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Abstract

This paper examines the political economy of coordination in a simple two-sector model in which individuals' choice of agricultural technology affects industrialization. We demonstrate the existence of multiple equilibria; the economy is either characterized by the use of a traditional agricultural technology and a low level of industrialization or the use of a mechanized technology and a high level of industrialization. Relative to the traditional technology, the mechanized technology increases output but leaves some population groups worse off. We show that the distributional implications of choosing the mechanized technology restrict the possibility of Pareto-improving coordination by an elected policy-maker, even when we allow for income redistribution.

Keywords: Industrialization, Choice of Technology, Government Policy.

JEL Codes: O14, H10

1 Introduction

An increase in industrial activity, accompanied by a decline in agriculture's share in total output, has been a central element of the development experience of almost every high-income country.[1] In many of these countries changes in agricultural technology either preceded or accompanied industrialization (Chenery, Robinson and Syrquin 1986). Historic examples include the widespread mechanization of agricultural production in England prior to the Industrial Revolution (Nurkse 1953), in the US between 1860s and World War I (Oshima 1984; Kawagoe, Otsuka and Hayami 1984), and in Japan at the turn of the century (Ohkawa and Rosovsky 1973).[2] More recent examples include the East Asian economies in the post World War II period. Between 1960 and 1990, relative to other Asian and African countries, these countries experienced a sharp rise in the agricultural capital-labor ratio and a decline in the use of labor in agriculture (see Figures 1 and 2).

This paper identifies how a coordination failure among investors in the agricultural sector can limit industrialization, and examines the constraints facing politicians seeking to rectify this failure. We construct a simple two sector model populated by landowners and workers. Relative to the traditional technology, the mechanized agricultural technology increases industrialization and returns to landowners but reduces workers' incomes. We show that multiple equilibria in the choice of technology can cause the use of the traditional agricultural technology and low levels of industrialization to persist. Further, the distributional implications of the mechanized technology may inhibit coordination by an elected policy-maker.

Specifically, we assume the policy-maker is elected from among the citizens and

[1] Kuznet (1959) remains among the best known expositions of this phenomenon.

[2] A common example of such mechanization was the widespread replacement of horse drawn equipment by equipment powered by internal combustion.

examine alternative policy regimes. In the first, the policy-maker directly chooses the agricultural technology, while in the second, she provides price subsidies but investment decisions remain decentralized. In either case she can redistribute income via an anonymous tax and transfer policy. In the absence of policy-commitment, the policy-maker's returns from the choice of technology and redistribution policy depend on her group identity. Hence, the policy-maker's group identity affects the possibility of coordination. If the policy-maker can directly invest in the agricultural technology then she chooses the mechanized technology and the population group to which she does not belong is made worse off. If investment decisions remain decentralized then the outcome varies with the policy-maker's group identity. If the policy-maker is a landowner, then the mechanized technology is chosen and workers are worse off. If the policy-maker is a worker, then landowners, anticipating high levels of redistribution, stick with the traditional technology. This last case constitutes a political failure since with the same set of policy instruments a Pareto superior equilibrium could be realized if the policy-maker could commit to a redistribution policy.[3]

In this model, a key feature of the mechanized technology is it's use of industrial inputs. The fact that newer, more efficient, agricultural technologies are also more likely to use industrial inputs is well documented, a well-known example being the adoption of high yielding crop varieties (Evenson and Westphal (1995)). However, the implications of such inter-sector linkages for industrialization remain controversial. Some, like Lewis (1955), and Hirschman (1958), argue that the mechanization of agricultural production helps transfer resources, especially labor, to the industrial sector. Others argue that changes in agricultural methods of production affect industrialization by increasing the (agricultural) demand for industrial goods (see, for

[3]Dixit and Londegran (1995) and Fernandez and Rodrik (1991) examine how the distributional consequences of investments can prevent their adoption. They differ from our paper in their focus on economic environments characterized by an unique equilibrium.

instance, Johnston and Mellor (1961) and Murphy, Shleifer and Vishny (1989a)). In our model we allow for both supply-side and demand-side linkages between the two sectors.[4]

The use of the mechanized technology shifts labor from a constant returns to scale sector (agriculture) to an increasing returns to scale sector (industry). This increases the number of industrial varieties produced and reduces the price per variety. This, in turn, reduces the price of adopting the mechanized technology and lowers consumer prices. Both forces work to make the combination of mechanized agriculture and industrialization self-sustaining. However, as prices are invariant to any single citizen's investment decision the choice of the traditional agricultural technology and low levels of industrialization also remains an equilibrium. This multiplicity of equilibria derives from the pecuniary externalities associated with use of the mechanized technology. The classic study documenting that technology adoption in agriculture is closely linked to profitability and market size remains the study by Griliches (1957) on the spread of hybrid seed corn in U.S. agriculture (see Besley and Case (1993) for a review of this literature).

The idea that a coordination failure among investors in the agricultural sector can cause agricultural stagnation and industrial backwardness to persist is echoed in the literature on 'big push' models of industrialization (see, for example, Murphy, Shleifer and Vishny (1989b)).[5] In these papers a coordination failure among investors can prevent the economy from obtaining the Pareto superior high industrialization equilibrium. Hence, the conclusion that governments should coordinate investment activity.[6] Our innovation is to demonstrate that this conclusion is sensitive to the

[4]The relative importance of supply-side and demand-side linkages between agriculture and industry was also the basis of the famous Corn law debate between Malthus and Ricardo.

[5]The idea that a coordination failure amongst investors may cause low levels of industrialization to persist was first discussed by Rosenstein Rodan (1943).

