Technological Development in a Dual Economy: Alternative Policy Levers for Economic Development

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Abstract

A system dynamics model of a dual economic system incorporating also the behavioral responses to competition and the ability to innovate on the part of the formal and self-employed sectors is developed and used as an experimental apparatus to search for technology-related entry points for achieving economic growth and changing income distribution. Policies to promote competition among the monopolistic formal firms while simultaneously providing positive assistance to the competitive informal firms appear to offer promising alternatives to the traditional fiscal policy levers mainly affecting prices and factor costs.

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Introduction

The studies on sources of economic growth conducted in the developed countries show that growth from technological change is significant. For the US economy, the works of Abramovitz (1956), Solow (1957), Denison (1962), Griliches (1963), although different in many ways with respect to time-period, coverage and basic methodology, concur that a large portion of the long-term growth in per capita output is accounted for not by an increasing quantity of capital and labor inputs, but by the rise in productivity attributed to technological change. This broad conclusion was further refined by Denison (1985), who unpacked technological change into a number of components. Denison estimated that only a quarter of the increase in output could be attributed to increased labor input of constant educational level, while another 16 percent was credited to the increased educational qualifications of the average worker. The growth of capital accounted for only 12 percent of the growth of output, which confirmed a similar earlier finding by Solow (1957), 11 percent came from improved allocation of resources, another 11 percent from economies of scale and a hefty 34 percent from the growth of knowledge or technological change in a narrow sense. Although these conclusions should have called for the economic development theories to consider technological change carefully as a policy lever, it has found limited use in the past. On the contrary, development planning in the developing countries has mainly sought to transfer technology from the developed countries rather than nurture its indigenous development. A few limited attempts have been made to create a climate conducive to indigenous technological growth and self-reliance, often through building science and technology parks, developing educational and training institutions, building industrial research organizations and providing financial support for the private sector research and development projects, imitating largely similar efforts in the industrialized countries[Choi 1984, 1986, 1989, Chatterji 1990, Subramanian 1987, Celso 1989]. A large variability has been experienced in the performance of such initiatives.

Using a formal system dynamics model of a dual economic system also incorporating mechanisms of technological development, this paper explores the possibility of commissioning technology development instruments for affecting economic growth and influencing income distribution. The formal model offers an opportunity to experiment with the various technology policies proposed and implemented in the past and to understand their performance under laboratory conditions. This experimentation helps to explain the variability of performance of the technology policy experienced, also pointing toward the critical elements for a successful policy framework. Policy guidelines are outlined for an effective technology-based intervention.

A system dynamics model of technological development in a dual economy

The information structure of the proposed model is adapted from a model of wage determination and income distribution developed by Saeed (1980). Saeed's original model draws on neo-classical economics to construct a basic structure for growth and market clearing, and modifies it further by relaxing its simplifying assumptions about aggregation of sub-economies, saving and investment behavior, and wage determination. The model proposed in this study further relaxes the assumption of absence of technological growth used by Saeed. Technological growth in the modified model occurs through investment in technological development motivated by competition between the two production sectors and facilitated by respective financial abilities. The modified model also formalizes the renting process through the introduction of a formal renting sector representing the economy of absentee owners receiving income from renting out capital. An overview of this model is shown in figure 1.

Both formal and self-employed production sectors in the model carry out production using capital, workers, technology embodied in capital and technology embodied in workers. Therefore, the capacity of a production sector is determined not only by the capital and labor it employs but also by the level of technology embodied in each. Capital investment is driven by profitability which is given by the marginal revenue product of capital and the interest rate, and financial capability which is given by liquidity [McKinnon 1973, Barro 1984]. Workers can be

self- employed. Wage workers are hired depending on the marginal revenue product of workers and the average wage rate. Workers unable to find wage employment are absorbed in the self-employed production sector. The average wage rate is set not according to the average marginal revenue product of workers as postulated in the neoclassical models of economic growth, but according to the bargaining power of the workers which depends on the opportunity cost of a worker to leave self-employment, given by the average consumption expenditure per worker [Sraffa 1960, Sen 1966].

