The Role of Productivity, Transportation Costs, and Barriers to Intersectoral Mobility in Structural Transformation

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Abstract

The process of economic development is characterized by substantial reallocations of resources across sectors. In this paper, we construct a multi-sector model in which there are barriers to the movement of labor from low-productivity traditional agriculture to modern sectors. With the barrier in place, we show that improvements in productivity in modern sectors (including agriculture) or reductions in transportation costs may lead to a rise in agricultural employment and through terms-of-trade effects may harm subsistence farmers if the the traditional subsistence sector is larger than a critical level. This suggests that policy advice based on the earlier literature needs to be revised. Reducing barriers to mobility (through reductions in the cost of skill acquisition and institutional changes) and improving the productivity of subsistence farmers needs to precede policies designed to increase the productivity of modern sectors or decrease transportation costs.

1 Introduction

In many developing countries, employment in the agriculture sector is very high relative to that in the developed countries. Globally, the poorest 5% of the countries have about 86% of their labor force in agriculture, whereas the richest 5% have less than 5%. In the process of development, economies experience significant movements of labor from agriculture into modern sectors. Differences in productivity in the agricultural sector between developing and developed countries are also much higher than differences in productivity in the non-agriculture

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sectors. Restuccia, Yang and Zhu (2008) look at labor productivity differences in both agriculture and non-agriculture between the richest 5% of the countries and poorest 5%. They report that GDP per worker differences in agriculture is a factor of 78, whereas in non-agriculture it is a factor of 5. Based on these productivity differences, McMilan and Rodrik (2011) argue that as much as a fifth of the productivity gap between developing and advanced countries would be eliminated if the inter-sectoral distribution of employment in the developing countries matched that in the developed countries.

The notion that economic growth and development has been associated with significant movements of labor out of agriculture and into manufacturing and services (structural transformation) has been put forward starting with Clark (1940), Kuznets (1966), Rostow (1959) and Chenery and Syrquin (1975). More recently economists have focused on structural transformation in the context of multi-sector models in order to present a more nuanced explanation of differences in productivity and growth rates across countries. This literature has emphasized, on the one hand, differences in productivity across agricultural and non-agricultural sectors and, on the other hand, barriers to structural transformation that include costs of transportation, of skill acquisition, and cultural factors. In this paper, we develop a general equilibrium model that incorporates both productivity differences and some empirically prominent barriers to the transformation of the economy from one where subsistence agriculture is dominant to one where modern sectors play a more significant role.

In what follows, we construct a three-sector model with a traditional subsistence agriculture, a modern agriculture, and a non-agricultural sector (manufacturing and/or services). Agricultural goods are produced in the rural sector, whereas manufacturing and services are produced in the urban areas. Our setup differs from the existing ones along a number of dimensions. Perhaps most importantly, we bring together two strands of the recent literature. The first of these as, exemplified for instance by Gollin and Rogerson (2014), emphasizes the role played by productivity differences between agricultural and manufacturing sectors and transportation costs in determining the observed lack of structural transformation in the poorest developing countries. The second strand, exemplified by Caselli and Coleman (2001) and Hayashi and Prescott (2008), focuses on barriers to labor mobility that keep agricultural employment relatively high for extended periods of time in the process of development. These barriers may take a number of different forms. Caselli and Coleman (2001) emphasize the costly acquisition of skills as the barrier that impedes the movement of labor from agriculture into non-agricultural employment. Hayashi and Prescott (2008), on the other hand, argue that both the cultural values of the Japanese extended family and the institutions of prewar Japan acted as barriers to the movement of labor out of agriculture in the 1885-1940 period.[1]. In the rest of the paper, we adopt the specific barrier suggested by Caselli and Coleman

[1] O'Brien (1996) argues that much of the explanation for the persistence of a comparatively large subsistence agriculture sector in France (as opposed to England) prior to the twentieth century lies in the cultural and institutional factors that kept a large fraction of the labor force in rural areas of France.

(2001) and suppose that labor employed in subsistence agriculture is unskilled, whereas both modern agriculture and manufactures employ skilled labor with no possibilities of substitution anywhere between these two types of labor. We also assume that the cost of skill acquisition is too high for unskilled workers. However, this specific barrier could be interpreted in any number of ways and as long as there exists some barrier to the mobility of labor between the traditional and modern sectors, our conclusions will remain valid. In addition our model incorporates productivity differences across sectors as well as transportation costs as in Gollin and Rogerson (2014). We model productivity differences by taking the idea that throughout the development process modern and traditional technologies coexist seriously and incorporate two agricultural sectors that produce a single agricultural good using a traditional technology (in the subsistence sector) and a modern technology. [2]. As for transportation costs, our model incorporates three types: the ones involved in transporting manufactures to both the modern agriculture (as both an intermediate and consumption good) and subsistence agriculture (as a consumption good) and those involved in transporting the agricultural good to the urban areas from the separate rural areas that use modern or traditional techniques.

Our model produces a number of novel insights with regard to the interaction of different sectors, technologies and barriers in the process of structural transformation. One of the most important of these insights concerns the effects of productivity improvements in modern agriculture. In a standard model of the type used in the existing literature, this improvement would lead to agriculture shedding labor and manufactures expanding employment and output. This is still the case in our model if the initial subsistence agriculture employment and output are lower than a critical value. However, if the initial size of the subsistence agriculture is large enough, the modern agriculture sector expands in response to a technological shock that makes it more productive. The intuitive reason for this hinges upon the changes in terms of trade faced by both agricultural sectors that produce the same good as the size of subsistence agriculture crucially affects the relative demand changes for both the agricultural and manufacturing goods. We also show that the interactions between the barrier to labor mobility and the simultaneous use of traditional and modern technologies in agriculture may give rise to welfare reductions for subsistence farmers who get hurt by the deterioration of their terms of trade when modern agriculture becomes more productive. Similar perverse welfare results arise in cases when there are reductions in transportation costs that lower the terms of trade subsistence farmers face. These results are established analytically in our setup.

We then turn to counterfactual numerical exercises by calibrating our model as far as possible to match the stylized features of a sub-Saharan African economy. Here we are interested in the magnitude of the differential effects of changes in productivity and transportation costs taken either separately or grouped to-

[2]Gollin, Parente and Rogerson (2004) also develop a growth model with agricultural sector where agricultural and non-agricultural output can be produced with different technologies, in their case however they focus on market and home production.

gether. Our focus is the consequences of these changes on the economy's potential structural transformation (as measured by the allocation of resources across sectors) and on the changes in welfare of different groups in society. We find that improvements in the productivity of modern agriculture have significant negative welfare consequences on subsistence farmers through terms of trade deteriorations, but benefit workers in the modern sectors. As mentioned before, in contrast to the findings in the existing literature, whether the modern agriculture sector expands or contracts in response depends on the initial size of subsistence agriculture. Improvements in manufacturing productivity improve the welfare of all workers (with subsistence farmers benefiting from a terms of trade improvement), yet their effect on the allocation of resources across sectors and the magnitude of changes in welfare depend again on the initial size of the subsistence agriculture sector. In terms of the direction and magnitude of structural transformation improvements in the productivity of the subsistence sector appear to be the most important as they lead to substantial reallocations of skilled labor away from (modern) agriculture to manufactures. Not surprisingly, subsistence farmers gain the most in terms of welfare when it is their productivity that rises. Reductions in transportation costs have comparatively small effects on the allocation of resources and welfare either taken by themselves or together with other changes. Finally, lowering the barrier to the intersectoral mobility of labor in the form of a reduction in the cost of skill acquisition that enables some unskilled to become skilled reduces the share of agricultural output in total output while raising (lowering) the share of skilled workers in modern agriculture (manufactures) with the magnitude of the effect depending negatively on the initial size of subsistence agriculture.

Our model is most closely related to Gollin and Rogerson (2014), as well as Adamopoulos (2011), Herrendorf et al. (2012). The first one allows heterogeneity in agriculture through differences in the costs of transportation. The flast two, focus on the consequences of differences in transportation costs for the allocation of resources.We differ most importantly from Gollin and Rogerson (2014) in that we allow for barriers to the mobility of labor between the subsistence sector and the modern sectors. Together with heterogeneity in agriculture through differences in production techniques, including the type of resources employed, our model yields a richer set of results concerning the effects of changes in (both agricultural and manufacturing) productivity and transportation costs. Thus, whether improvements in, say the productivity of modern agriculture, result in a reallocation of labor away from it depends crucially on the size of the subsistence agricultural sector that is modeled to be less productive. Our richer set of results include those of Gollin and Rogerson (2014) as a subset: the smaller is the size of subsistence agriculture the more likely it is for improvements in productivity of modern agriculture to reduce the latter's share of employment. Further, we show that such improvements may reduce the welfare of subsistence farmers through their negative impact on the terms of trade such farmers face. What these results suggest, in contrast to the existing literature, is that in those poorest developing countries with large subsistence agriculture sectors, policy needs to follow a sequence. Measures that reduce barriers to labor mobility from subsistence farming to modern sectors and that help raise the productivity of subsistence farmers need to precede implementation of policies that are designed to increase productivity in modern sectors or decrease transportation costs.