[6]The East Asian growth miracle is often, in part, attributed to the government's coordination

assumption that citizens have identical factor endowments. In our model, adoption of the mechanized technology benefits landowners but leaves workers worse off. These distributional implications of technological change affect both the possibility and the welfare implications of policy-led coordination.[7]

The rest of the paper is organized as follows. Section 2 uses a two sector model in which landowners face a choice of agricultural technology to examine how landowners' investment decisions affect industrialization. Section 3 examines the political economy of coordination, and Section 4 concludes with a discussion of possible extensions. Proofs are in the Appendix.

2 Agricultural Technology Adoption and Industrialization

In this section we show how, in the presence of inter-sector production linkages, landowners' agricultural technology choice affects the extent of industrialization, as measured by the number of industrial varieties produced.

2.1 Economic Environment

The economy consists of N citizens, indexed by $j \in \mathcal{N} = \{1, ..., N\}$, and lasts a single period. Total labor and land endowments are $L > 1$ units of labor and one unit of land. Citizen $j's$ labor endowment is denoted as $\alpha_j L$, and her land endowment as β_j

policy, e.g. Wade (1990).

[7]Sah and Stiglitz (1984, 1987) examine how policy led changes in the agriculture-industry terms of trade affect industrialization, and note that industrial policies may make some citizens' worse off. They, however, do not examine how these adverse distributional consequences affect the feasibility of industrialization.

where $\alpha_j, \beta_j \in [0,1]$. All landowners have identical land endowments, and there is no market for land. Labor is fully mobile across sectors.

A citizen supplies her labor and land endowment for production, and earns income $y_j \equiv \alpha_j wL + \beta_j \pi$, where π is the return on land and w is the wage. She uses her income to buy food and manufactures, denoted as F and M respectively. Her preferences take the form: $u_j = F^{\nu} M^{1-\nu}$, where $\nu \in]0,1[$, and $\nu \neq \frac{1}{2}$.

Landowners produce food using either a *basic* or *mechanized* technology, indexed by $\tau \in \{b, m\}$. These technologies are defined as:

$$F_b = \min(l, h)$$

$$F_m = \min\left(\frac{l}{\gamma}, h, \frac{M}{\kappa}\right)$$

l denotes the labor requirement and h the land requirement. The parameters $\gamma \in]0,1[$ and $\kappa \in]0,1]$ characterize the efficiency of the production function. I assume that $M > \kappa$ and that land supply limits food production. Hence, independent of the agricultural technology in use one unit of food is produced.[8] Use of the mechanized technology is, however, associated with an additional demand for κ units of manufactures and a reduced labor demand of $\gamma < 1$ units. We normalize the price of food and denote the price of manufactures by P. Returns to land vary with agricultural technology: $\pi_b = 1 - w_b$ and $\pi_m = 1 - \gamma w_m - \kappa P$. We assume the labor endowment is sufficiently large so that $L > \frac{1}{2\nu - 1}$. This implies that $\pi_b > w_b L > 0$.[9] We also assume that no single individual's actions can influence factor prices.

Manufactures are produced in the industrial sector which is characterized by monopolistic competition. A continuum of firms, indexed by i, produce different varieties of manufactures. Firm i produces quantity x_i of variety i and prices it at p_i. These

[8] $\nu > 0$ rules out the corner solution of zero food production.

[9] The condition $\pi_b > w_b L$ simplifies to $L > \frac{1}{2\nu - 1}$. The condition $w_b L > 0$ simplifies to $\frac{(1-\nu)}{\nu(L-1)} L > 0$ which is positive for $L > 1$.

varieties are aggregated into a single manufactures good via a production function which exhibits constant elasticity of substitution in the quantities of each product type (Dixit and Stiglitz (1977) and Ethier (1982)). That is,

$$M \equiv \left(\int_{i \in n} x_i^{\frac{\varepsilon-1}{\varepsilon}} di \right)^{\frac{\varepsilon}{\varepsilon-1}}$$

and

$$P \equiv \left(\int_{i \in n} p_i^{1-\varepsilon} di \right)^{\frac{1}{1-\varepsilon}}$$

n is the set of varieties produced in equilibrium and ε is the elasticity of substitution across varieties. I assume $\varepsilon > 1$ such that product varieties are imperfect substitutes. $\rho \equiv \frac{\varepsilon-1}{\varepsilon}$ measures citizens' intensity of preference for variety. Given a sufficiently large number of industrial varieties, the elasticity of inverse demand faced by a producer can be approximated as $1 - \rho$ (Dixit and Stiglitz 1977). Costless product differentiation by firms implies that each firm produces a different variety.

The production functions for all industrial varieties are identical.[10] Production of variety i involves a fixed cost of δ labor units and a marginal cost of ϕ units of output. Firm i 's production function is:

$$x_i = \frac{l_i - \delta}{\phi} \text{ for } l_i > \delta; \text{ 0 otherwise}$$

with associated profits: $p_i x_i - w(\phi x_i + \delta)$.
Monopolistic competition implies that, in equilibrium, variety $i's$ price equates marginal revenue (ρp_i) and marginal cost. Hence $p_i(\frac{\varepsilon-1}{\varepsilon}) = \phi w$. For notational simplicity assume $\phi = \frac{\varepsilon-1}{\varepsilon}$. Thus variety $i's$ price equals the wage, or

$$p_i = w \tag{1}$$

[10]The industry wide demand for labor is $l^d = \frac{npx}{w}$.

Monopolistic competition also implies that, in equilibrium, $p_i x_i = w(\phi x_i + \delta)$. Hence, output per firm is constant at

$$x_i = \frac{\delta}{1-\phi} \tag{2}$$

Firms produce the same output per variety, x, and price each variety identically at price p.[11] The manufactures production function simplifies to $M = n^{\frac{\varepsilon}{\varepsilon-1}} x$ (with $P = n^{\frac{1}{1-\varepsilon}} p$).

To solve for equilibrium we first characterize the production and consumption decisions associated with each agricultural technology and then identify landowners' technology choice. As landowners are identical we restrict attention to the case where all landowners choose the same technology.