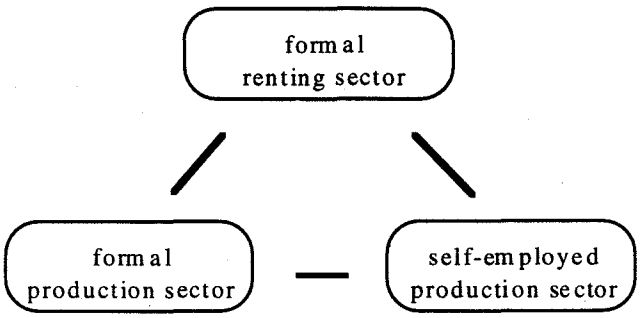

Figure 1 An overview of the model

Technology embodied in capital is the integration of the technology embodied in each unit of capital employed by a production sector. The technological level of capital of a production sector is calculated by the total amount of technology embodied in its capital divided by the capital. Technology embodied in workers is calculated similarly for each sector. When a worker moves from one sector to the other, the worker embodied technology is concomitantly transferred. Technology embodied in capital and workers can be increased through innovation and learning rates, which are determined by the technological capabilities of the respective sectors and their investment in technology [Dosi 1988, Mansfield 1971]. The pressure to invest in technology is determined by market competition. A firm must innovate to improve its productivity to function in a competitive market. However, when a firm has a monopoly, it does not have to innovate since its profitability is already high [Kamien and Schwartz 1982, Auerbach 1988]. The other factor which greatly affects the investment in technology is the production sector's financial muscle. A high liquidity makes a production enterprise capable of taking the risk involved in the investment in technology [Dosi 1988]. The literature on diffusion of innovation also suggests that the size of investment for the adoption of innovations affects the rate at which it diffuses [Mansfield 1971]. This implicitly means that a production enterprise may not be able to adopt an innovation because it does not have enough cash to invest in technology.

Cash balance determines the liquidity of a sector. A shortage in the cash balance of a sector can defer the investment expenditures it might be warranted to make on the basis of economic criteria. Cash balance of each production sector is increased by its revenue and borrowings and decreased by the investment, debt payments and consumption of savings. The output of each production sector, determined by the demand and the production capacity, goes to its inventory from which sales are made. The price of output of a production sector depends on goods availability in the economy as well as the quality of the sector's output, which is determined by the technology used in its production [Betz 1987]. All workers, whether self- or wage- employed are assumed to maximize their consumption. On the other hand, the capitalists are assumed to maximize profit [Sen 1966, Averitt 1968, Applebaum, 1979]. In maximizing profit a capitalist can transfer his assets to production or renting activities.

All types of renting are interpreted in the model into equivalent financial terms through borrowing and deposit activities carried out through an invisible bank. The production sectors have debt accounts at the bank while the formal renting sector has a deposit account. Cash balance of the bank is increased by the deposit rate and interest income and decreased by consumption expenditure and withdrawal rate. The renting capitalists can put their excess cash into deposit or can withdraw their deposit when they are short of cash. The bank balances these accounts by setting the interest rate. The bank always balances the debts and deposits and makes

no charges, i.e. the total interest payments received from the borrowers are transferred in whole to the depositors. It should be recognized that the model is not concerned with the relationship between the banking system and the creation of money, but rather tracks the net deposits and borrowings of each sector in the economy. Technical detail of the model are available from the authors on request.

Model behavior and the history of technological performance of developing countries

The historical analysis of the model behavior consists of two parts. The first part explains the occurrence of feudalism, which prevailed in the history of most developing countries when modern technologies were not available. In the second part, the model is used to replicate the behavior of the present-day technological and economic systems this study is concerned with.

a) Economy with no modern technology: the occurrence of feudalism

Before modern technologies became available to the developing countries, their economies were predominantly feudalist with most of the resources owned by a small number of capitalists. Most production was carried out by self-employed workers who had to rent resources from the capitalists. The distribution of income in such economies was highly unequal. In order to see how the model can generate such economic conditions, following simulation experiment is set up.

A neoclassical equilibrium is created in the model with the assumptions that the economy is fixed and without technological differentiation between the two sectors, wage rate is determined by the marginal revenue product of workers, renting is not allowed so that the initial values of deposit and debt are zero. As an arbitrary initial condition, the two production sectors are allowed to have an equal share in the production of the economy. This equilibrium also requires that the marginal revenue products of capital and worker be the same in the two production sectors and equal to their corresponding factor costs. Further, the total demand for production of output equals the production capacity of the economy and all revenues and expenditures are in balance. The equilibrium of the model is disturbed by modifying the wage and rent assumptions at year 5. The wage rate is switched t o be determined by the average consumption expenditure per worker and renting is allowed. The result of the simulation are shown in Figure 2. After the wage and rent assumptions are modified, the formal production sector gradually shrinks in size while the formal renting sector expands. In the final equilibrium, all production of the economy is carried out by the self-employed using rented resources.