The paper proceeds as follows. Section 2 describes the model. Section 3 presents the calibration and quantitative evaluation. Section 4 concludes.

2 The Model

2.1 Production

A typical assumption made in the literature on structural transformation is that agricultural sector is the traditional one and manufacturing and services are the modern ones without taking into consideration the heterogeneity of production technologies in the economy. In contrast, we assume that there are two available technologies for producing the agricultural good: a subsistence/traditional and a modern technology.[3] Mundlak, Butzer and Larson (2012) employ a heterogeneous technology framework where implemented technology is chosen jointly with inputs in a panel data for agriculture production functions and show that under certain specifications schooling induces people to choose agricultural technologies that are more productive. Foster and Rosenzweig (1996) in a study of the diffusion of the Green revolution in India show that more schooled farmers (i.e. with primary education) have a comparative advantage in implementing new technologies. Caselli and Coleman (2001) develop an overlapping generations model and using historical US data show that increased education lead to a decrease in cost of migration of labor from agriculture to manufacturing sector. Larson and Mundlak (1997) show that education improves labor mobility and off-farm migration. In what follows, we suppose that education is a barrier to adopting modern technologies, where modern technology could be used in either modern agriculture or non-agriculture sector, while subsistence farming uses unskilled labor as the only factor of production. Letting population be equal to n and the number of educated workers equal to n_e yields the number of unskilled workers as $n - n_e$. Assuming a constant input-output coefficient of $1/A_t$, the output, Y_t^A, of "food" by the subsistence agriculture sector is then given by

$$Y_t^A = A_t (n - n_e) \tag{1}$$

The modern agriculture sector produces food by combining intermediate inputs z and a fraction of skilled labor in a CRS Cobb-Douglas form:

[3] One could argue that heterogeneous technologies exist in both the agriculture and non-agriculture sectors and focusing on the different technologies in the agriculture sector may be misleading. However, we focus on the heterogeneity in the agriculture sector for two reasons. First, as Eberhardt and Teal (2012) show the heterogeneity of production functions (measured by the capital coefficients) in agriculture is much wider than that in the manufacturing sector. Secondly, this heterogeneity is quite substantial in the poorest developing countries on which this paper focuses.

$$Y_n^A = A_n(\theta n_e)^{\beta_n} z^{1-\beta_n} \tag{2}$$

Intermediate inputs are produced in the manufacturing sector which operates in the urban area and are subject to iceberg transportation costs η, such that the farms in modern agriculture pay effectively $p(1+\eta)$, where p is the relative price of manufactured good in terms of food. Thus, the optimal amount of intermediate inputs used in modern agriculture satisfy the condition:

$$z(1+\eta) = (1-\beta_n)\frac{Y_n^A}{p} \tag{3}$$

The total amount of labor in agriculture is thus $n_a = n - n_e + \theta n_e$

An educated worker can work in either of the two sectors that use modern technologies. The non-agricultural sector produces industrial commodities, used for consumption and as intermediate inputs in the modern agricultural sector (fertilizers, agricultural capital). The only input of production in the manufactures sector is skilled labor:

$$Y^M = A_m n_M \tag{4}$$

where $n_M = (1-\theta)n_e$.

There is free movement of skilled labor between sectors such that the non-arbitrage condition holds:

$$w^M = pA_m = \beta_n A_n(\theta n_e)^{\beta_n - 1} z^{1-\beta_n} = w_n^A \tag{5}$$

Using 3 and 5 we can derive:

$$p = \left(\frac{1-\beta_n}{1+\eta}\right)^{1-\beta_n} A_n A_m^{-\beta_n} \beta_n^{\beta_n} \tag{6}$$

In addition, we impose the condition that MPL of labor in modern agriculture is always higher than in traditional agriculture, with the result that skilled workers will choose to work only in the modern sectors.

2.2 Consumers

Both type of workers supply their labor endowment inelastically and consume food and manufactured goods. All workers have the same non-homothetic utility function, and differ only in the budget constraint that they face. Their preferences are given by

$$u(c^A, c^M) = \alpha ln(c - \overline{c_A}) + lnc^M \tag{7}$$

where $\overline{c_A} > 0$ denotes the subsistence level of food consumption and $\alpha > 0$ is the relative weight of food in preferences. Note further that the superscript M represents consumers that work in the modern manufacturing sector, and $i = \overline{s, A}$

represents consumers that work in traditional (subsistence) and modern agriculture sector, respectively. Finally, c_j^A denotes individual consumption of food andc_j^M denotes individual consumption of manufacturing good ($j = \overline{M, s, A}$). This formulation yields an income elasticity of food demand that is below one.

Consumers living in the urban areas receive a wage from working in the manufacturing sector and the price they pay for food includes the cost, η_2, of transporting it from the rural areas:

$$w_M = c_M^A(1+\eta_2) + pc_M^M \tag{8}$$

Consumers in rural areas pay a price inclusive of transportation costs, η_1, for the manufactured goods, and receive a wage equal to their marginal product of labor:

$$w_i = c_i^A + p(1+\eta_1)c_i^M \tag{9}$$

We also assume that the level of agricultural productivity is high enough so that our economy operates above the subsistence level of food (i.e. $A_t \geq \bar{c_A}$) .

The optimality conditions imply that households equate the marginal rate of substitution between the two consumption goods to the relative price, incorporating transportation costs such that

$$c_i^A = \overline{c_A} + \alpha p(1+\eta_1)c_i^M \tag{10}$$

where $i = \overline{s, A}$ and

$$c_M^A = \overline{c_A} + \frac{\alpha p c_M^M}{1+\eta_2} \tag{11}$$

Using the first order conditions for the unskilled and skilled workers, the profit maximization conditions for the firms in the modern sectors, and the labor market equilibrium conditions we can derive analytically individual consumption levels for both unskilled and skilled workers.

$$c_S^A = \frac{\overline{c_A} + \alpha A_t}{1+\alpha}, c_S^M = \frac{A_t - \overline{c_A}}{p(1+\alpha)(1+\eta_1)} \tag{12a}$$

$$c_A^A = \frac{\overline{c_A} + \alpha p A_m}{1+\alpha}, c_A^M = \frac{pA_m - \overline{c_A}}{p(1+\alpha)(1+\eta_1)} \tag{12b}$$

$$c_M^A = \frac{\overline{c_A}(1+\eta_2) + \alpha p A_m}{(1+\alpha)(1+\eta_2)}, c_M^M = \frac{pA_m - (1+\eta_2)\overline{c_A}}{p(1+\alpha)} \tag{12c}$$

Aggregating across sectors and assuming that markets are in equilibrium we derive:

$$Y^A = Y_s^A + Y_n^A = (n - n_e)c_s^A + \theta n_e c_A^A + (1-\theta)n_e c_M^A(1+\eta_2) \tag{13}$$

where Y^A is total food production and

$$Y^M = (1+\eta_1)\left[(n-n_e)c_s^M + \theta n_e c_A^M\right] + (1-\theta)\, n_e c_M^M + z(1+\eta) \tag{14}$$

So that

$$Y^A = n\overline{c_A} + \eta_2\,(1-\theta)\, n_e \overline{c_A} + \alpha p[Y^M - z(1+\eta)] \tag{15}$$

If we assume for simplicity that $\eta_1 = \eta_2 = 0$, equation (15) becomes

$$Y^A = n\overline{c_A} + \alpha p[Y^M - z(1+\eta)] \tag{16}$$

and we can derive analytically some steady state and comparative statics results.

2.3 Productivity shocks

We now turn to a discussion of some counterfactual experiments starting with productivity shocks in the three sectors of the economy.