2.2 Choice of Technology

Agricultural labor demand, and therefore the wage, varies with the choice of technology. Equating labor demand and supply under each technology gives us

$$w_b = \frac{x n_b p_b}{L-1} \quad \text{and} \quad w_m = \frac{x n_m p_m}{L-\gamma} \tag{3}$$

Combining equation (3) with the price wage identity (equation (1)) gives us our first result.

Proposition 1: *Use of the mechanized agricultural technology increases industrialization.*

Use of the mechanized agricultural technology reduces agricultural labor demand by $(1-\gamma)$ units. The main issue is whether the increase in industrial labor supply only alters factor prices or also increases the number of industrial varieties produced. Proposition 1 tells us that the latter holds. This reason is that since industrial varieties

[11] The symmetric way in which industrial varieties enter the formulation of M and convexity $(0 < \rho < 1)$ implies that citizens consume identical amounts of each variety.

are imperfect substitutes ($\rho < 1$), consumers exhibit a love for variety. Hence, the production of industrial varieties exhibit positive returns to the division of labor. As a result labor availability, not demand, limits industrialization. By shifting labor away from a constant returns to scale sector (agriculture) to an increasing returns to scale sector (industry) the mechanized agricultural technology increases output .

The final demand for variety x in the economy is

$$x = \left(\frac{P_\tau}{p_\tau}\right)^{\varepsilon} \frac{E_\tau}{P_\tau} \tag{4}$$

E_τ is the total expenditure on manufactures, consisting of consumer and agricultural sector expenditure. Consumer expenditure is given by $\sum_{j=1}^{N}(1-\nu)y_j$.[12] Use of the mechanized agricultural technology generates an additional agricultural sector demand of κP_a units. Hence,

$$\begin{aligned} E_b &= (1-\nu)((L-1)w_b + 1) \\ E_m &= (1-\nu)((L-\gamma)w_m + 1) + \kappa\nu P_m \end{aligned} \tag{5}$$

Combining equations (4) and (5) gives the price of industrial varieties associated with the use of each technology.

$$p_b = \frac{1-\nu}{\nu n_b x} \quad \text{and} \quad p_m = \frac{1-\nu}{\nu n_m (x - n_m^{\frac{\varepsilon}{1-\varepsilon}} \kappa)} \tag{6}$$

Due to imperfect substitutability between industrial varieties the efficiency of manufactures production is increasing in the number of varieties produced.[13] Therefore, for a fixed E_τ, P falls as n rises. This affects p in three ways. For any single firm i a fall in P reduces the profits associated with producing variety i. This negative

[12]Identical homothetic preferences imply that total consumer demand is the aggregation of individual demand functions.

[13]Imperfect substitutability between varieties implies that the lower is n the more intensively consumers substitute for missing inputs in their consumption of the manufactures aggregate.

product market effect lowers p. On the other hand, the fall in P creates two positive pecuniary externalities. First, it reduces the cost of using the mechanized agricultural technology and makes its adoption more likely. Conditional on its adoption, manufactures demand increases. This cost (or forward) linkage between firms and the agricultural sector enhances firm profits and raises p. For similar reasons, a fall in P also generates a demand (or backward) linkage by raising consumer expenditure on manufactures.

The strength of the inter-sector linkages, and the extent of labor saving associated with the mechanized agricultural technology, determine the relative strengths of the negative product market effect and positive pecuniary externalities. These, in turn, determine the price of industrial varieties, p, and landowners' technology choice.

Proposition 2: *Landowners' technology choice varies with the strength of inter-sector linkages, κ, and the extent of labor saving, γ, associated with the mechanized agricultural technology*

(i) Landowners choose the mechanized technology if $\frac{\kappa}{(1-\gamma)} < n_b^{\frac{1}{\varepsilon-1}}$ *and the basic technology if* $\frac{\kappa}{(1-\gamma)} > n_m^{\frac{1}{\varepsilon-1}}$

(ii) Multiple investment equilibria exist such that landowners either choose the basic or the mechanized technology whenever

$$n_m^{\frac{1}{(\varepsilon-1)}} \geq \frac{\kappa}{(1-\gamma)} \geq n_b^{\frac{1}{(\varepsilon-1)}}$$

For low values of κ and γ the mechanized agricultural technology minimizes landowners factor costs. This leads to an unique investment equilibrium in which all landowners choose the mechanized agricultural technology. However, as $\frac{\partial p_m}{\partial \kappa} > 0$, the mechanized technology becomes more expensive as κ rises. For a sufficiently high κ the positive pecuniary externalities associated with use of the mechanized technology cannot compensate for the higher factor prices. An unique investment equilibrium in which landowners choose the basic agricultural technology results.

For intermediate values of κ and γ increasing returns in the manufacturing sector, combined with the possibility of pecuniary externalities, creates multiple investment equilibria. If landowners choose the basic technology few industrial varieties are produced at a relatively high cost. Given this price structure, a landowner's best response is to choose the basic technology. The result is an equilibrium in which landowners choose the basic technology. If, instead, landowners choose the mechanized technology more industrial varieties are produced and the cost of adopting the mechanized technology is reduced. In addition, consumer demand for manufactures rises. This makes the combination of landowners choosing the mechanized technology and a higher level of industrialization sustainable.

