impact of trade on employment and the informal sector is in its infancy, to say the least.[3] It is a new

[3] See, for example, Brock and Durlauf (2005). The model of this article is written in NetLogo, a Java-based front end for multi-agent system modelling. See Railsback et al. (2007), for a review of various platforms available for the task. NetLogo is from Wilensky (1998). The model of this article is similar to the Sugarscape model of Epstein and Axtell (1996). See Gibson (2007, 2008).

methodology that has been applied to a wide range of economic problems, but little has been written on the question of how the presence of an informal sector impacts employment growth.

According to Farmer and Foley (2009), an agent-based model is a simulation in which a range of self-interested decision makers, the agents, interact in a relevant institutional structure. Agents are bred for specific characteristics, but within each breed, they are also heterogeneous so that it is unlikely that two agents would ever behave in precisely the same way. This sets agent-based models in rather stark opposition to the representative agents of stochastic general equilibrium models or even computable general equilibrium models. In the latter, there are certainly agents, but emphasis there is on rational choice structurally constrained. The question therefore is: whether an equilibrium exists and what are the comparative static, or dynamic, responses to exogenous shocks? Since the equilibrium most always exists, there is rarely a surprising regularity that arises out of the solution. In agent-based or multi-agent systems, the surprising regularities are known as 'emergent properties'.

Phase transition is a well-know example of an emergent property. All such transitions have an order parameter, which is zero on one side of the transition and non-zero on the other. There are few restrictions on how the order parameter is defined, but it must 'flip' in some observable way at a critical point. When multi-agent systems approach a critical point of phase change, they may vacillate between the alternative and distinct macro states for very small changes in external or environmental variable. Some examples include when liquid water changes to ice at a constant temperature or in percolation when the fractional size of a spanning cluster reaches a critical value.

The transition of interest in a multi-agent model of the informal sector might simply be defined as when the informal sector disappears or reaches some minimal threshold. Just as it is impossible to deduce from the molecular structure of hydrogen and oxygen the temperature and pressure at which liquid water transitions to ice, it is also impossible to deduce from the properties of rational optimising agents when the transition to full formality will occur, if it does at all. In the analysis of the informal sector, this article replaces 'temperature and pressure' with nature of the trading regime, the level of outsourcing and offshoring.

In the multi-agent systems literature, agents are simply data structures. Agent i is randomly assigned to one of a given number of countries, c_j, and one of a given number of goods, g_j. Agents are positioned on a grid with coordinates (x, y) and may or may not move, as described later, at each sweep of the model. Agents

need not remain in the country to which they are initially assigned, but may go offshore.

Here, each agent operates a process with a given, but not fixed, level of productivity, ρ_j, and employs l_j workers. Output of the ith process, in the jth country is q_{ij}, and is then given by:

$$q_{ij} = \rho_{ij} l_{ij}$$

Agents can then be thought of as scalable production processes. Global output of the ith good is the sum of the output of the processes over countries j:

$$Q_i = \sum_j \rho_{ij} l_{ij}$$

In agent-based models, there are no supply and demand functions per se. A trade is defined as an encounter between two agents that results in the exchange of goods at a negotiated price in a given period or sweep t. Agents may rely on local trading conditions, competition, to aid in the bargaining process in the standard way. If agent i is bargaining with agent j, for example, an adjacent trade between agents k and l, at a different barter rate, may well have an effect on the settled price ratio in the i with j trade. The extent to which this does or does not occur affects the size and the distribution of the gains from trade in period t.

What matters most for the purposes of the model of this article is how the agents respond to the terms of trade in period $t + 1$. In the standard account, agents who benefit the most from trade in the previous period will expand production and those that benefited the least will contract. The response function is not modelled explicitly here but is taken to depend loosely on the productivity of the production process. Once the response is known, the model can then say something about the demand for labour and the impact of growth on formal sector employment. In the model, growth is random but not entirely so: processes that experience a more rapid rate of growth of productivity increase their output by more; and those with slower productivity growth increase hiring at a slower rate.

At each sweep of the model, a randomly selected agent increases hiring by an amount:

$$l_{jt+1} = l_{jt} (1 + \hat{\rho})$$

where, $\hat{\rho}$ is the rate of growth of labour productivity. Agents who have not experienced any productivity growth will, according to this rule, not increase their hiring.

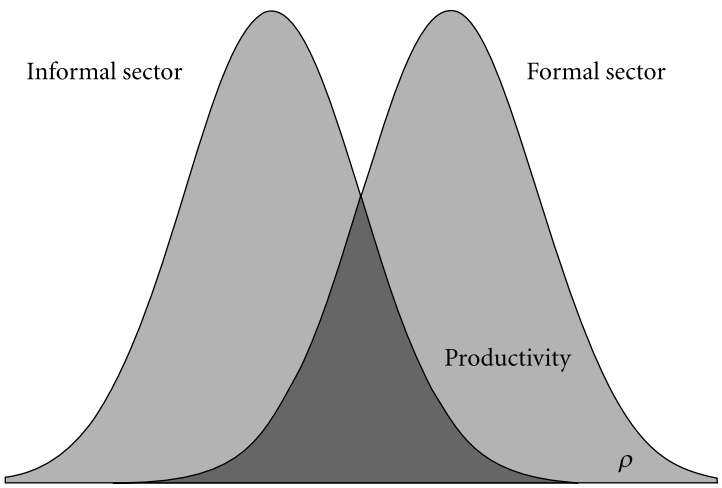
3.2 Informality

Low productivity indicates *informality.* Figure 3 shows the distribution of productivities assumed in the model. The mean productivity of the informal sector is lower than that of the formal sector, but as the diagram makes evident, there is overlap. There are some formal sector processes that operate at lower productivity than their informal counterparts. The graph shows the productivity distribution for all goods of the model, i, but there is nothing in the assumptions of the model that prevents the informal sector from producing a given commodity at a higher level of productivity than the formal sector. The probability is low but it does occasionally happen. An agent, a_j, is therefore defined by the vector:

$$\alpha_i = (\rho, l, c, x, y, \tau, \lambda, \mu)$$

where, τ is the degree of effective protection offered to this process by country c. The variable λ indicates the product life cycle and μ is a variable that indicates the degree to which the process is affected by local macroeconomic conditions such as inflation, the exchange rate and interest rate in the country in which the firm operates. The parameter τ determines the probability that agents will be blocked by tariffs and non-tariff barriers. If an agent encounters a potential trading partner, the trade is more likely to be blocked the higher the setting for the τ parameter.