2.3.1 In Manufacturing Sector

An increase in productivity of manufacturing sector leads to a decrease in the price of manufactured good, $\partial p/\partial A_m < 0$, and increase in wages in modern sector. Consumption of manufactured final good for both skilled and unskilled workers increases,$\partial c_S^M/\partial A_m > 0$, $\partial c_M^M/\partial A_m > 0$, as well as consumption of food for skilled workers$\partial c_M^A/\partial A_m > 0$ and the amount of intermediate goods used in modern agriculture $\partial z/\partial A_m > 0$. The increase in productivity of modern agriculture increases only the wages of skilled workers, and thus increases income inequality. However as unskilled workers can consume more of the manufactured good, their welfare increases as well. Production of food increases in the modern agriculture sector, but the effect on labor flows is ambiguous $\partial \theta/\partial A_m \leq 0(>0)$ and depends on the size of the subsistence agriculture sector, $Y_t^A \leq (>) n\overline{c_A}$. This last result is interesting as it goes against the conventional result that improvements in productivity always lead to the flow of labor out of the agricultural sector.

To see the effect of an increase in manufacturing productivity, A_m, on the allocation of skilled labor between manufactures and the modern agricultural sector, it is useful to observe Figure 1. The figure depicts the share, θ, of skilled labor in the modern agricultural sector on the horizontal axis and the value marginal product of labor in this sector (on the left) and in the manufactures (on the right) on the vertical axes. The value marginal product of labor (and, thus, the wage rate) in the latter sector is given by $w_M = pA_m$ and is drawn as a horizontal line. The value marginal product of labor in the modern agricultural sector decreases in the quantity of labor used in the sector and is shown as the downward-sloping w_N^A curve. The intersection of the marginal productivity curves determines the sectoral allocation of skilled labor. The figure depicts an initial allocation at θ_A.

Consider now an increase in A_m. This would ceteris paribus shift the w_M curve upwards. Yet, the increase in A_m also reduces the relative price, p, of

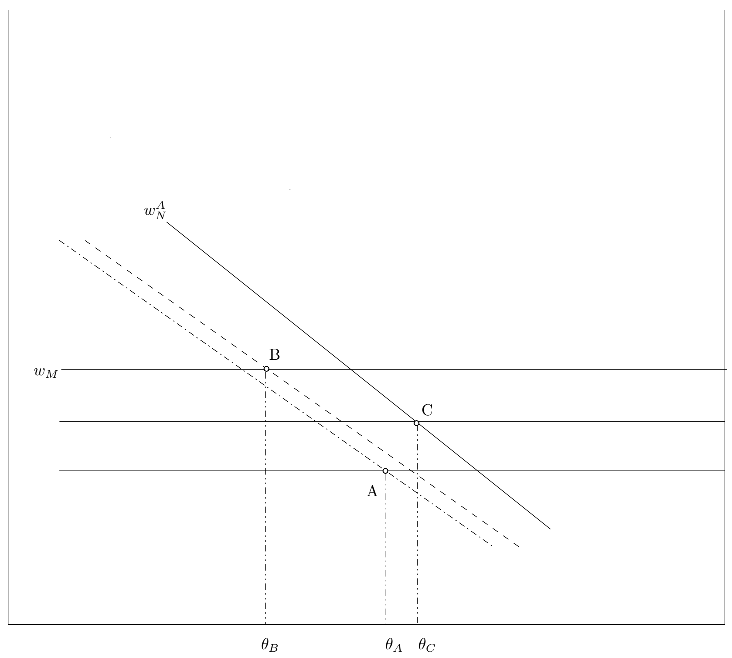


Figure 1: Productivity shock in manufacturing

manufactures. It is straightforward to show that the net affect of the opposing changes in A_m and p on w_M is positive. In order to understand the reallocation of skilled labor across manufactures and modern agriculture, it is important to separate out the different mechanisms at work here. Most important for our purposes is to recognize the direct and indirect effects of the rise in A_m on p. The magnitude of the direct effect on p depends on the size of the subsistence agriculture sector. To see this note that in addition to increasing supply, the rise in productivity, A_m, affects the demand for manufactures as it raises the wages of skilled workers in manufactures. This increase in demand dampens the fall in p. By how much it does so depends on the magnitude of the shift in demand. For our purposes, it is useful to note that the larger is the size of subsistence agriculture and the income generated there, the smaller is the relative shift of the demand curve generated by the increase in incomes in the manufactures sector. As a result, the larger is the size of subsistence agriculture, the more pronounced will be the fall in p directly attributable to the rise in A_m, for a given allocation of skilled labor θ, yielding a smaller rise in $w_M = pA_m$. This, however, is not the only change associated with the fall in p. Recall that manufactures are also used as an input in the production of food in the modern agricultural sector. A decrease in their price, p, also induces a rise in their use as an input, raising the productivity of skilled labor in this latter sector. In the figure this is depicted by an upward shift of the w_N^A curve. Once again, the larger is the size of subsistence agriculture, the more pronounced is the fall of p, the bigger is the increase in the use of manufactures as an input, and, thus, the larger is the shift of the w_N^A curve, resulting in labor moving away from manufactures to modern agriculture. As θ rises, this raises the marginal productivity of the manufactured input, raises demand for it, and puts, thus, through this indirect channel upward pressure on the relative price of manufactures, p. If the subsistence agriculture is large enough then, the end result of these processes is that skilled labor moves from manufactures to modern agriculture.[4]

To see the implications of this on the sectoral allocation of skilled labor, compare the initial allocation, θ_A given by point A to the allocations θ_B and θ_C. If the subsistence agriculture sector is small, the initial direct fall in p is small leading to a relatively large initial shift of the w_M curve, a small shift of the w_N^A curve, and a decline in θ, which precipitates indirectly a fall in the marginal productivity of z and a downward shift of the w_N^A curve, reducing θ further. This yields the labor allocation $\theta_B < \theta_A$. If, however, the size of the subsistence agriculture sector is larger, the initial direct fall in p would also be more pronounced, with w_M shifting up be less and w_N^A shifting more. As θ rises as a result, this increases z and shifts the w_N^A curve up. In this case the two curves intersect at point C, with the modern agriculture sector gaining labor at the expense of manufactures, so that $\theta_C > \theta_A$.

[4]Note that the combined effect of the direct and indirect mechanisms on p is such that changes in productivity have the same effect on relative prices regardless of the size of subsistence agriculture (see equation (6)).