Food production is the same under the two technologies, but industrial output is higher with the mechanized technology in use. Social surplus (SS) is given by the sum of citizens' indirect utilities, such that

$$SS_b = \frac{1}{\nu}\left[\frac{\nu n_b{}^{\frac{\varepsilon}{\varepsilon-1}}x}{1-\nu}\right]^{1-\nu} \quad \text{and} \quad ; SS_m = \frac{1}{\nu}\left[\frac{\nu(n_m{}^{\frac{\varepsilon}{\varepsilon-1}}x-\kappa)}{1-\nu}\right]^{1-\nu} \tag{7}$$

Lemma 1: *The mechanized agricultural technology maximizes social surplus in the multiple equilibria regime.*

Consumers' love of variety implies that social surplus is increasing in the number of industrial varieties produced. On the other hand, social surplus is decreasing in the strength of inter-sector linkages (as captured by κ) since $\frac{\partial p_m}{\partial \kappa} > 0$. The mechanized technology maximizes social surplus only if the efficiency gains (in terms of the number of industrial varieties produced) outweighs the potential price increase associated with its use. Lemma 1 tells us that this is true in the multiple equilibria regime.

3 The Political Process and Coordination

The role for the government as a coordinator of economic activity has been widely discussed in the literature on coordination failures in industrial investment.[14] Murphy, Shleifer and Vishny (1989b), for instance, write in the context of big push models of industrialization, 'The analysis may have implications for the role of government in the development process. First, a program that encourages industrialization in many sectors simultaneously can substantially boost income and welfare even when investment in any one sector appears unprofitable.'

Most existing multiple equilibria models of industrialization are representative agent models. In these, it is immediate that all individuals are better off in the output-maximizing high industrialization equilibrium. The possibility of welfare-improving coordination in these models, therefore, turns on whether policies which make the high investment equilibrium the unique outcome for the economy exist (on this, see Bond and Pande (2005)). However, with heterogeneity in factor endowments some individuals may be worse off in the high investment equilibrium. In such a setting examining how the political economy of coordination can affect a governments' ability to implement a Pareto superior outcome for the economy becomes relevant.

We focus on the case where multiple investment equilibria exist, that is $n_m^{\frac{1}{(1-\varepsilon)}} \geq \frac{\kappa}{(1-\gamma)} \geq n_b^{\frac{1}{(1-\varepsilon)}}$, and every citizen is either a landowner or a wage laborer. To focus on the aggregate investment effects of government led coordination we consider a large

[14] An early argument in favor of government coordination was offered by Scitovsky (1954),' Market prices, however, reflect the economic situation as it is and not as it will be. For this reason they are more useful for coordinating current production decisions .. than .. for coordinating investment decisions which have delayed effects .. hence the belief that there is need either for centralized investment planning or some additional communication system to supplement the pricing system as a signalling device.'

population ($N \rightarrow \infty$), and fixed landowner and worker population shares.[15] Every landowner ℓ ($\in \mathcal{K} = \{1, ..k\}$) owns $\frac{1}{k}$ units of land and earns an income $y_\ell = \frac{\pi_\tau}{k}$, while every worker ω ($\in \mathcal{W} = \{k+1, ...N\}$) supplies $\frac{L}{N-k}$ labor units and earns an income $y_\omega = \frac{w_\tau L}{N-k}$. Finally, we assume that k satisfies the inequality $\frac{\pi_b}{k} > \frac{w_b L}{N-k}$.

We consider a citizen candidate model of politics in which citizens choose whether to stand for election (Osborne and Slivinski (1996); Besley and Coate (1997)). The time line of events is – Citizens decide whether to enter as candidates. Then, citizens elect a policy-maker from the pool of citizen candidates. The policy-maker announces the parameters of the coordination policy. Finally, landowners invest in an agricultural technology, and payoffs are realized. A key assumption is that candidates cannot commit to policies prior to election. This implies that the policy-maker will always select the policy which maximizes her private return. Anticipating this, citizens will condition their vote on candidates' policy preferences.[16] The inability of politicians to commit to policies has been documented in a wide variety of contexts – see, for instance, Butler, Lee and Moretti (2004) and Pande (2003).

We restrict attention to one candidate equilibria in which a member of the majority group stands for election and wins. Such an equilibrium exists as long as one group of citizens constitute a strict population majority and the cost of standing for election is not too high (for details, see Besley and Coate (1997)). We assume these conditions are satisfied.

The absence of policy commitment implies that the elected policy-maker will seek

[15]Hence, factor prices are invariant to a single investor's actions and changes in her pre-tax income (holding other citizens income constant) does not affect her income transfer. $\alpha_j = 0$ and $\beta_j = \frac{1}{k}$ for landowners; and $\alpha_j = \frac{1}{N-k}$and $\beta_j = 0$. for workers

[16]We, therefore, restrict attention to time-consistent policies, that is policies which the policy-maker will not have an incentive to change after the technology choice is realized.

to implement the agricultural technology τ^* which maximizes her utility, such that:

$$\tau^* = \arg\max \left(X \left(\frac{w_\tau L}{N-k} \right) + (1-X) \left(\frac{\pi_\tau}{k} \right) \right) P_\tau^{-(1-\nu)} \quad (8)$$

where X equals 0 if the policy-maker is a landowner and 1 otherwise.[17]

A policy intervention is feasible only if it is budget balancing in equilibrium. We do not require budget balancing off the equilibrium path. This assumption is similar to the restrictions assumed in the Ramsey capital accumulation model. We also assume that policy interventions are strongly anonymous, i.e. a citizen's final payoff only depends on her strategy.

We examine coordination under two different policy regimes. First, the case where the policy-maker directly chooses the agricultural technology. Historic examples include the Soviet collectivization of agriculture in the 1930s, and the setting up of Chinese state farms in the 1960s. Second, we consider the case where the government announces price subsidies but investment decisions are chosen by landowners. We require that the choice of price subsidies satisfies the budget constraint in equilibrium.[18] Throughout we assume the policy-maker can redistribute final incomes via an anonymous tax and transfer schedule, denoted as (t, T) with the associated budget constraint $t \sum_j y_j = NT$. We also assume that, absent coordination, landowners choose the basic technology. Hence, our welfare comparisons contrast the outcomes associated with state-led coordination with an equilibrium in which all landowners' choose the basic technology.