Figure 3 Distribution of Productivity in Formal and Informal Sectors

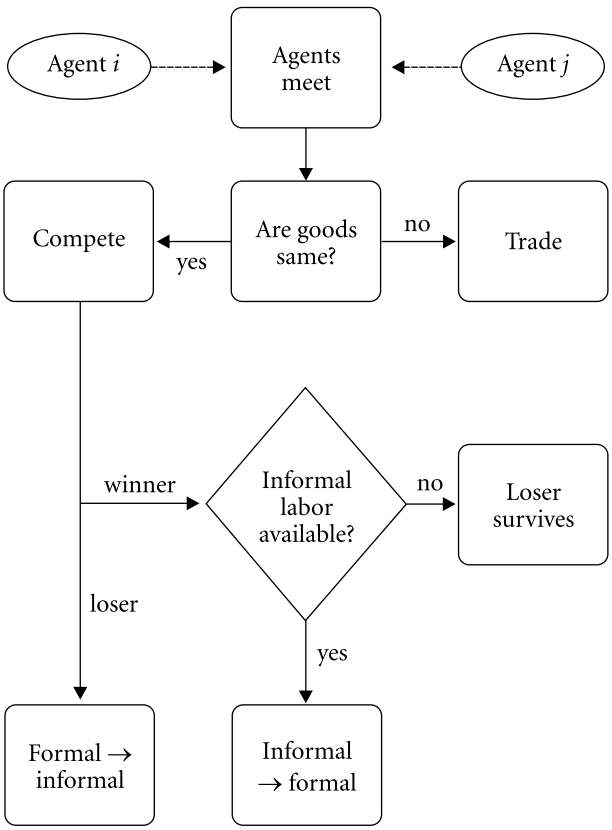


Source: Author's compilation.

Macro policies play a similar role when agents are deciding whether to relocate to another country. Again, if a uniformly distributed random variable exceeds μ, then macro policies of the host country are said to have blocked the relocation of formal sector labour to the new country. Both macro policies and protection can be thought of as increasing the friction against which agents pursue their objectives. The life cycle or product parameter is included in the model to insure that trades, once begun, do not last forever. At sweep t, all agents whose product cycle has expired stop trading and must look for another trading partner.

The model is built around two concepts, outsourcing and offshoring. Figures 4 and 5 show the flow chart of each of the governing logical structures in the model. We begin with a detailed description of agent interaction as captured in Figure 4.

Figure 4 Model Flow Chart for Outsourcing



Source: Author's compilation.

3.3 A Sweep

At each sweep of the model, distance, $d(i, j)$, between agents

$$d(i,j) = \sqrt{(x_i - x_j)^2, (y_i - y_j)^2}$$

is measured. When d reaches a minimum threshold, agents meet and interact. Here, the model is trying to capture the serendipitous nature of economic encounters and crudely models imperfect information, or better, the locality of informational flows. Agents are not aware of all the activities on the grid, but neither are the y entirely ignorant of others. Over time, agents can interact with a significant fraction of other agents. Agents are assigned formal or informal status at the beginning of a run as an initial condition. Note that the economically active population is necessarily greater than the number of agents, since each hires a randomly assigned number of initial employees. Agents with *formal* status hire between two and some upper bound specified in the initialisation of the parameters of the model. The simulations reported next are based on formal sector employment determined by:

$$l_i = 1 + U(0, 9)$$

where, U denotes the uniform distribution of integers. The maximum initial amount of employment is then 10. Informal processes are all assigned one employee each. Note that it is possible for some formal processes to also have one employee. This treatment implicitly assumes some overlap of the size of formal and informal firms. Which agents have the possibility of trading, dissolving because of outsourcing or going offshore, is randomly decided when each process is designated as either formal or informal.

3.4 Trade

Figure 4 is a flow chart depicting the logic of the model. Agents on the grid, designated as formal and who are not already trading, move about looking for potential trading partners. Provided two agents are from different assigned countries, on an encounter, they trade or compete. If the agents from different countries produce different goods, $g_{jk} \neq g_{jl}$ trade can begin with *no loss of employment* or growth in the informal sector in either country. The trade takes place at some unspecified terms of trade and the system's GDP is unaffected. The welfare of each agent will increase because of the well-known benefits of trade, but neither the magnitude nor the distribution of these gains from trade are tracked in the model. Agents trade because they are better-off doing

so. Trade between the *i*th and *j*th agent has no external effect.[4] Barter trade is thus employment neutral and has no effect on employment or output in the informal sector in either of participants' countries. It is assumed to take place exclusively in the formal sector with no change in the demand for the factors of production. In this simplest form of trade, the pattern of specialisation in production does not change. Since each agent (process) only produces one good, there is only the possibility of either consuming the good that the agent has produced or trading all or part of that good for the good produced by its trading partner, if the agent prefers it more. The point here is that at the agent level, there is only the binary choice to produce or not to produce. There is no choice as in the standard trade model of specialisation and trade. For the country as a whole, the choice is an emergent property, a product of the agent-based model rather than assumed.

3.5 Competition, Outsourcing and Informality

If agents from different countries, k and l, produce same goods, g_{ik} and g_{jl}, agents compete rather than trade, as shown in left branch of the flow chart in Figure 4. The competition is over who can produce the good most cheaply and leads to the generalisation of the most productive of the two processes. When

$$\rho_i > \rho_j, \tag{4}$$

the *i*th agent will attempt to produce all the output:

$$\bar{Q}_i \leq Q_i + Q_j$$

where, $\bar{Q}_i$ is the new level of output for the *i*th agent. To determine the level of employment in c_i, it is assumed that the sum of output of the two competing processes remains fixed while the agents compete. Whether the *i*th agent is in fact successful in finding sufficient informal labour depends on the local labour conditions in c_i, the country in which the i agent is located.

In order to produce the combined output $\bar{Q}_i$, there must be sufficient labour in the informal sector in c_i. In principle, nothing prevents hiring workers from other formal sectors, but for the purposes of the model, there is no loss of generality if it is assumed that the net increase in the demand for labour in the winner's country is satisfied by informal workers.