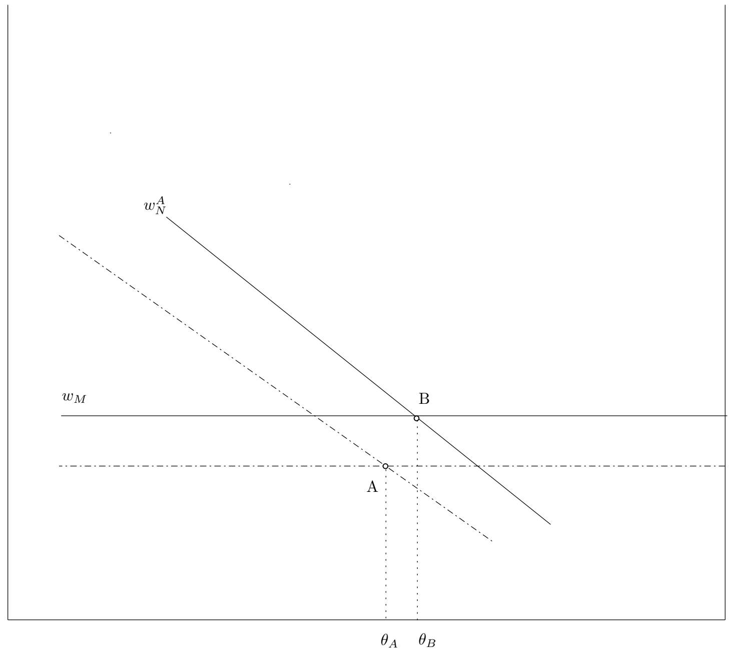
2.3.2 In Modern Agriculture

An increase in the productivity of the modern agriculture sector leads to an increase in the supply of food, a decline in its relative price, and, thus, a rise in the relative price of manufactured good, $\partial p/\partial A_n > 0$, and increase in the wages of skilled workers who are employed solely in the modern sectors. As a result, skilled workers are able to consume both more agriculture and manufactured goods $\partial c_M^M/\partial A_n > 0$, $\partial c_M^A/\partial A_n > 0$. As the increase in productivity of modern agriculture has no effect on the wages of unskilled workers, it increases income inequality. Consumption of the manufactured good decreases for unskilled workers $\partial c_S^M/\partial A_n < 0$, reducing their welfare. Production of food increases in the modern agriculture sector. However, the effect on labor flows out of agriculture $\partial\theta/\partial A_n \leq 0(> 0)$ and the amount of intermediate inputs used in modern agriculture $\partial z/\partial A_n \leq 0(> 0)$ depends as before on the size of subsistence agriculture $Y_t^A \leq (>) n\overline{c_A}$. To see the effects of the increase in A_n on θ and$z$, it is again useful to refer to Figure 1, where the initial labor allocation is indicated by θ_A. The rise in A_n shifts the w_N^A curve upwards. Ceteris paribus, this would lead to an inflow of skilled labor into modern agriculture away from manufactures. The increase the relative price of manufactures, shifts $w_M = pA_m$ upwards as well, leading to an opposite movement of skilled labor. Which of these two opposing forces dominates depends, among others on the size of the subsistence agriculture. The larger the latter is, the smaller is the ceteris paribus direct decrease in the relative price of food, thus, the rise in p for a given allocation of skilled labor. Consequently, a productivity shock that raises A_n would allocate labor away from manufactures to the modern agricultural sector. As this reallocation raises the marginal productivity of the manufactured input in modern agriculture, this raises z, shifting the w_N^A curve further upwards, reducing further the relative price of food, and raising p, if the subsistence agriculture sector is large enough ($Y_t^A > n\overline{c_A}$). In Figure 2 the labor allocation θ_C depicts this case. The existing literature emphasizes the opposite case (shown as labor allocation θ_B in the figure) as it typically assumes away subsistence agriculture, with the result that the increase in p is always sufficiently large enough to attract (skilled) labor to the manufactures sector.

2.3.3 In Subsistence Agriculture

A rise in the productivity, A_t, of the subsistence agriculture, increases the incomes of the farmers there, leading to higher levels of consumption of both food and manufactures. Ceteris paribus, the increase in the supply of food coupled with the higher demand for manufactures raises the relative price, p, of the latter. As the wage rate in manufactures goes up, skilled labor moves away from the modern agriculture sector to manufactures. The decline in the amount of labor in the former reduces the marginal productivity of the intermediate input and its use. Higher employment of labor in manufactures, on the other hand, lowers it marginal productivity and skilled wages. Reduced production of food by the modern agricultural sector as well as the higher supply of manufactures,

Figure 2: Productivity shock in modern agriculture



reduces the latter's relative price, p. The net effect of these changes, is an unchanged p, higher wages in the subsistence sector, and unchanged wages and consumption levels for skilled workers.

2.4 Transportation costs of intermediate inputs

An decrease in the cost, η, of transporting the intermediate input to modern agriculture leads to a decrease in the cost of producing food in that sector and an increase in the relative price, p, of manufactured goods, $\partial p/\partial \eta < 0$, as well as a rise of wages in the modern sector. Consumption of both agricultural and non-agricultural goods increases for skilled workers $\partial c_M^M/\partial \eta < 0$, $\partial c_M^A/\partial \eta < 0$, whose welfare improves. As p rises, consumption of the final manufactured good decreases for unskilled workers $\partial c_S^M/\partial \eta > 0$. Production of agricultural goods in the modern sector goes up, as well as the quantity of intermediate inputs effectively used in the modern agricultural sector$\partial z/\partial \eta < 0$. A fall in transportation costs, η, leads to a decrease in the welfare of workers in subsistence agriculture as the terms of trade they face deteriorate with a higher p, which increases income inequality. The effect of the fall of η on labor flows out of agriculture $\partial \theta/\partial \eta \geq 0(< 0)$, the overall amount of intermediate inputs designed to be used in modern agriculture $\partial z(1+\eta)/\partial \eta \geq 0(< 0)$, as well as the total production of manufactured goods $\partial Y^M/\partial \eta \leq 0(> 0)$ depends on the size of subsistence agriculture $Y_t^A \leq (>) n\overline{c_A}$.

Figure (2.4) shows the effects of the decrease of η on the allocation of skilled labor. Here the decrease in costs in modern agriculture shifts the w_N^A curve up leading, ceteris paribus, to a movement of skilled labor to the modern agriculture sector. The accompanying rise in p, on the other hand, shifts w_M upward as well, resulting in an opposite movement of skilled labor. Which effect dominates depends as before on the size of the subsistence agriculture sector for, by now, familiar reasons. See Figure 3 for the case where the former effect dominates the latter.

2.5 Skilled labor available to work in the modern sectors

As long as the marginal product of labor is higher in the modern sectors than in subsistence agriculture, an increase in skilled labor leads to a decrease in the overall number of workers in the agricultural sector $\partial n_a/\partial n_e < 0$, as well as an increase in the number of workers in both the manufacturing sector $\partial(1-\theta)n_e/\partial n_e > 0$ and in the modern agricultural sector$\partial \theta n_e/\partial n_e > 0$. As the rise in the number of workers in modern agriculture increases the productivity of the intermediate inputs, their use goes up as well. As equation (6) indicates, there is no change in relative prices. To see why note the following. For any given p the reallocation of labor reduces the supply of food by the subsistence sector but increases the supply by modern agriculture. Given p and A_m the wages of skilled workers, therefore their per capita demand for either of the two goods remain unchanged. What the the increase in the quantity of skilled labor does is to increase the supply of manufactures and the overall (but not

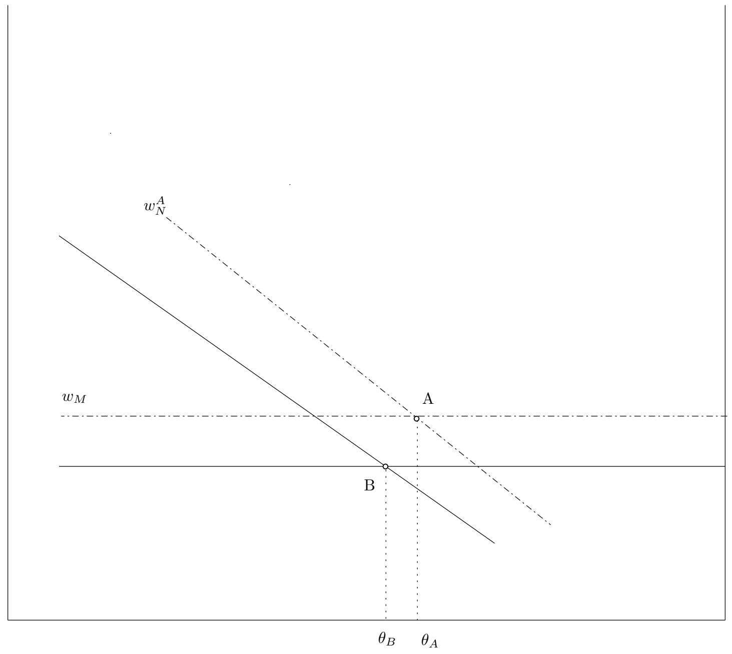


Figure 3: Transportation costs of intermediate inputs

	p	n_a	θ	z	c_s^A	c_M^A	c_A^A	c_s^M	c_M^M	c_A^M	Y^A/Y
$\bar{c_A} = 0.6$	0.77	0.71	0.04	0.036	0.66	0.75	0.83	0.33	1.32	1.16	0.5
$\bar{c_A} = 0.8$	0.77	0.75	0.16	0.14	0.83	0.92	1	0.16	1.04	0.99	0.59

Table 1: Base equilibria $w_m/w_s = 2$

	p	n_a	θ	z	c_s^A	c_M^A	c_A^A	c_s^M	c_M^M	c_A^M	Y^A/Y
$\bar{c_A} = 0.6$	1.00	0.72	0.05	0.07	0.66	1.01	1.16	0.25	2.68	2.17	0.43
$\bar{c_A} = 0.8$	1.00	0.73	0.11	0.15	0.83	1.18	1.33	0.13	2.46	2.05	0.49

Table 2: Base equilibria $w_m/w_s = 4$

per capita) demand for manufactures which match each other, keeping their relative price constant. With $w_m = pA_m$ and $w_s = A_t$ also unchanged, the wage premium remains constant as well.

3 Quantitative analysis

In this section we complement the analytical results obtained above with a quantitative analysis designed to illustrate the relative magnitudes of the effects of the counterfactual experiments described previously. We calibrate our model to be consistent with the most salient features of sub-Saharan economies relevant for our purposes. This numerical analysis also allows us consider the relative welfare consequences of changes in productivity, transportation costs, and the share of skilled workers in the labor force. We also incorporate the transportation costs of the final goods.