[17] The policy-maker's group identity depends on whether workers or landowners constitute a strict majority.

[18] A different way of distinguishing between these policies is that the first, where the policy-maker chooses the technology, ignores the budget constraint while in the second the policy must be budget balancing in equilibrium.

3.1 Socialization of Investment

We define investment in the economy as *socialized* whenever the elected policy-maker directly invests in the agricultural technology. The sequence of events is – a single candidate from the majority group stands for election and is elected. She then invests in the agricultural technology and announces the redistribution policy.[19]

Proposition 3: *With socialized investment the mechanized technology is chosen. If a landowner is policy-maker then no redistribution occurs and workers are worse off. If a worker is policy-maker then full redistribution occurs and landowners are worse off.*

The mechanized technology maximizes social surplus (Lemma 1). However, the use of the mechanized technology reduces the relative price of manufactures and raises landowners' profit. Hence, the mechanized technology maximizes landowners' indirect utility. In contrast, the price wage equality (equation 1) implies workers are made worse off.

A landowner's income exceeds that of a worker. Therefore, if elected policy-maker, she will invest in the mechanized technology and choose zero redistribution.[20] Proposition 3 tells us that this leaves workers' worse off than when the basic technology was in use. A worker, if elected policy-maker, implements the mechanized technology and full redistribution. Proposition 3 also tells us that, whenever landowners' are a population minority, a landowner's agricultural profits from the basic technology exceed

[19]The political equilibrium can be justified as follows: by assumption, the policy-maker cannot commit to an agricultural technology during the election campaign. Therefore, citizens' anticipate candidates' policy preferences and vote for the candidate who shares their preferences. For sufficiently low entry costs this implies an equilibrium in which a candidate from the majority group stands for election and win. Anticipating this outcome no other candidate will stand for election.

[20]By assumption $\frac{\pi_b}{k} > \frac{w_b L}{N-k}$. From proposition 3 we know that $\frac{\pi_m}{k} > \frac{\pi_b}{k}$ and $\frac{w_m L}{N-k} < \frac{w_b L}{N-k}$. Hence $\frac{\pi_m}{k} > \frac{w_m L}{N-k}$.

the per capita income associated with the use of the mechanized technology. Hence landowners' are worse off whenever the policy-maker is a worker. Which of these two outcomes occurs depends on which group constitutes the population majority.

3.2 Decentralized Investment and Coordination

We now consider the case where investment decisions remain decentralized, i.e. are privately chosen by landowners. The policy-maker seeks to affect technology choice by the use of price subsidies, potentially combined with income redistribution. Examples of such a policy include the provision of subsidized inputs by agricultural extension services in many developing countries (Evenson and Westphal 1995).

We start by noting that the multiplicity of equilibria is invariant to income redistribution.

Lemma 2: *The multiplicity of equilibria is robust to the use of a budget balancing linear tax and transfer scheme.*

The proof is as follows – with a linear tax and transfer scheme a citizen's final income remains a function of her pre-tax income and total income. That is, $y_j^c = (1-t)y_j + \frac{1}{N}\left(t \sum_{j \in \mathcal{N}} y_j\right)$. Start with an equilibrium in which all landowners choose the basic technology. If a single landowner deviates to the mechanized technology then both her pre-tax income (y_j) and total income are reduced (see the proof of proposition 2). Since an investor's post tax income is a linear combination of these two it also falls. Hence, investing in the mechanized technology cannot constitute a profitable deviation for any single investor.[21]

Multiple investment equilibria arise when an investor's optimal strategy depends on other investors' strategy (Cooper and John 1988). To affect coordination a policy

[21] This reasoning is similar to the argument provided by Murphy, Shleifer and Vishny (1989b) for why profit spill-overs are insufficient to engender multiple equilibria.

must make investing in the mechanized technology a dominant strategy for an investor (for a more general discussion of the issues, see Bond and Pande (2005)). Lemma 2 states that a linear income-based intervention fails to do so.

We now consider the joint use of price subsidies and a linear tax and transfer scheme by the policy-maker. We assume that price subsidies are not conditioned on any single investor's investment choice.

Proposition 4 *A landowner, if elected policy-maker, announces zero redistribution and price subsidies such that final prices are* p_m, P_m*. Landowners respond by choosing the mechanized technology and workers are made worse off. If a worker is, instead, elected policy-maker then, independent of her choice of price subsidies, multiple investment equilibria persist.*

A landowner, if elected policy-maker, announces the prices associated with use of the mechanized technology, and zero redistribution. It follows from proposition 2 that a landowner's best response is to invest in the mechanized technology. This policy is budget balancing in equilibrium and maximizes landowners' income. This choice of redistribution, however, leaves workers worse off (see proof of proposition 3 for details).

In contrast, if a worker is elected policy-maker then, conditional on landowners choosing the mechanized technology, she will always implement full redistribution such that each individual earns (the same) fraction of total output. This renders a landowner's final income independent of her actions and implies that investing in either the basic or the mechanized technology constitutes a (weakly) dominant strategy for a landowner. Hence, the existence of multiple investment equilibria is robust to any price subsidies proposed by the policy-maker. This outcome reflects how the absence of policy commitment can lead to a political failure – with the same set of policy instruments, a policy-maker who could commit to less than complete redistribution, could have delivered a Pareto superior outcome for the economy.

4 Discussion

In this paper we identify how a coordination failure among investors in the agricultural sector can limit industrialization in this sector, and in linked sectors. We also find that the mechanization of agriculture creates both winners and losers. The distributional consequences of technological change affect the policies chosen by an elected policy-maker. In the absence of policy commitment, government led coordination is likely to be ineffective or leave some citizens worse off.