[4] The trade between two agents need not leave prices and wages necessarily the same. Negotiation between the two trading partners may cause the relative prices of their goods to change and as a result, the distribution of wages and profits could change as well. For simplicity, none of this is tracked in the model of this article.

If there is adequate labour in the informal sector in c_i, an encounter between two agents in the formal sector producing the same good will cause the most efficient process of the two to produce the entire output and some global employment loss will take place. The informal sector in c_j will expand and in c_i, informal labour is converted into formal labour. Output rises in c_i and falls in c_j. The supply of the good, g, has then been *outsourced* from c_i to c_j.

For the ith agent, when the inequality 4 holds, formal employment in country c_i increases to:

$$\bar{l}_i \leftarrow l_i + \frac{\rho_j l_j}{\rho_i}$$

The change in employment in c_j is:

$$\Delta l = i_i + \frac{\rho_j l_j}{\rho_i} - (l_i + l_j)$$

or, simplifying,

$$\Delta l = (1 - \frac{\rho_j}{\rho_i}) l_j$$

due to the outsourcing of production in the country of the least productive process, j. As Δl workers depart for the informal sector as many new processes are created, each with

$$l_j = 1.$$

The productivity of the new processes are drawn from the left side of Figure 3. Thus, the central observation made by McMillan and Rodrik (2011) that trade does not lead to an increase in productivity in the importing country is replicated in the model.

If two agents encounter each other and compete, then it is possible that the most productive agent, the ith agent, cannot find sufficient informal labour to hire in order to replace the output of the contracting jth agent. In this case, both agents, i and j, continue to produce. Employment in ith process absorbs all available informal labour in c_i. This implies that output in the ith sector is:

$$\bar{Q}_i = \rho_i (l_i + n_i)$$

where, n_i is the informal sector of country i. Agent j continues to produce $\bar{Q}_j$ at:

$$\bar{Q}_j = Q_i + Q_j - \bar{Q}_i = Q_j - \Delta Q_i$$

where the bar indicates the new level of output of the less productive process j and ΔQ_i is the change in output of the more productive process i sector as constrained by the size of the informal sector. Employment in sector j is then given by:

$$\bar{l}_j = \frac{\bar{Q}_j}{\rho_j} = \frac{Q_i}{\rho_j} + \frac{\Delta Q_i}{\rho_j}$$

or

$$\bar{l}c_j = L_j - \Delta Q_i \frac{\rho_i}{\rho_j}$$

in other words, the employment required to produce the residual output at the jth sector's lower productivity. Jobs lost, $\tilde{\imath}c_j$, are just

$$\tilde{\imath}c_j = \Delta Q_i \frac{\rho_i}{\rho_j}$$

and this is how many new informal jobs are created in country c_j, through outsourcing. The informal sector will experience some growth in the importing country. Informal output will rise by the level of the informal productivity for the good the newly created processes are randomly assigned. Global informal output, q_j, will rise by:

$$\Delta q_j = \Delta L_j \rho_j$$

where, ρ_j is the productivity drawn from the distribution on the left of Figure 3, as noted earlier.

In the analytical model given here, the global loss in employment results from the increase in productivity, providing the analogue to the partial derivative:

$$\frac{\partial F}{\partial \rho} < 0$$

If the informal sector in c_i is exhausted before the agents compete, it follows that there can be no increase in formal employment resulting from outsourcing and thus ρ will remain constant. This implies that

$$\frac{\partial F}{\partial L} < 0$$

since as global formal employment increases and the informal sector contracts, there will be only smaller increases in formal employment over time, eventually zero. Outsourcing, as developed in this section, explains why the $\dot{L}$-isocline in Figure 1 is negatively sloped.

In the standard model, trade enables factors of production to be released from less productive uses to then be employed in the more productive traded goods sector. In the account offered here, labour in the winner's informal sector graduates to formality through trade and competition, and in the process global productivity increases. While productivity increases in the exporting country, workers in the importing country are less fortunate, and as is often observed, trade leads not to a rise but a fall in productivity, at least temporarily. Competition is thus modelled as a process that brings rising and falling productivity at the same time on different parts of the grid. It is an uneven and noisy process that unfolds over time and space, as opposed to an instantaneous event that replaces less efficient production methods worldwide with more productive ones. The standard model compresses a number of steps of a sequence that need not unfold precisely as it specifies. At this stage in the development of the model of this article, global informality rises as the counterpart of higher global productivity brought about by outsourcing.

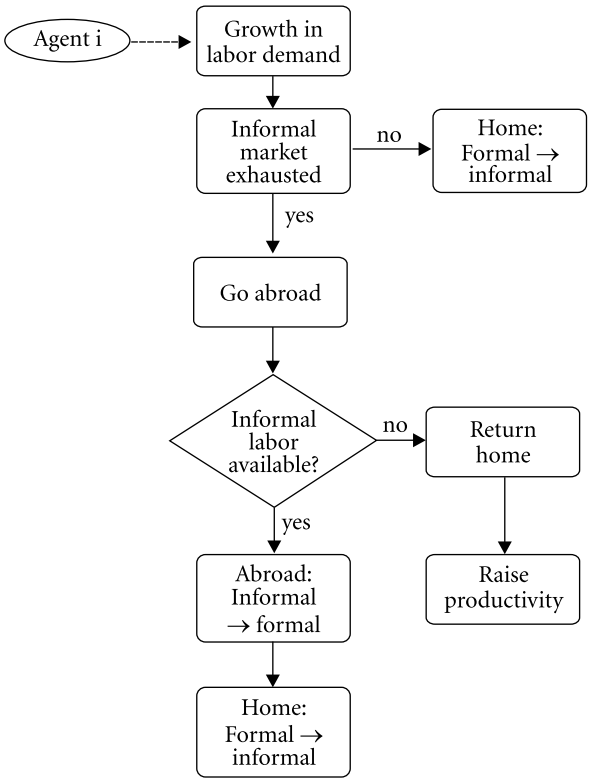
3.6 Growth, Offshoring and the Informal Sector

Were this all that is involved, the model would pin the responsibility for high worldwide rates of unemployment squarely on trade and its attendant productivity growth. Note that this is implicitly involved in the standard account of trade. There, one sector contracts due to the inflow of imports while the other expands. We have already described the mechanism by which the contracting sector disappears in the agent-based account, but the expansion of the other sector requires additional workers. This will raise employment somewhere in the system but not necessarily in the country that lost employment.