Since average consumption expenditure of workers includes entitlements both from value additions by labor and capital, a wage based on it exceeds the marginal revenue product of workers in the formal production sector when wage and rent assumptions are modified. This causes a decrease in the profitability of workers in this sector, prompting it to lay off workers, who are accommodated in the self-employed production sector. However, as the profitability of production activity decreases due to the decrease in the rate of return in the formal production mode, the profitability of renting activity increases in the capitalist sector since the increase in the workforce of the self-employed sector generates an increasing demand for renting resources, this also causing an increase in the interest rate. Therefore, the capitalists transfer their investment from production activity to renting activity, which appears in the model as deposits available for lending. Since an increase in production caused by the expanding self-employed workforce inflates the marginal revenue product of capital, the need for capital in the self-employed sector rises, which necessitates borrowing as the cash resources of this sector are limited. Thus, the debt of the self-employed sector increases.

These spiraling actions allow gradual adjustment of workers, capital and debt of the two production sectors, and the deposit of the formal renting sector. In the long run, the formal production mode dies out. However, since renting is allowed, the production capitalists in the formal production sector transfer all their assets to the renting activity. From the above explanation it can be seen that feudalism emerges due to the distortion in the labor market arising from the way the wage rate is determined by the average consumption expenditure per worker, the requirement of self-finance for investment and the availability of renting activity which allows the capitalists to earn their living from renting out their assets.

b) Economy with modern technology: the appearance of dualism

In this experiment the model is used to replicate the development of the dual technological and economic systems widely experienced in the developing countries after economic development effort began. The simulation of the base case is generated by stepping up the ambient level of technology in the formal production sector while also allowing the population to grow after the end conditions of the simulation of Figure 2 have been reached, and simulating further.