We assume all workers are equally suited to working in either the agricultural or industrial sectors. Papers such as Caselli (1999) suggest that, in reality, labor may be heterogenous with skilled and unskilled labor benefitting differentially from the introduction of new technologies. A natural way of allowing for labor heterogeneity would be to assume that only a subset of workers can work in the industrial sector and that labor in the industrial sector earns a wage premium. This would imply another source of pecuniary externalities in the economy and the economy would continue to exhibit multiple investment equilibria.[22] Finally, our findings on the political economy of coordination would continue to hold as technological change continues to leave some citizens, here unskilled labor, worse off.

The choice of the mechanized technology (partially) substitutes industrial input for labor. It, however, does not allow for substitution away from land towards manufactures. A natural justification is that land is essential for growing food. However, it could be that a mechanized technology allows the same amount of food to be produced on less land, say via multi-cropping. To account for this our agricultural production function could be generalized to allow the industrial input and land to be substitutes. This will potentially reduce the gains for landowners associated with adoption of the

[22]This wage mechanism is similar to the source of pecuniary externalities that underlies the multiplicity of equilibria in Murphy, Shleifer and Vishny (1989b)

mechanized technology. However, as long as the wage reduction associated with the adoption of the mechanized technology was sufficient the landowners' would continue to earn higher profits with manufactures, and our findings in this paper would hold.

The political economy of coordination has received limited attention in the literature, in part because most models of coordination failure consider an economy populated by individuals with identical endowments. Our findings demonstrate that once we move to a setting with heterogenous agents, the political economy of coordination is central to understanding the choice of policies. Perhaps most striking is our finding with decentralized investment decisions a policy-maker belonging to the group whose factor returns are adversely affected by technological change cannot affect coordination. Moreover, the reason for this is her inability to commit to not redistribute income in favor of her group.

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5 Appendix

Proof of Proposition 1

From equation (1) $p_\tau = w_\tau$. This, combined with the wage equation (equation (3)), gives:

$$n_b = \frac{L-1}{x} \quad \text{and} \quad n_m = \frac{L-\gamma}{x} \tag{9}$$

$\gamma < 1 \Rightarrow n_m > n_b$. Hence, the number of industrial varieties produced is strictly higher with the mechanized technology.

Proof of Proposition 2

By assumption $\pi_b > 0$. Consider an equilibrium in which all landowners choose the basic technology. In equilibrium all landowners make a positive profit. This equilibrium is Nash if, conditional on all other landowners' choosing the mechanized technology, it is not profitable for any single landowner to choose the mechanized technology. This is true iff $\beta_j \pi_b \geq \beta_j \pi_m$ or

$$1 - w_b \geq 1 - \gamma w_b - \kappa P_b$$

Substituting for w_b and P_b, an equilibrium in which all landowners choose the basic technology exists if

$$\frac{\kappa}{(1-\gamma)} \geq n_b{}^{\frac{1}{(\varepsilon-1)}} \tag{10}$$

Now consider an equilibrium in which landowners choose the mechanized technology. Landowner j will not deviate to investing in the basic technology iff $\beta_j \pi_m \geq \beta_j \pi_m$ or

$$(1 - \gamma w_m - \kappa P_m) \geq (1 - w_m)$$

which simplifies to

$$\frac{\kappa}{(1-\gamma)} \leq n_m{}^{\frac{1}{(\varepsilon-1)}} \tag{11}$$

Comparing (10) and (11) and noting that $n_m > n_b$ implies that the economy is characterized by multiple investment equilibria if

$$n_b^{\frac{1}{(\varepsilon-1)}} \leq \frac{\kappa}{(1-\gamma)} \leq n_m^{\frac{1}{(\varepsilon-1)}} \tag{12}$$

Further, equations (10), (11) and (12) imply a unique equilibrium in which landowners invest in the basic technology if

$$\frac{\kappa}{(1-\gamma)} > n_m^{\frac{1}{(\varepsilon-1)}}$$

and a unique equilibrium in which landowners invest in the mechanized technology if

$$\frac{\kappa}{(1-\gamma)} < n_b^{\frac{1}{(\varepsilon-1)}}$$

Proof of Lemma 1

The mechanized technology maximizes social surplus if $P_b > P_m$ or

$$\kappa < x(n_m^{\frac{\varepsilon}{\varepsilon-1}} - n_b^{\frac{\varepsilon}{\varepsilon-1}}) \tag{13}$$

Combining (12) and (13) it follows that the mechanized technology maximizes social surplus in the M.E. regime if

$$x(n_m^{\frac{\varepsilon}{\varepsilon-1}} - n_b^{\frac{\varepsilon}{\varepsilon-1}}) > (1-\gamma)n_m^{\frac{1}{(\varepsilon-1)}}$$

Rearranging this expression gives:

$$\frac{n_m^{\frac{\varepsilon}{\varepsilon-1}} - n_b^{\frac{\varepsilon}{\varepsilon-1}}}{n_m^{\frac{1}{\varepsilon-1}}} > \frac{1-\gamma}{x} \tag{14}$$

Note that $\frac{1-\gamma}{x} = \frac{(L-\gamma)-(L-1)}{x} = n_m - n_b$. Substituting in (14) and solving gives

$$n_m^{\frac{1}{\varepsilon-1}} > n_b^{\frac{1}{\varepsilon-1}} \tag{15}$$

Equation (15) always holds. Hence, the mechanized technology maximizes social surplus in the multiple equilibria regime.

Proof of Proposition 3

In the multiple equilibria regime $p_m < p_b$. To see this note $P_m < P_b$ (from Lemma 1). Further from proposition 1 we know that $n_m > n_b$. It follows that, since $P_\tau = n_\tau^{\frac{1}{1-\varepsilon}} p_\tau$ a necessary condition for $P_m < P_b$ is $p_m < p_b$.