We normalize the size of the population n, to be equal to one. We set $n_e = 0.3$, so that 70 percent of the population works in subsistence agriculture. We set labor income share in the modern agriculture sector $\beta_n = 0.4$, implying a share for intermediate inputs of $1 - \beta_n = 0.6$. The preference parameter for food is $\alpha = 0.2$. We focus on a range of transportation costs, η between 0.1 and 0.6, which are respectively the lower and upper limits for transportation costs considered in Gollin and Rogerson (2014) when discussing close and remote regions. We normalize $A_t = 1$.

For the benchmark cases shown in 1 and 3 we set transportation costs $\eta = \eta_1 = \eta_2 = 0.3$ close to Adam, Bevan and Gollin (2013), who consider transportation costs of about 20% of total final consumption to be a reasonable estimate in their analysis of Tanzania. MORE DISCUSSION, RESTUCCIA

We choose the technology parameters $A_n = A_m = 2.59$ to obtain a wage premium of $w_m/w_s = 2$ (reported in Table 1) and $A_n = A_m = 4$ to obtain a wage premium of $w_m/w_s = 4$ (reported in Table 2).

We focus on two different values for $\bar{c_A}$, so that in the comparative statistic analysis we could use these values to have a quantitative discussion similar to that in Section 2.3

Given the calibration of of parameters discussed above, the benchmark equilibria we obtain have between 71% and 75% of population employed in agriculture, depending on the minimum level of food consumption required for survival, $\bar{c_A}$, and the skill premium (or wage inequality arising from duality), w_m/w_s. with those in the subsistence sector spending between 17 to 34 percent of their income on manufactured goods. Consumers in the two modern sectors have the same income, but due to transportation costs which lead to different prices for the two locations, their consumption patterns are not the same. As 1and 3 show, workers in modern agriculture who live in rural areas consume more of the agriculture good$c_A^A > c_M^A$, whereas workers that live in the cities consume more of the manufactured good $c_A^M < c_M^M$. The higher their wages are relative to subsistence, the more pronounced these differences are. With $\bar{c_A} = 0.8$ and ${w_m}/{w_s} = 2$, c_A^A is 8.7% higher than c_M^A, and c_M^A is 4.44% lower than c_M^M. If the subsistence threshold is lower (e.g $\bar{c_A} = 0.6$) c_A^A is 10.66% higher than c_M^A, and c_M^A is 12.12% lower than c_M^M. If additionally the workers in modern sectors receive relatively higher incomes (e.g ${w_m}/{w_s} = 4$ and $\bar{c_A} = 0.6$), c_A^A is 14.85% higher than c_M^A, and c_M^A is 19.03% lower than c_M^M. One last point to note is that if the skill premium is higher, the relative price of manufactured goods (see Table 1 and Table 2) is higher and thus welfare of workers in subsistence agriculture is lower. Inequality in our model has a direct impact on welfare through its impact on relative prices because of the non-homotheticity built into the model through subsistence level of food consumption.

3.1 Changes in Productivity and Transportation Costs

We focus on the four potential driving forces in the allocation of labor in agriculture: productivity shocks in manufacturing, subsistence and modern agriculture, and transportation costs. More specifically we consider an increase of 10% in productivity of modern sectors, i.e. $A_n = 1.1 * A_{n0}$, $A_m = 1.1 * A_{m0}$, $A_t = 1.1 * A_{t0}$, and a reduction in transportation costs of 10%, i.e. $\eta = 0.9 * \eta_0$, together with different combinations of these shocks.

The first point to note about the simulation results concerns the changes in the relative price of manufactures, p, as these affect the terms of trade producers face, and thus, their welfare. Here, unlike the case for many of the variables of interest, changes in p are independent of initial conditions, determined by the different shocks that we analyze. Similarly percentage changes in c_s^M are invariant to the initial conditions. However since the levels of c_s^M are affected, the effect of shocks on welfare differ depending on how close the economy is to subsistence levels and/or on initial levels of inequality, as measured by the wage wedge ${w_m}/{w_s}$. Both higher inequality, which makes the manufactured goods relatively more expensive, and closeness of workers in subsistence agriculture to subsistence level food consumption have the effect of reducing the quantity of manufactured goods that they can consume. Given diminishing returns to scale, a proportional decrease in c_s^M then leads to a more pronounced decrease in welfare.

All the shocks we analyze are positive shocks and thus they affect positively the amount of food and manufactured good that is consumed throughout the economy. However they lead to the reallocation of consumption among the different types of workers, and thus can potentially reduce overall welfare. Increases in A_n and reductions in the cost of transportation of intermediate goods, η, through their negative effect on the terms of trade subsistence farmers face have negative effects on these farmers' consumption of manufactures, c_s^M. However if the reduction in transportation costs is not confined to that affecting intermediate good prices, but also affects the prices of the final goods, the relative price (including iceberg costs) of manufactured goods, p, decreases and c_s^M increases slightly.

Starting with a positive productivity shock in modern agriculture that increases A_n by 10 percent, we see that this leads to a proportional increase in p. If initially the output of the subsistence agriculture sector is not high enough to cover the subsistence level food needs of the economy, the technological improvement in modern agriculture results in this modern sector losing labor to manufactures and a proportional decrease of intermediate inputs used. On the other hand, if the initial output of the subsistence agriculture sector is sufficient to meet the subsistence food requirements of the economy, the modern agriculture sector expands attracting labor away from manufactures and ends up using more of the intermediate good. The magnitude of the reallocation of resources as a result of the rise in A_n depends on the initial wage premium. As tables Table 3-6 show, the decline (rise) in the share, θ, of skilled labor in modern agriculture is more pronounced if the wage premium is smaller. The increase in A_n, even when it is combined with a decrease in labor in agriculture leads to an increase in overall consumption of food of about 1%. This increase is quite small, due to the fact that consumption of food by farmers in subsistence agriculture is not affected and they represent 70% of consumers. Consumption of food increases by 2.77% for people in urban areas, and about 3.33% for skilled workers living in rural areas. As incomes of workers in modern sectors increase, their consumption of manufactured goods increases by 9.84% for people in urban areas and 6.06% for skilled workers working in rural areas. The terms of trade deterioration for subsistence farmers, on the other hand, implies a 9% fall in their consumption of manufactures and a corresponding significant decline in their welfare. As subsistence farmers account for such a large share of the population, overall welfare for the economy decreases. This result has important policy consequences: it highlights the fact that improvements in technology used in modern agriculture does have redistributional effects that are welfare improving for some (workers in modern agriculture and manufactures) but welfare reducing for others (subsistence farmers) in dual economies that have significant barriers to mobility among sectors.

Second, consider an increase of 10% in productivity, A_m, in manufactures. The increase in the supply of manufactures reduces their relative price by 3.74% (approximately $\beta_n \frac{dA_m}{A_m}$, see equation (6)) If initially the output of the subsistence agriculture sector is not high enough to cover the subsistence level food needs of the economy, the technological improvement in manufactures results in this sector attracting labor away from modern agriculture. On the other hand, if the initial output of the subsistence agriculture sector is sufficient to meet the subsistence food requirements of the economy, the modern agriculture sector expands attracting labor away from manufactures and ends up using more of the intermediate good. The magnitude of the reallocation of resources as a result of the rise in A_m again depends on the initial wage premium. As Tables 3-6 show, the decline (rise) in the share, θ, of skilled labor in modern agriculture is more pronounced if the wage premium is smaller. The rise in the wages of the workers in the two modern sectors that follows the productivity shock increases their consumption of both goods, with the fall in the relative price of manufactures inducing a sharp rise in its consumption, but a small increase in food consumption as expected. For subsistence farmers, the improvement in their terms of trade allows higher consumption of manufactures. These increases in consumption imply improvements in the welfare of all agents in the economy.

As for a 10 percent productivity improvement in subsistence farming, we observed above that this does not affect the terms of trade subsistence farmers face. Consequently, the rise in the output of such farmers, increases their income, welfare, and consumption of both goods. As the output of modern agriculture suffers a decline, labor is allocated from this sector to manufactures. With wages of skilled labor employed in the modern sectors as well as the relative prices remaining unchanged, the consumption and welfare of these workers remain constant. As a result, we observe a nine percent decline in the wage premium. As subsistence farmers comprise 70 percent of the labor force, the welfare gains they enjoy translate into the sharpest increase in overall welfare (ranging from 10 to 32 percent depending on the specification) that we see in response to any of the counterfactual experiments of an isolated productivity improvement that we conduct.