Were the effects discussed in the previous section the end of the matter, trade would simply increase informality over time. In the analytical model given earlier, however, high formal employment drives productivity growth, and this is reflected as well in the agent-based model. Figure 5 shows how a rise in labour demand leads to a self-reinforcing increase in productivity. As a randomly selected agent grows, its demand for labour increases in proportion to its recent productivity growth:

$$\Delta l = f(\hat{\rho}) \tag{5}$$

Figure 5 Model Flow Chart for Offshoring



Source: Author's compilation.

where, $\hat{\rho}$ is the rate of change of productivity. Faster productivity growth induces a more rapid increase in the rate of change of employment. In order to satisfy this demand for labour, however, agent must find adequate stores of informal workers. In each country, *c*, there is a local supply of informal labour denoted $nc_i \geq 0$. If

$$\Delta l_i > nc_i,$$

then the *i* agent attempts to relocate to another country, that is, to go *offshore*. As indicated in the flow chart of Figure 5, if there is no country with a sufficiently large informal sector, then the agent returns to the country of origin. At this stage in the programme, the agent increases output according to:

$$\Delta Q_i = \rho_i \Delta l_i$$

Productivity is then adjusted to reflect the quantity of informal labour to which the agent has access. Productivity is then reset to:

$$\rho_i = \frac{Q_i + \Delta Q_i}{l_i + n_i}$$

where $n_i \geq 0$ is the amount of informal labour in c_i.

Note that the most rapid rise in productivity growth occurs when informal labour is converted to formal labour. With outsourcing, total formal labour demand *decreases* as the production moves from country k to $k+1$. With offshoring, total labour demand increases as processes expand. Were there no increase in employment, as given by Equation 5, then offshoring would simply translate formal employment from k to $k+1$, with no increase in global informality. The rise in informality in k would be offset by a decline in informality in $k+1$.

When firms go offshore, the change in productivity is given by:

$$\Delta\rho = (\bar{\rho}_f - \bar{\rho}_n)\frac{\Delta l_i}{l_i + n_i} > 0 \tag{6}$$

where, $\bar{\rho}_i$, $i = f, n$ is average productivity of the formal and informal sectors respectively and n is number of informal workers converted to formal workers. The total change in ρ is this average differential times the number of informal employees graduated to formal as a share of the total.

When there is net job growth, however, productivity advances less rapidly with offshoring than if the increase in demand for labour were translated into a rise in output growth in the home country using the same number of workers. This could occur through investing in more productive capital equipment, of course, but diminishing returns would eventually set in, causing productivity growth to slow. In the model, diminishing returns is imposed by way of a productivity ceiling, $\rho_{\max}$, which depends on the level of productivity in the process operated by the given agent. Without diminishing returns, productivity would grow faster as global full employment was reached, contradicting the slope of the $\dot{\rho}$-isocline claimed earlier. With a productivity cap imposed, some agents reach their maximum level and cease to grow thereafter.

The growth in global employment demand decreases according to Equation 5 for some agents, while others continue to go offshore raising productivity by absorbing informal workers into formal sector jobs.

The overall path of productivity improvement is thus a combination of some agents experiencing rapid productivity growth, as the global informal sector

begins to disappear, and then slowing down as more processes are constrained by their productivity caps. This produces something like a logistic curve for overall productivity growth. The most rapid growth occurs when large firms cannot satisfy their demand for labour abroad but have not yet reached their productivity caps. Smaller firms also contribute to the rise in overall productivity as they soak up informal labour. As time passes, more firms reach their caps and productivity growth slows down.

Offshoring, as defined in the present context, sets the shape of the $\dot{\rho}$-isocline in Figure 1. Enhancements in the productivity of labour come entirely at labour's expense along the $\dot{L}$-isocline, but along the former there are both high and low-employment equilibria, and high employment is associated with high levels of productivity. The equilibrium in the model as a whole is where the two isoclines intersect and is stable according to the theory just outlined.

At any moment in the model, four different kinds of agent interactions are taking place: (a) when the number of processes in the model is the same as the number of goods, agents trade goods they have already produced; (b) when the number of processes in the model exceeds the number of goods, some processes are replaced by more productive ones as agents encounter each other on the grid; (c) when the supply of local labour is exhausted, agents decamp for neighbouring economies with more adequate labour supplies; and (d) alternatively, agents retain their country affiliation and reduce employment per unit of output, that is, raise productivity so that labour demand and supply come into balance. The adjustment mechanisms are described more visually in the two flow charts in Figures 4 and 5.

3.7 Policy Variables

As noted earlier, in-country policies can retard or accelerate the processes involved. There are two exogenous policy variables in the model: first, the parameter τ determines the probability that trading between agents will be blocked by tariffs and non-tariff barriers. If an agent encounters a potential trading partner, the trade is more likely to be blocked by the higher setting for the τ parameter. Second, μ is a parameter that indicates the degree to which the offshoring of processes is affected by local macroeconomic conditions such as inflation, the exchange rate and interest rate in the country in which the firm operates. Higher values of μ reflect more coherent and hospitable macroeconomic policies.

If protection is low, outsourcing in the model increases and the number of processes producing the same goods is reduced. When macroeconomic policies are sound, offshoring accelerates. These mechanisms combine in the model to

determine the rate of job destruction, and thus the slope of the $\dot{L}$-isocline in Figure 1.

4. Simulation Results

4.1 Results of the Agent-based Simulations

Agents are assigned formal status, a country, employment, productivity and lifespan idiosyncratically. Tarif protection and macro policy management are also randomly assigned to counties, and thus are entailed in the country assignment to agents. The agents are randomly distributed about a grid. Table 2 shows some of the principal settings for the agent-based model.

Table 2 Data of the Agent-based Model

Countries	*50*
Sweeps per run	2k
Agents	Uniform random between 2 and 100 per country
Structure	Formal and informal goods sectors
Employment	Uniform random between 1 and 10 per firm
Productivity—informal	N(1, 0.2)
Productivity—formal	N(2, 0.5)
Initial proportion of informal sector	0.8
Number of goods	5
Average lifespan	50 sweeps
Macroeconomic management	Range from 0 to 1 with 1 the highest
Average level protection	Range from 0 to 1 with 1 the highest

Source: Author's calculations.