We first show that the mechanized technology raises landowners' indirect utility, but reduces workers. That is:

$$\frac{Lw_m}{N-k} P_m^{-(1-\nu)} < \frac{w_b L}{N-k} P_b^{-(1-\nu)} \quad \text{and} \quad \frac{\pi_m}{k} P_m^{-(1-\nu)} > \frac{\pi_b}{k} P_b^{-(1-\nu)} \tag{16}$$

Equation (16) simplifies to

$$w_m P_m^{-(1-\nu)} < w_b P_b^{-(1-\nu)} \quad \text{and} \quad ; \pi_m P_m^{-(1-\nu)} < \pi_b P_b^{-(1-\nu)}$$

$P_b > P_m($ from Lemma 1). Therefore, a necessary condition for $w_m P_m^{-(1-\nu)} < w_b P_b^{-(1-\nu)}$ is that $w_m < w_b$. Importantly this is also sufficient. To see this first note that $w_\tau = p_\tau . w_m P_m^{-(1-\nu)} < w_b P_b^{-(1-\nu)} \Rightarrow \frac{P_m^{(1-\nu)}}{p_m} > \frac{P_b^{(1-\nu)}}{p_b} \Rightarrow$

$$n_m^{(1-\nu)(\varepsilon-1)} p_b^v > n_b^{(1-\nu)(\varepsilon-1)} p_m^\nu \tag{17}$$

Since $n_m > n_b$ and $p_b > p_m$ this inequality (17) always holds. Further a sufficient condition for $\pi_m P_m^{-(1-\nu)} > \pi_b P_b^{-(1-\nu)}$ is that $\pi_m > \pi_b$. Therefore if $w_m < w_b \Rightarrow \pi_m > \pi_b$ then equation (16) always holds.

$\pi_b < \pi_m$ holds if $(\gamma w_m + \kappa P_m) < w_b$. This simplifies to $(\gamma + \kappa n_m^{\frac{1}{1-\varepsilon}}) w_m < w_b$. Therefore

$$w_m < w_b \quad \text{and} \quad ; \pi_m > \pi_b \tag{18}$$

if $\max\left[w_m, (\gamma + \kappa n_m^{\frac{1}{1-\varepsilon}}) w_m\right] < w_b$. Clearly if $(\gamma + \kappa n_m^{\frac{1}{1-\varepsilon}}) < 1$, then the sufficient condition for (18) is $w_m < w_b$.

$(\gamma + \kappa n_m^{\frac{1}{1-\varepsilon}}) < 1 \Rightarrow \kappa < (1-\gamma) n_m^{\frac{1}{\varepsilon-1}}$. This condition always holds in the multiple equilibrium regime. Hence, $w_m < w_b \Rightarrow \pi_m > \pi_b$.

By assumption $\frac{\pi_b}{k} > \frac{w_b L}{N-k}$. It follows that a worker's income must be less than the per capita income i.e. $\frac{w_b L}{N-k} < \frac{1}{N\nu}$. From proposition 3 we also know that $\frac{\pi_m}{k} > \frac{\pi_b}{k}$ and $\frac{w_m L}{N-k} < \frac{w_b L}{N-k}$. Hence $\frac{\pi_m}{k} > \frac{w_m L}{N-k}$.

It follows that a landowner, if elected, will select the mechanized technology and no redistribution. A worker maximizes her indirect utility by selecting the mechanized technology and undertaking full redistribution, such that the post tax-transfer income of a citizen equals the per capita income of the economy – $\frac{1}{N\nu}$. Landowners are better off, if

$$\frac{\pi_b}{k} P_b^{-(1-\nu)} < \frac{1}{Nv} P_m^{-(1-\nu)}$$

This expression simplifies to

$$\frac{k}{N} > \frac{\nu L - 1}{L - 1} \left(\frac{P_m}{P_b}\right)^{(1-\nu)} \tag{19}$$

This inequality cannot hold if

$$\frac{\nu L - 1}{L - 1} \left(\frac{P_m}{P_b}\right)^{(1-\nu)} > \frac{1}{2}$$

as a worker would never be elected in that case. Hence, landowners are worse off whenever

$$\left(\frac{P_m}{P_b}\right)^{(1-\nu)} > \frac{1}{2} \left(\frac{L-1}{\nu L - 1}\right)$$

A sufficient condition for this is that

$$\frac{1}{2} \left(\frac{L-1}{\nu L - 1}\right) < 0$$

which simplifies to

$$L > \frac{1}{2\nu - 1}$$

which holds under our large economy assumption.

Fig. 1 Capital - Labour Ratio (No. of Threshers, Tractors & Harvesters used per 100 Agricultural Labour Force) [1]