We now turn to two different combinations of productivity improvements. First, consider the case of a productivity increase in the two modern sectors that takes the form of a 10 percent rise in both A_n and A_m. Given what we observed when these productivity improvements are taken separately, the results here are mostly what we expected. As the effect of A_n on p dominates that of A_m, terms of trade move against agriculture, with the result that subsistence farmers suffer welfare losses as before. The reallocation of skilled labor across the two modern sectors follows the same logic observed before and depends on the initial size of subsistence agriculture. However, the share of agricultural output in total output declines regardless of the direction of the reallocation of labor. Skilled labor having become more productive, it benefits from the improvements and experiences relatively large welfare gains that outweigh the losses suffered by subsistence farmers. The second combined productivity improvement we experiment with is a 10 percent rise in A_t, A_n, and A_m. This uniform productivity improvement results in price movements and reallocations of resources one typically associates with structural transformation: the relative price of the agricultural good declines and labor moves out of (modern) agriculture into manufactures. Consumption levels of both goods by all workers goes up. The increases in welfare that are registered are the highest (ranging from 11.5 to 38 percent depending on the parameter values) among all counterfactual experiments that we conduct.

Finally, we consider different combinations of reductions in the transportation costs. Starting with a fall of 10 percent in the cost, η, of transporting manufactured intermediates, we see in Tables 3-6 that the relative price of manufactures rises. This has the, by-now-familiar, negative effect on the consumption and welfare of subsistence farmers. Skilled workers, on the other hand, benefit from this fall in transportation costs, increasing their consumption of both goods. Again the allocation of skilled labor across the two modern sectors depends on the initial size of the subsistence agriculture sector as before. If all transportation costs (η, η_1, and η_2) fall simultaneously, though p rises, changing relative prices inclusive of transportation costs benefit subsistence farmers as well, who increase their consumption of manufactures. Another difference with the previous case is that now the reallocation of labor is independent of the initial size of subsistence agriculture, and skilled labor moves away from modern agriculture to manufactures regardless. The effects of productivity improvements combined with decreases in transportation costs are also reported in Tables 3-6 . In these cases, as the effects of productivity improvements uniformly dominate those of declines in transportation costs of the same magnitude, the results shown are similar in sign to those obtained for the productivity changes.

What our analysis suggests so far in terms of policy analysis is that policies that encourage improvements in modern sector productivity or reductions in transportation costs can have perverse effects on the allocation of labor between agriculture and manufactures and may turn out to be welfare reducing in those economies where the initial size of the subsistence agriculture sector exceeds a critical value. On the other hand, improvements in the productivity of subsistence agriculture always improve welfare and allocate labor away from agriculture. These considerations suggest the following sequence for policy. Measures that reduce the barriers to mobility between subsistence and modern sectors should be adopted first to decrease employment in subsistence farming. These can be implemented simultaneously with policies that encourage adoption of improved technologies in subsistence farming. It is only after the share of employment in the subsistence sector has declined that policies that incentivize agents to adopt more productive technologies in the modern sectors or that lower transportation costs should be implemented.

We now turn to the effects of a reduction in the barrier to labor mobility between subsistence and modern sectors.

3.2 Changes in the size of the skilled labor force

The last counterfactual experiment we report here is designed to analyze the effects of the crucial barrier to structural transformation in our model: education. As our modeling choice prevents unskilled workers employed in the subsistence agriculture sector from moving to either of the two modern sectors, it is important to see how the economy reacts to an increase in the share of skilled labor which effectively allows subsistence farmers to move to either of the later. We saw in section 2.5 that the increase in n_e leaves relative prices, the wage rates, and per capita consumption levels unchanged. However, as some unskilled workers acquire skills and start earning higher skilled-worker wages by reallocating to the modern sectors per capita welfare in the economy rises, with the magnitude of the increase essentially depending positively on the existing skill premium. Our simulations also suggest that the share of the additional skilled workers absorbed by modern agriculture depends positively on the initial size of the subsistence sector, that sees in some cases an almost 50 percent increase in its share of skilled workers in response to a 10 percent increase in n_e. However, in all cases the increase in the share of skilled workers reduces the share of agricultural employment, though the magnitude of this decline remains relatively small: around three percent for every 10 percent rise in n_e.

When changes in n_e are interacted with either productivity changes, A_n and A_m, or transportation costs, η_i, in our counterfactual experiments, the welfare effects of these interactions typically turn out to yield results that are simple linear combinations.

4 Conclusion

Many poor developing countries have relatively large parts of their labor force employed in agriculture. Though some of these workers are employed by farms using modern agricultural equipment and technology, a significantly high share of agricultural employment remains in subsistence or-quasi subsistence agriculture, using traditional technologies with low productivity. Why these countries have such large fractions of their workers in agriculture remains an open question.

Our paper suggests that a number of mechanisms may help answer this question. First, barriers to labor mobility from the subsistence farming hinterland to the modern sectors (taking perhaps a number of forms including high costs of skill acquisition, as well as cultural and institutional restrictions) would help explain why employment in the subsistence sector remains high. However, even when we lower this barrier, the share of agricultural employment in total employment responds rather sluggishly. In our simulations reducing the labor force share of unskilled subsistence farmers by 10 percent decreases agriculture's share of employment by only about 3 percent. Second, productivity differences and transportation costs play an important role but not necessarily in the direction suggested by the existing literature. We show, among others, that productivity improvements in modern agriculture may actually increase the employment share of agriculture in those countries where subsistence agriculture is initially large. Similarly reductions in certain transportation costs may increase the employment share of agriculture in these economies. Intuitively, these results that run counter to the findings in the previous literature arise from the barriers to the movement of labor out of subsistence agriculture as well as the terms of trade effects of changes in productivity and transportation costs. Such terms of trade effects also have rather significant negative consequences for subsistence farmers as well. Further, where such farmers comprise a sizable enough

	A_n	A_m	η,η_1,η_2	η	n_e	A_n,η_i	Am,η_i	A_n, A_m	n_e,η_i	A_n,A_m,η_i	A_n,A_m,n_e	A_t	A_n,A_m,A_t
$\triangle\%p$	10.00	-3.74	1.41	1.41	0	11.55	-2.38	5.88	1.41	7.38	5.88	0	5.88
$\triangle\%n_a$	-0.314	-0.19	-0.177	-0.05	-2.96	-0.47	-0.36	-0.49	-3.16	-0.64	-3.56	-1.5	-1.78
$\triangle\%\theta$	-5.02	-3.06	-2.83	-0.76	6.22	-7.62	-5.75	-7.83	3.34	-10.30	-2.45	-23.97	-28.52
$\triangle\%z$	-5.02	6.63	-0.53	1.58	16.85	-5.44	6.11	1.38	16.35	0.99	18.03	-23.97	-21.37
$\triangle\%c_s^A$	0	0	0	0	0	0	0	0	0	0	0	2	2
$\triangle\%c_M^A$	2.77	1.63	1.056	0.4	0	3.94	2.75	4.57	1.06	5.81	4.57	0	4.57
$\triangle\%c_A^A$	3.33	1.96	0.47	0.47	0	3.85	2.46	5.49	0.47	6.038	5.49	0	5.5
$\triangle\%c_s^M$	-9.09	3.88	0.94	-1.39	0	-8.24	4.86	-5.55	0.93	-4.67	-5.55	50	41.66
$\triangle\%c_M^M$	9.84	16.62	3.97	1.52	0	13.46	20.75	26.85	3.97	30.6	26.85	0	26.85
$\triangle\%c_A^M$	6.06	14.07	3.31	0.93	0	9.43	17.75	20.37	3.31	24.11	20.37	0	20.37
$\triangle\%{}^{Y^A}/{}_Y$	0.078	-3.92	-0.37	0	-3.06	-0.26	-4.28	-3.80	-3.45	-4.13	-6.89	-1.18	-4.75
$\triangle\%Welf_s$	-11.85	4.74	1.16	-1.74	0	-10.7	5.90	-7.11	1.16	-5.95	-7.11	100.9	93.77
$\triangle\%Welf_A$	4.85	5.13	1.27	0.74	0	6.07	6.37	9.75	1.27	10.93	9.75	0	9.75
$\triangle\%Welf_M$	7.185	6.84	2.92	1.12	0	9.77	9.55	13.52	2.92	15.95	13.52	0	13.52
$\triangle\%Welf$	0.79	5.94	2.14	0.15	5.52	2.75	7.96	6.43	7.82	8.3	12.91	31.86	38.4
$\triangle\%c^M$	4.30	12.88	3.08	0.66	6.06	7.15	16.13	17.38	9.41	20.38	25.35	13.77	30.55
$\triangle\%c^A$	0.90	0.53	0.30	0.13	0.38	1.24	0.85	1.49	0.71	1.85	2.03	1.25	2.74
$\triangle\%{}^{w_m}/{}_{w_s}$	10.00	5.88	1.41	1.41	0	11.55	7.37	16.47	1.41	18.12	16.47	-9.09	5.88