4.2 Verification

If the model is to be used for thinking about policy making, it must have some demonstrated link to reality. One way to verify the model is to see if the data generated by it produces the same statistical profile as presented by the actual data discussed earlier. Table 3 shows the result of fixed effects regressions, similar to Table 1. Note that the coefficient on productivity is similar in magnitude to that of the real data shown in Table 1. The exception is the free market regression, Equation 4. Under the assumption that macro constraints never bind and no country attempts to protect its domestic economy, formal employment responds much more quickly to productivity than is seen in the

actual data. These conditions do, in fact, occur in the real world, so this result is hardly surprising.

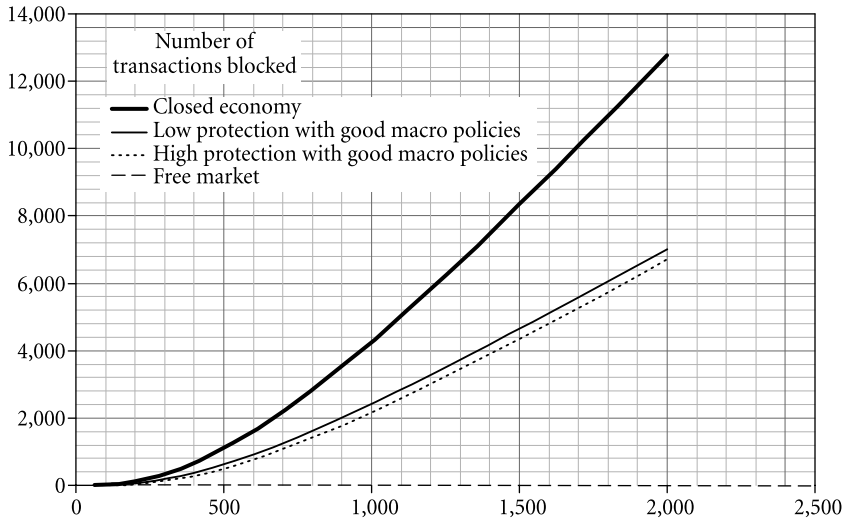
Table 3 Fixed Effects Regression

Equation	*1*	*2*	*3*	*4*
Protection	0	1	1	none
Macro policies	1	1	0	none
Productivity[2]	0.398***	0.407***	0.465***	1.065***
	(0.009)	(0.008)	(0.010)	(0.017)
Constant	7.662***	7.684***	7.635***	7.365***
	(0.010)	(0.008)	(0.010)	(0.015)
R^2-adjusted	0.859	0.849	0.884	0.502
Observations	200000	200000	200000	200000
F-stat	1817	2383	2094	3814

Source: Author's calculations.
Notes: (a) Standard errors in parentheses.
(b) ***p < 0.01; **p < 0.05; *p < 0.1.
1. The dependent variable is the log of the formal employment.
2. The variable *productivity* is the log of productivity.

Figure 6 shows the results of the average of 100 runs of the model under four configurations. In the top one, offshoring is blocked almost 13k times during the 2k runs. The setting here is with high protection, a maximum of one with uniform random distribution across the 50 countries of the model and poor macro policies discouraging offshoring. This 'closed economy' setting is clearly effective in blocking offshoring. The thick line at the bottom is the opposite, the 'free market' setting, in which macro policies are disregarded and no country tries to protect its employment structure from trade. This produces no blocked offshoring. In between are two intermediate settings. The thin solid line represents a simulation with low protection and good macro policies (maximum of one). The dotted line just below is a simulation with high protection and the same setting for macro policies. It is evident that fewer offshore relocations are blocked by poor macro policies when protection is high. This can only be because fewer firms want to go offshore when protection is high and as a result, fewer are blocked by poor macro policies. This data is for blocked offshore relocation. A similar pattern emerges when blocked trades are tabulated according to the same settings. High protection blocks trades the most, of course, with some 7.5k trades not taking place by the end of the simulated period. Figure 7 shows how productivity plays out in the four configurations. The highest level

Figure 6 Number of Blocked Offshore Relocations



Source: Author's computation.

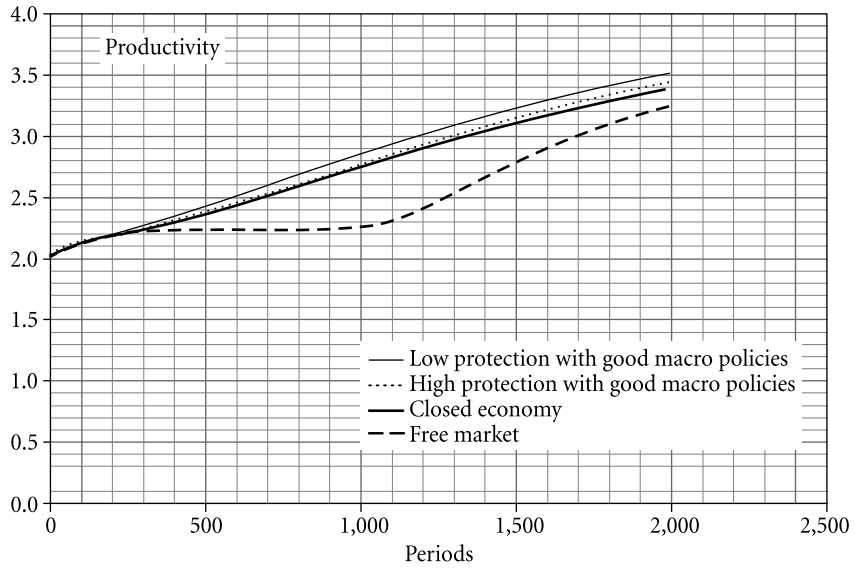
productivity comes about with low protection and good macro policies. High protection is somewhat worse, followed closely by the closed economy. This figure is, no doubt, somewhat puzzling since it is quite evident that the free market does poorly.

Only after the 1.1k sweeps does productivity in free market rise rapidly. Even so, it never manages to catch up with the others (Figure 7). Figure 8 shows what is occurring in this simulation. The free market assumptions amount to the smallest gain in productivity since there is rarely a reason to introduce labour-saving investment when there are no impediments to hiring informal labour the world over. There is no opportunity to raise productivity levels until there is a constraint on employment and under these assumptions, the constraints are the smallest. The free market distributes employment opportunities globally but in the process, finds no reason to save on labour until it becomes globally scarce.