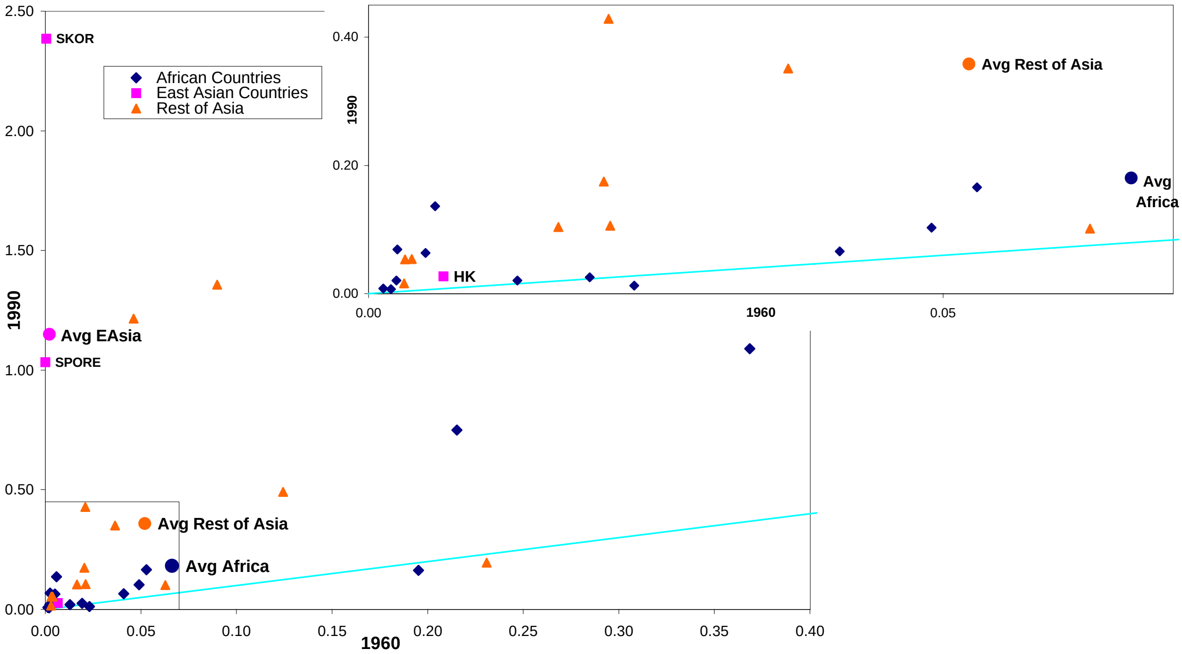
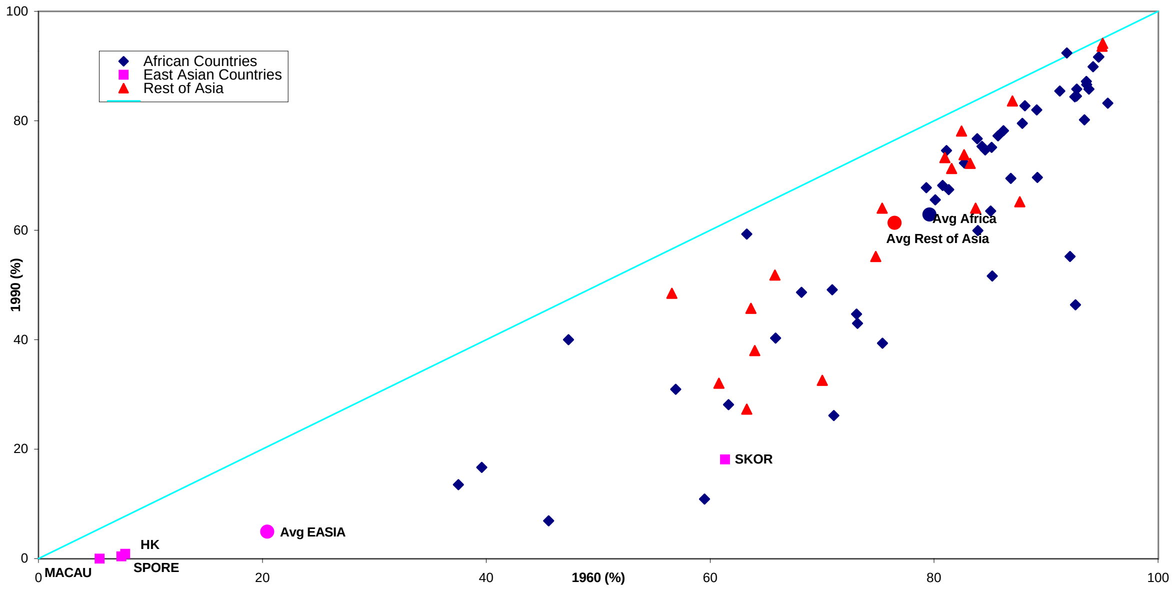


Fig. 2 Share of Agricultural Labour Force [2]



1. Data Source: Food & Agricultural Organisation (FAO) website http://www.fao.org. The capital-labour ratio of 1960 is the no. of threshers, tractors & harvesters used in 1961 divided by the agricultural labour force in 1960. The ratio of 1990 is derived from data in 1990. The countries studied are:

African Countries:	Central African Republic, Chad, Congo Republic, Egypt, Ethopia PDR, Gambia, Ghana, Côte dIvoire, Kenya, Mali, Mauritania, Morocco, Senegal, Sudan, Uganda
East Asian Countries:	Hong Kong, Singapore, South Korea
Rest of Asia:	Bangladesh, China, India, Indonesia, Laos, Malaysia, Myanmar, Nepal, Pakistan, Philippines, Sri Lanka, Thailand, Vietnam

2. Data Source: FAO website (see footnote 1). The share of agricultural labour force is defined as the percentage of total labour force engaged in agricultural production. The countries studied are:

African countries:	Algeria, Angola, Botswana, Benin, Burundi, Cameroon, Cape Verde, Central African Republic, Chad, Comoros, Congo Republic, Congo Dem Republic, Egypt, Eq Guinea, Ethopia PDR, Gabon, Gambia, Ghana, Guinea, Côte dIvoire, Kenya, Lesotho, Liberia, Libya, Madagascar, Malawi, Mali, Mauritania, Mauritius, Morocco, Mozambique, Nambia, Niger, Nigeria, GuineaBissau, Réunion, Rwanda, Senegal, Sierra Leone, Somalia, South Africa, Sudan, Swaziland, Tanzania, Senegal, Sierra Leone, Somalia, South Africa, Sudan, Swaziland, Tanzania, Togo, Tunisia, Uganda, Burkina Faso, Zambia, Zimbabwe
East Asian Countries:	Hong Kong, Macau, Singapore, South Korea
Rest of Asia:	Bangladesh, Bhutan, Cambodia, China, East Timor, India, Indonesia, Korea DPR, Laos, Malaysia, Maldives, Mongolia, Myanmar, Nepal, Pakistan, Philippines, Sri Lanka, Thailand, Vietnam