Table 3: Productivity shocks when subsistence agriculture does not cover the subsistence needs of food for the whole economy ($\bar{c_A} = 0.8$, ${}^{w_m}/{}_{w_s} = 2$)

	A_n	A_m	η, η_1, η_2	η	n_e	A_n,η_i	Am,η_i	A_n, A_m	n_e,η_i	A_n,A_m,η_i	A_n,A_m,n_e	A_t	A_n,A_m,A_t
$\triangle\%p$	10.00	-3.74	1.41	1.41	0	11.55	-2.38	5.88	1.41	7.38	5.88	0	5.88
$\triangle\%n_a$	0.09	0.06	-0.1	0.015	-3.14	0.00	-0.03	0.15	-3.25	0.068	-3.09	-1.6	-1.21
$\triangle\%\theta$	5.93	3.62	-6.02	0.9	49.14	0.46	-2.06	9.24	42.59	4.08	51.60	-94.6	-72.31
$\triangle\%z$	5.93	13.98	-3.8	3.3	64.05	2.83	10.27	20.16	60.55	17.19	83.44	-94.6	-69.54
$\triangle\%c_s^A$	0	0	0	0	0	0	0	0	0	0	0	2.5	2.5
$\triangle\%c_M^A$	3.38	2	1.28	0.48	0	4.80	3.36	5.58	1.29	7.08	5.58	0	5.58
$\triangle\%c_A^A$	4.0	2.35	0.56	0.56	0	4.62	2.95	6.58	0.56	7.24	6.58	0	6.58
$\triangle\%c_s^M$	-9.09	3.88	0.93	-1.39	0	-8.23	4.86	-5.56	0.93	-4.67	-5.55	25	18.05
$\triangle\%c_M^M$	5.81	13.90	2.34	0.88	0	7.94	16.34	19.94	2.34	22.16	19.94	0	19.94
$\triangle\%c_A^M$	3.89	12.62	2.97	0.59	0	6.90	15.91	16.66	2.97	20.00	16.67	0	16.67
$\triangle\%^{Y^A}/_Y$	0.76	-4.27	-0.30	0.11	-3.16	0.47	-4.56	-3.47	-3.48	-3.75	-6.67	-1.05	-4.3
$\triangle\%Welf_s$	-4.35	1.740	0.43	-0.64	0	-3.92	2.16	-2.61	0.42	-2.18	-2.61	20.38	17.76
$\triangle\%Welf_A$	3.65	4.25	1.048	0.55	0	4.67	5.28	7.78	1.05	8.784	7.78	0	7.78
$\triangle\%Welf_M$	4.71	5.02	1.89	0.71	0	6.45	6.83	9.52	1.89	11.19	9.52	0	9.52
$\triangle\%Welf$	-0.16	3.25	1.084	-0.01	2.41	0.862	4.30	2.99	3.56	3.98	5.89	10.8	13.84
$\triangle\%c^M$	0.21	10.14	1.85	0.032	4.53	1.9	12.07	10.35	6.52	12.12	16.18	9.57	19.48
$\triangle\%c^A$	1.13	0.66	0.40	0.16	0.47	1.57	1.09	1.86	0.91	2.33	2.52	1.55	3.41
$\triangle\%^{w_m}/_{w_s}$	10	5.88	1.41	1.41	0	11.55	7.37	16.47	1.41	18.12	16.47	-9.09	5.88

Table 4: Productivity shocks when subsistence agriculture covers the subsistence needs of food for the whole economy($\bar{c_A} = 0.6$, $^{w_m}/_{w_s} = 2$)

	A_n	A_m	η, η_1, η_2	η	n_e	A_n,η_i	Am,η_i	A_n, A_m	n_e,η_i	A_n,A_m,η_i	A_n,A_m,n_e	A_t	A_n,A_m,A_t
$\triangle\%p$	10	-3.74	1.41	1.41	0	11.55	-2.38	5.88	1.41	7.38	5.88	0	5.88
$\triangle\%n_a$	-0.16	-0.10	-0.09	-0.03	-3.41	-0.25	-0.19	-0.26	-3.51	-0.34	-3.72	-0.78	-0.93
$\triangle\%\theta$	-3.62	-2.21	-2.08	-0.55	4.41	-5.53	-4.18	-5.64	2.27	-7.44	-1.84	-16.97	-20.25
$\triangle\%z$	-3.62	7.56	0.23	1.79	14.85	-3.29	7.88	3.79	15.16	4.22	18.77	-16.97	-12.28
$\triangle\%c_s^A$	0	0	0	0	0	0	0	0	0	0	0	2	2
$\triangle\%c_M^A$	4.35	2.56	1.65	0.61	0	6.17	4.31	7.16	1.65	9.09	7.16	0	7.168
$\triangle\%c_A^A$	5.00	2.94	0.70	0.71	0	5.77	3.69	8.24	0.70	9.06	8.24	0	8.24
$\triangle\%c_s^M$	-9.09	3.88	0.94	-1.39	0	-8.24	4.86	-5.56	0.94	-4.67	-5.56	50	41.66
$\triangle\%c_M^M$	3.19	12.14	1.28	0.48	0	4.35	13.48	15.45	1.28	16.67	15.45	0	15.45
$\triangle\%c_A^M$	2.27	11.52	2.72	0.35	0	5.01	14.53	13.88	2.72	16.91	13.88	0	13.88
$\triangle\%{}^{Y^A}/_{Y}$	0.749	-4.38	-0.25	0.10	-3.57	0.53	-4.62	-3.58	-3.83	-3.78	-7.06	-0.45	-3.91
$\triangle\%Welf_s$	-17.54	7.02	1.72	-2.58	0	-15.82	8.74	-10.52	1.72	-8.80	-10.52	149.25	138.72
$\triangle\%Welf_A$	2.30	2.95	0.73	0.34	0	3.01	3.67	5.21	0.72	5.91	5.21	0	5.21
$\triangle\%Welf_M$	2.66	3.22	1.06	0.4	0	3.67	4.25	5.80	1.06	6.78	5.81	0	5.81
$\triangle\%Welf$	-0.92	3.85	1.14	-0.13	7.50	0.17	4.97	2.87	8.71	3.95	10.92	26.16	29.04
$\triangle\%c^M$	1.83	11.23	1.40	0.28	8.34	3.12	12.69	13.13	9.88	14.49	22.87	5.78	18.63
$\triangle\%c^A$	1.67	0.98	0.57	0.23	1.18	2.30	1.59	2.74	1.81	3.42	4.21	1.14	3.89
$\triangle\%{}^{w_m}/_{w_s}$	10	5.88	1.41	1.41	0	11.55	7.38	16.47	1.41	18.12	16.47	-9.09	5.88

Table 5: Productivity shocks when subsistence agriculture does not cover the subsistence needs of food for the whole economy($\bar{c_A} = 0.8$, ${}^{w_m}/_{w_s} = 4$)