It is evident from the figure that this occurs after the 1.2kth period. At that point, the free market exhausts the global informal sector. Thereafter, productivity skyrockets.[5] The diagram illustrates one of the major results of the article: it

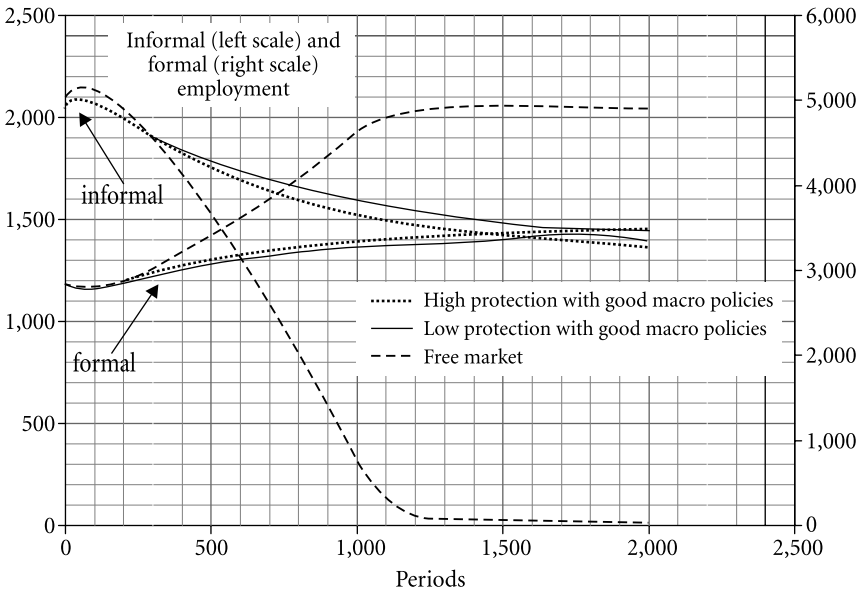
[5] The closed economy is left out of this figure for simplicity. In any case, it more or less closely tracks the two simulations in which protection is high and low for good macro policies.

Figure 7 Productivity



Source: Author's computation.

Figure 8 Formal and Informal Employment



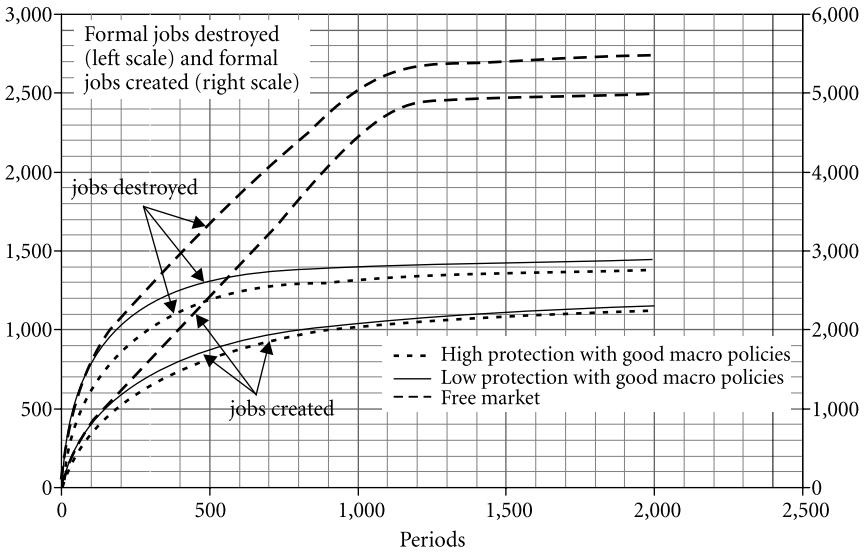
Source: Author's computation.

is evident why countries seek to protect their local job markets. Formal employment rises more rapidly with protection, as is clearly evident in Figure 8. The cost of protection does not immediately show up in the productivity data. Even in the medium term, productivity is higher in a protected economy.

The costs of this policy stance are made plain however, even though they are delayed.[6] Only with free market policies does the model eventually eliminate the informal sector all together. As the figure shows, informal employment trails off to zero in that configuration, while approaching a non-zero steady state with the other parameter settings. As a result, formal employment (measured on the right-hand scale) only comes to exceed informal employment by the 1.5–1.7k period, compared to the intersection of formal and informal labour in period 550 with free market policies.

Figure 9 continues with this theme. It is obvious that the free market is good at creating formal jobs, but even better at destroying them. This illustrates the reason that the free market lags behind the protected markets in formal job creation. While these jobs come into existence quickly, they just as quickly get extinguished by the combined forces of outsourcing and offshoring. Do free market policies cause informality? Figure 10 shows that much less informality

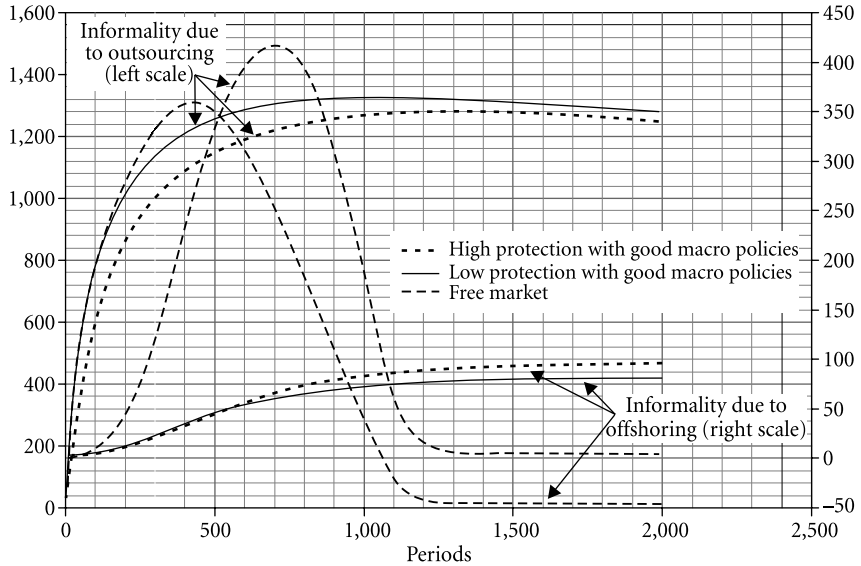
Figure 9 Formal Jobs Created and Destroyed



Source: Author's computation.