	A_n	A_m	η, η_1, η_2	η	n_e	A_n,η_i	Am,η_i	A_n, A_m	n_e,η_i	A_n,A_m,η_i	A_n,A_m,n_e	A_t	A_n,A_m,A_t
$\triangle\%p$	10	-3.7406	1.4107	1.4107	0	11.5518	-2.3827	5.88	1.4107	7.379	5.8853	0	5.88
$\triangle\%n_a$	0.0509	0.0312	-0.0501	0.0078	-3.5097	0.0055	-0.0161	0.08	-3.5704	0.0364	-3.4864	-0.8	-0.61
$\triangle\%\theta$	2.2888	1.4023	-2.2491	0.3498	18.7126	0.2456	-0.723	3.56	16.2331	1.6353	19.6629	-36.02	-27.42
$\triangle\%z$	2.2888	11.5425	0.06	2.7203	30.5838	2.6136	11.7844	13.92	30.8767	14.4397	44.7922	-36.02	-20.17
$\triangle\%c_s^A$	0	0	0	0	0	0	0	0	0	0	0	2.5	2.5
$\triangle\%c_M^A$	5.0666	2.9829	1.9285	0.7147	-0.0001	7.188	5.0232	8.34	1.9281	10.593	8.35	0	8.35
$\triangle\%c_A^A$	5.7175	3.3649	0.8065	0.8067	-0	6.6048	4.2191	9.42	0.8065	10.3588	9.42	0	9.42
$\triangle\%c_s^M$	-9.0909	3.886	0.9383	-1.3911	0	-8.2379	4.8607	-5.56	0.9383	-4.6721	-5.56	25	18.05
$\triangle\%c_M^M$	2.1986	11.4791	0.8869	0.3365	0.0001	3.0048	12.399	13.76	0.8862	14.6002	13.76	0	13.76
$\triangle\%c_A^M$	1.6018	11.0773	2.6131	0.2451	0	4.2299	13.9617	12.74	2.6131	15.6412	12.74	0	12.74
$\triangle\%^{Y^A}/_Y$	1.3831	-4.5797	-0.1638	0.1975	-3.5772	1.2459	-4.7257	-3.16	-3.751	-3.2798	-6.62	-0.315	-3.35
$\triangle\%Welf_s$	-4.9393	1.9757	0.484	-0.726	0	-4.4553	2.4597	-2.96	0.484	-2.4796	-2.96	23.13	20.16
$\triangle\%Welf_A$	2.0456	2.7682	0.6801	0.3043	0	2.7174	3.4432	4.78	0.68	5.4483	4.78	0	4.78
$\triangle\%Welf_M$	2.2739	2.9361	0.9012	0.3395	0	3.1433	3.8169	5.16	0.901	6.0138	5.16	0	5.16
$\triangle\%Welf$	-0.7924	2.5241	0.7163	-0.1134	3.9503	-0.0936	3.2291	1.7	4.7073	2.3935	6	9.8	11.50
$\triangle\%c^M$	0.0853	10.0579	0.975	0.0132	7.2084	0.9827	11.0771	10.14	8.2687	11.0847	18.51	4.88	14.78
$\triangle\%c^A$	2.0322	1.1964	0.7309	0.2867	1.4429	2.8363	1.9697	3.34	2.2416	4.1994	5.12	1.39	4.74
$\triangle\%^{w_m}/_{w_s}$	10	5.8853	1.4107	1.4107	0	11.5518	7.379	16.47	1.4107	18.1169	16.47	-9.09	5.88

Table 6: Productivity shocks when subsistence agriculture covers the subsistence needs of food for the whole economy($\bar{c_A} = 0.6$, $^{w_m}/_{w_s} = 4$)

majority of the population, the welfare losses they suffer outweigh the gains that accrue to the rest of the population such that winners cannot compensate the losers. These results suggest that in economies with significant distortions, second-best welfare paradoxes may be important and policy recommendations concerning public investment in infrastructure designed to improve productivity in the modern sectors or lower transportation costs need to be reconsidered. Our model instead would provide basis for policies designed to improve productivity in subsistence agriculture and lower the cost of education of subsistence farmers should come first. Once the barriers to labor mobility have been reduced and the subsistence sector becomes smaller, policies directed at the modern sectors and transportation costs would have the desired effects.

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5 Appendix

Using 16 and 3 we derive

$$Y_t^A - n\overline{c_A} = Y_n^A \left(\alpha \frac{\beta_n - \theta}{\theta} - 1 \right) \tag{17}$$

which is $\geq (<) 0$) depending on the size of subsistence agriculture $Y_t^A \geq (<) n\overline{c_A}$.

Using 2, 3 and 6 we derive

$$Y_n^A = \left(\frac{1-\beta_n}{\beta_n} \right)^{1-\beta_n} \left(\frac{A_m}{1+\eta} \right)^{1-\beta_n} A_n \theta n_e \tag{18}$$

$$z = \theta n_e A_m \frac{1-\beta_n}{\beta_n (1+\eta)} \tag{19}$$

$$p = \left(\frac{1-\beta_n}{1+\eta} \right)^{1-\beta_n} \left(\frac{\beta_n}{A_m} \right)^{\beta_n} A_n \tag{20}$$

Thus we can derive:

$$\frac{\partial\theta}{\partial A_m} = \frac{1-\beta_n}{1+\alpha}\frac{\theta}{A_m}\left(\alpha\frac{\beta_n-\theta}{\theta}-1\right) \geq (<)0 \tag{21}$$

if $Y_t^A \geq (<) n\overline{c_A}$.

$$\frac{\partial z}{\partial A_m} = \frac{1-\beta_n}{\beta_n}\frac{\theta n_e}{1+\eta}\left(\frac{1-\beta_n}{1+\alpha}\left(\alpha\frac{\beta_n-\theta}{\theta}-1\right)+1\right) > 0 \tag{22}$$

$$\frac{\partial p}{\partial A_m} = -\beta_n\left(\frac{1-\beta_n}{1+\eta}\right)^{1-\beta_n}\beta_n^{\beta_n}A_mA_n < 0 \tag{23}$$

$$\frac{\partial\theta}{\partial A_n} = \frac{1}{1+\alpha}\frac{\theta}{A_n}\left(\alpha\frac{\beta_n-\theta}{\theta}-1\right) \geq (<)0 \tag{24}$$

if $Y_t^A \geq (<) n\overline{c_A}$.

$$\frac{\partial z}{\partial A_n} = \frac{\partial\theta}{\partial A_n}A_mn_e\frac{1-\beta_n}{\beta_n(1+\eta)} \geq (<)0 \tag{25}$$

if $Y_t^A \geq (<) n\overline{c_A}$.

$$\frac{\partial p}{\partial A_n} = \left(\frac{1-\beta_n}{1+\eta}\right)^{1-\beta_n}\left(\frac{\beta_n}{A_m}\right)^{\beta_n} > 0 \tag{26}$$

$$\frac{\partial\theta}{\partial\eta} = -\frac{1-\beta_n}{1+\alpha}\frac{\theta}{1+\eta}\left(\alpha\frac{\beta_n-\theta}{\theta}-1\right) \leq (>)0 \tag{27}$$

if $Y_t^A \geq (<) n\overline{c_A}$.

$$\frac{\partial z}{\partial\eta} = -\frac{z}{1+\eta}\left(\frac{1-\beta_n}{1+\alpha}\left(\alpha\frac{\beta_n-\theta}{\theta}-1\right)+1\right) < 0 \tag{28}$$

$$\frac{\partial z(1+\eta)}{\partial\eta} = \frac{\partial\theta}{\partial\eta}n_eA_m\frac{1-\beta_n}{\beta_n} \leq (>)0 \tag{29}$$

if $Y_t^A \geq (<) n\overline{c_A}$.

$$\frac{\partial p}{\partial\eta} = -\left(1-\beta_n\right)\left(1-\beta_n\right)^{1-\beta_n}\left(\frac{\beta_n(1+\eta)}{A_m}\right)^{\beta_n}A_n < 0 \tag{30}$$

$$\frac{\partial\theta^2}{\partial A_m\partial\eta} = -\frac{\partial\theta}{\partial\eta}\frac{1-\beta_n}{A_m} \geq (<)0 \tag{31}$$

if $Y_t^A \geq (<) n\overline{c_A}$.

$$\frac{\partial\theta^2}{\partial A_n\partial\eta} = -\frac{\partial\theta}{\partial\eta}\frac{1}{A_n} \geq (<)0 \tag{32}$$

if $Y_t^A \geq (<) n\overline{c_A}$.

$$\frac{\partial \theta n_e}{\partial n_e} = \frac{\theta n_e}{1+\alpha}\left(\frac{A_t}{Y_n^A} + \frac{\alpha\beta_n}{\theta n_e}\right) > 0 \tag{33}$$

$$\frac{\partial \left(\theta n_e\right)^2}{\partial n_e \partial \eta} = \frac{\theta n_e}{1+\alpha}\frac{1-\beta_n}{1+\eta}\frac{A_t}{Y_n^A} > 0 \tag{34}$$

$$\frac{\partial z}{\partial n_e} = \frac{1-\beta_n}{\beta_n}\frac{A_m}{1+\eta}\frac{\partial \theta n_e}{\partial n_e} > 0 \tag{35}$$

$$\frac{\partial n_a}{\partial n_e} = \frac{\theta n_e}{1+\alpha}\left(\frac{A_t}{Y_n^A} + \frac{\alpha\beta_n}{\theta n_e}\right) + \theta - 1 \leq 0 \tag{36}$$

if $w_t \leq w_N^A$.

$$\frac{\partial p}{\partial n_e} = 0 \tag{37}$$