[6] Costs that are born in the long run with only partially offsetting benefits in the short is the age-old trap that frequently ensnares policy makers.

Figure 10 The Cause of Informality



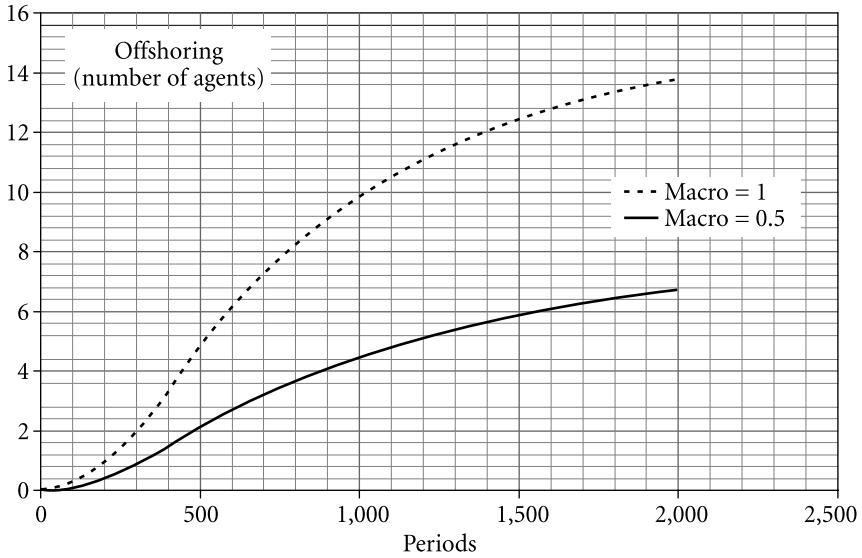
Source: Author's computation.

is due to offshoring than to outsourcing in the model. The right-hand scale measures informality caused by outsourcing, and it is evident that all parameter configurations essentially remain the same. The major difference is that the free market setting more quickly runs out of surplus labour than do the other policies. The free market setting does converge to a steady state in which there are still some informal workers caused by outsourcing, but none due to offshoring.

4.3 Macro Policies

As noted, offshoring occurs when there is an inadequate number of informal sector workers to satisfy labour demand. This arises in the model when agents create jobs. Offshoring decreases labour demand in the home market of the agent and increases it in the host country. In the process of offshoring, the firm increases its output and world GDP rises. The direction of jobs flow in offshoring is just the same as in outsourcing but it is the product of growth rather than competition. Figure 11 shows the impact of macro policies on the offshoring decision. If agents are unable to find workers in their home country, they search the grid for another country with adequate labour supplies. A second condition is agent specific and relates to the exchange rate and its stability as

Figure 11 Macro Policies and Offshoring



Source: Author's computation.

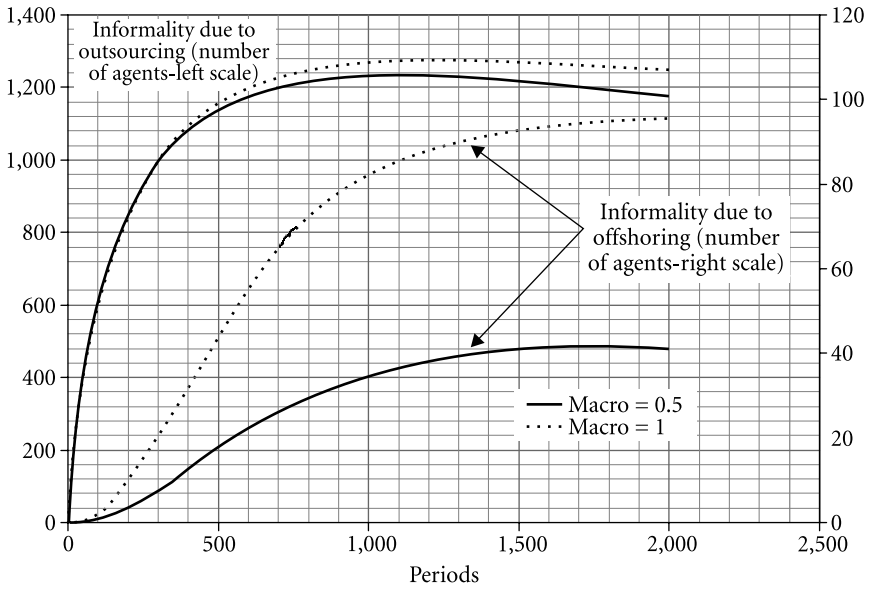
well as tax and regulatory policies of the host country. Since outsourcing plays a significant role in the determination of long-run productivity improvements, it is worthwhile to survey the impact of good macroeconomic policies on the performance of the model. A move offshore for any agent requires affirmative answers to the following queries:

1. Is there sufficient labour in the home country to meet production goals? If so, then the agent remains in the home country. If not, then:
2. Are the macroeconomic conditions in the host country acceptable?

Both conditions must hold for offshoring. As the agent moves offshore, workers previously employed are converted to informal sector workers. They are then assigned a good, a lifespan and a productivity drawn from the informal distribution, as described earlier. Each informal worker only employs one employee (herself). The reverse occurs in the host country as informal workers are absorbed into the formal labour force in the country of destination. If the agent cannot find a country with adequate macro policies and sufficient informal labour, the agent returns to the country of origin. In this case, the agent must invest to raise the productivity of the workers to produce the output that would have been generated by offshore workers had they been available.

Figure 12 shows the effect on informality of improving macroeconomic policies, by raising the maximum macro policy parameter from 0.5 to 1.0.[7] Better macro policies cause the number of firms rejecting offshoring to a particular country to decrease with a resulting increase in informality.[8] The right-hand scale shows that in the steady state, more open capital markets nearly double the level of informality.[9] The figure shows that the overwhelming cause of informality in the model comes from outsourcing, the direct consequence of international competition and division of labour. Offshoring does not contribute much to informality in the model and the effect is measured on the right-hand scale.

Figure 12 Improved Openness



Source: Author's computation.

[7] Countries are assigned macro polices based on the uniform distribution from 0 to a maximum of 1, as noted earlier.

[8] The number of such rejections is tracked by the model and with improved macro polices, the steady state value is close to a third fewer rejections. This means that an agent is significantly less likely, after finding adequate labour in a foreign country, to reject relocating there because of a poor macroeconomic environment.

[9] Although this latter effect is not large, it sheds important light on the workings of the model and so is worth a brief explanation for why it occurs. At first glance, it would seem that offshoring would not have any bearing whatsoever on outsourcing. When offshoring is blocked, however,

At its maximum, the gap between good and not-so-good macro policy is that 25 more informal jobs are created by better macro policies. The difference rises for outsourcing. The figure shows that better macro policies are responsible for more outsourcing, almost 50 more informal jobs created, but this out of 900 or so jobs lost to outsourcing. The main reason here is that with better macroeconomic policies worldwide, output, productivity and formal employment are higher, but only marginally so, and why the difference is only marginal is quite revealing.

Ironically, poor macroeconomic policies might actually increase the rate of job creation in the system, offsetting the lost formal employment opportunities created by offshoring. This is not as perverse as it may seem in that poor macro management creates a worldwide shortage of informal labour, at least as seen from *outside* the poorly managed economy. These workers are effectively walled off from the beneficial impact of direct foreign investment. Agents wishing to relocate to countries with more labour and blocked by the macro policy variable, behave as if surplus labour were globally exhausted.[10]

Fixed effects regressions, however, contradict the possibility that poor macro policies do indeed improve formal employment prospects. Table 4 shows the effects of policy intervention on the formation of formal jobs. The free trade equation is not shown since there are, by definition, no blocked trades or barriers to capital movements. Similarly, in the first equation, there is no protection (maximum protection set to 0) and so, the variable *trade blocked* is omitted for lack of statistical leverage. Since the *macro blocked* coefficient is highly significant in each regression, the table shows that data of model contradicts the hypothesis that poor macroeconomic polices increase the rate of formal job creation.

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agents raise their productivity at home as a result of a labour shortage up to a given limit. The country that repels foreign capital investment, however, sees no improvement in its productivity. In contrast, when macro policies are better, the rise in the demand for labour is spread out, pushing an additional country closer to informal sector exhaustion. Moreover, fewer countries hit the productivity cap. Eventually, a larger number of countries will go offshore and some subset will return home to increase productivity. Simulations not shown confirm that better macro policies do indeed improve average productivity (although by a small amount). Higher global productivity implies that when countries trade more, informal labour is created. This explains the association of good macro policies with slightly higher levels of informal labour due to outsourcing.

[10] Since it is in fact not, the result is a widening inequality gap as workers in the agent's home country avoid joining the local informal labour force and at the same time, enjoy higher productivity brought on by the investment. The distribution between wages and profits is not at issue here, since home country workers will benefit from either higher wages or higher returns to their savings.

Table 4 Fixed Effects Regression on Model Data

Equation	*1*	*2*	*3*
Productivity[1, 2]	0.671***	0.630***	0.587***
	(0.028)	(0.030)	(0.047)
Trade blocked[3]	.	0.000***	0.000***
	(.)	(0.000)	(0.000)
Macro blocked[4]	–0.000***	–0.000***	–0.000***
	(0.000)	(0.000)	(0.000)
Constant	7.439***	7.478***	7.511***
	(0.023)	(0.022)	(0.034)
R^2-adjusted	0.890	0.916	0.915
Observations	200000	200000	200000
F-stat	1182	1184	1002

Source: Author's calculations.
Notes: (a) Standard errors in parentheses.
(b) ***p < 0.01; **p < 0.05; *p < 0.1.
1. The dependent variable is the log of formal employment.
2. Log of productivity.
3. Number of agents not trading because of protection at each sweep.
4. Number of agents not going offshore at each sweep because of macro policies in the host country.

5. Conclusions

The impact of trade policies on the informal sector, as portrayed in this agent-based framework, is to stimulate productivity growth in a step-wise fashion. In its simplest form, trade has *no* impact on informal employment, which is logically prior to trade. Agents simply exchange what they produce. The perception of the state of demand does not flow backward to the production decision. The standard account of specialisation and trade is not yet an emergent property of the system and roughly corresponds to Edgeworth's account of trade that takes place, *post factum*, and therefore can have no bearing on the size of the informal sector since it has no impact on formal sector employment.

The principal conclusions that arise out of the model are several. The first hypothesis is that policy interventions that restrict current and capital account activity may have a positive impact on formal job creation. The data of the model support this hypothesis for trade restrictions, but do not support the restricting capital movements. A second hypothesis is that a steady state exists with non-zero participation of the informal sector. This steady state was derived from a simple but general dynamic model of productivity and employment. That model

assumed all employment was formal however, and the more complete agent-based model attempted to remedy this shortcoming by modelling the presence of the informal sector explicitly. Self-interested agents create informality as they seek out profit opportunities at home and abroad. Current account restrictions that block competitive pressure to accumulate capital and modernize production (outsourcing) preserve formal sector jobs. There is also a theoretical case to be made that capital account restrictions on foreign direct investment (offshoring) also work in the same direction. The data of the model support the hypothesis for outsourcing but contradict the hypothesis for offshoring.

The data of the model also suggest that policy intervention, restrictions on current and capital account activity, can improve the opportunity to work in formally organised occupations. Only when these restrictions are lifted, however, does the informal sector disappear asymptotically. The rationale for intervention remains clear since the process of eliminating the informal sector takes a significant amount of time and, more importantly, creates a larger informal sector in the near term.

Finally, the results of the agent-based simulation support the hypothesis advanced in the simple dynamic model that trajectories approach steady states with a monotonic relationship between employment and productivity. The stable focus of Figure 2 was never observed in the output of the simulations. The idea that any real economy would spend a significant amount of time in the north-east quadrant, with productivity increasing and employment decreasing, is probably not correct.

The agent-based model of this article is not intended to exhaust the possibilities of the framework. The methodology can be employed in many creative ways to test hypotheses about how various policies can interact. As Epstein notes in his 2006 *Generative Social Science*, 'growing' artificial societies is the way to determine *in silico* whether given microfoundations are in themselves sufficient to generate the observed macro phenomena. This implies that imposing macro regularities, the stylised facts, is not fundamentally sound since this sort of calibration automatically guarantees that the model will be consistent with the data. Computable general equilibrium models, as do many top-down calibrated system, sufer from the criticisms of Epstein and Axtell (1996). Since they are true by definition, they cannot be used to test hypotheses.

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