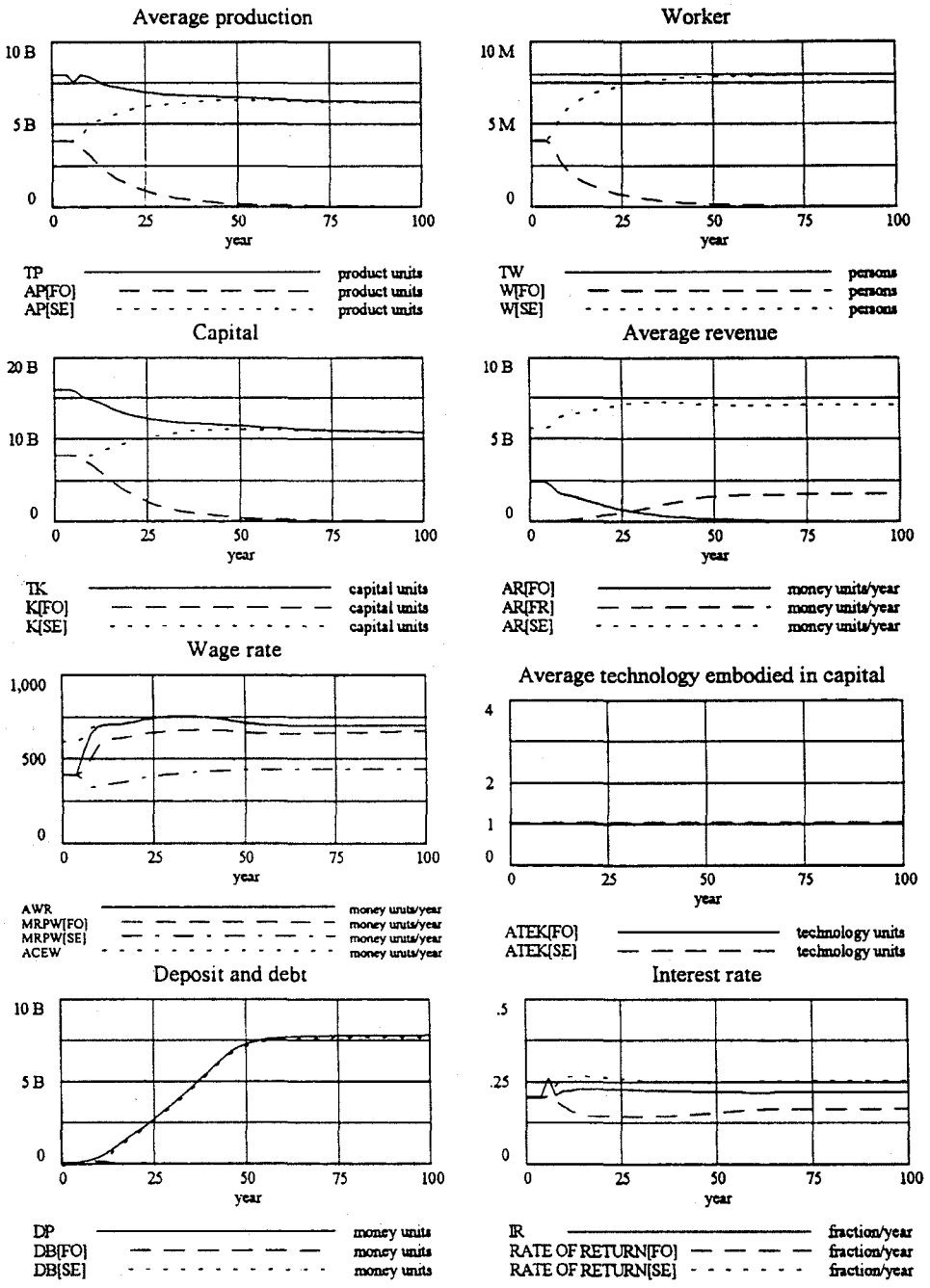

Figure 2 Occurrence of feudalism

The formal production sector is also assumed to have a higher capability to innovate than the self-employed sector on account of its better resource position. These changes represent introduction of modern technologies for the formal production mode. All other parameters and behavioral relationships remain unchanged. The results of this simulation are shown in Figure 3. The total output of the economy rises, although the average technology embodied in capital stagnates in both production sectors. Also, the relative size of the formal production sector expands while that of the self-employed sector is reduced. The availability of modern technology offers an opportunity to both sectors to improve their productivity. The formal production sector, which has a high pressure to innovate due to the prevailing unprofitability, affects an increase in the average technology embodied in its capital and also in its workers. The self-employed production sector also attempts to upgrade its technology but is limited both by its ambient poor technological capability and financial constraints.

For the formal production sector the increase in the average technology embodied in the capital causes an increase in the marginal revenue product of both workers and capital, which causes its size to expand. The increase in the technology of the formal production sector also induces an increase in the profitability of the production activity compared to the renting activity so the capitalists in the formal renting sector tend to transfer more resources to invest in the formal production mode.

For the self-employed production sector, the rate of increase in the average technology embodied in capital is slow compared to the formal production sector. Therefore, its production efficiency and quality are also low. The marginal revenue products of workers and capital in this sector decrease, which causes its size to decline, also further decreasing its liquidity. The decrease in the liquidity cannot be checked by borrowing since the size of the available collateral also declines, which suppresses the self-employed investment in technology and hence its innovation rate. Thus, the average technology embodied in the capital of the self-employed sector will further lag behind that of the formal production sector. The decrease in the production output of the self-employed also decreases the income share of the workers which reduces the average consumption per worker. This suppresses wage rate also in the formal sector.

Both the decrease in the wage rate and the increase in the average technology embodied in the capital of the formal production sector fuel expansion in the production of the formal sector. The spiraling action of these changes allows gradual adjustment of the workers, the capital, the debt of the two production sectors and the deposit of the formal renting sector in a way that the formal production mode expands, while the self-employed mode declines. However, as the profitability in the formal production sector rises, the pressure to innovate declines and the investment in technology is neglected. In the self-employed sector the investment in technology is low any way due to the constraint from its liquidity position. Hence, the aggregate technological capability is also restricted.

Technology policy as an alternative lever for economic development

The policies proposed to address technological and economic stagnation in the developing countries fall into three broad categories: 1) Building institutions and infrastructure to upgrade technological ability of production units; 2) Mobilizing funds for technology-related investments; and 3) Creating indirect incentives for upgrading technology in the production units [Choi 1984, 1986, 1989, Chatterji 1990, Celso 1989]. These policies have often not differentiated between the two production sectors suggested in the model, which could be one of the reasons why their performance is varied. The experiments in this sections of the paper attempt to understand the variability of the performance of these policies, also attempting to identify guidelines for an effective technological development plan that should serve as an alternative to the traditional direct and indirect instruments for economic development.

The efficacy of each tested policy is evaluated by comparing its results with the base case in Figure 3. The criteria for this comparison are the output labor ratio, the average production, the average revenue share of the self-employed production sector, and the average wage rate at constant prices compared at the end of the simulation. The first two criteria represent growth in technology and production of the overall economy, the remaining two indicate how evenly the growth is distributed. The policies to upgrade technological capability of the production sectors (1, 2) represent strategies for human resources development often sought through technical education and training, and technological infrastructure development attempted through private

and public sector institution building for assisting production units in adopting sophisticated technologies. This policy is simulated by stepping up the normal fractional innovation rate and the normal fractional worker learning rate in each production sector after the system has settled into a dual mode.

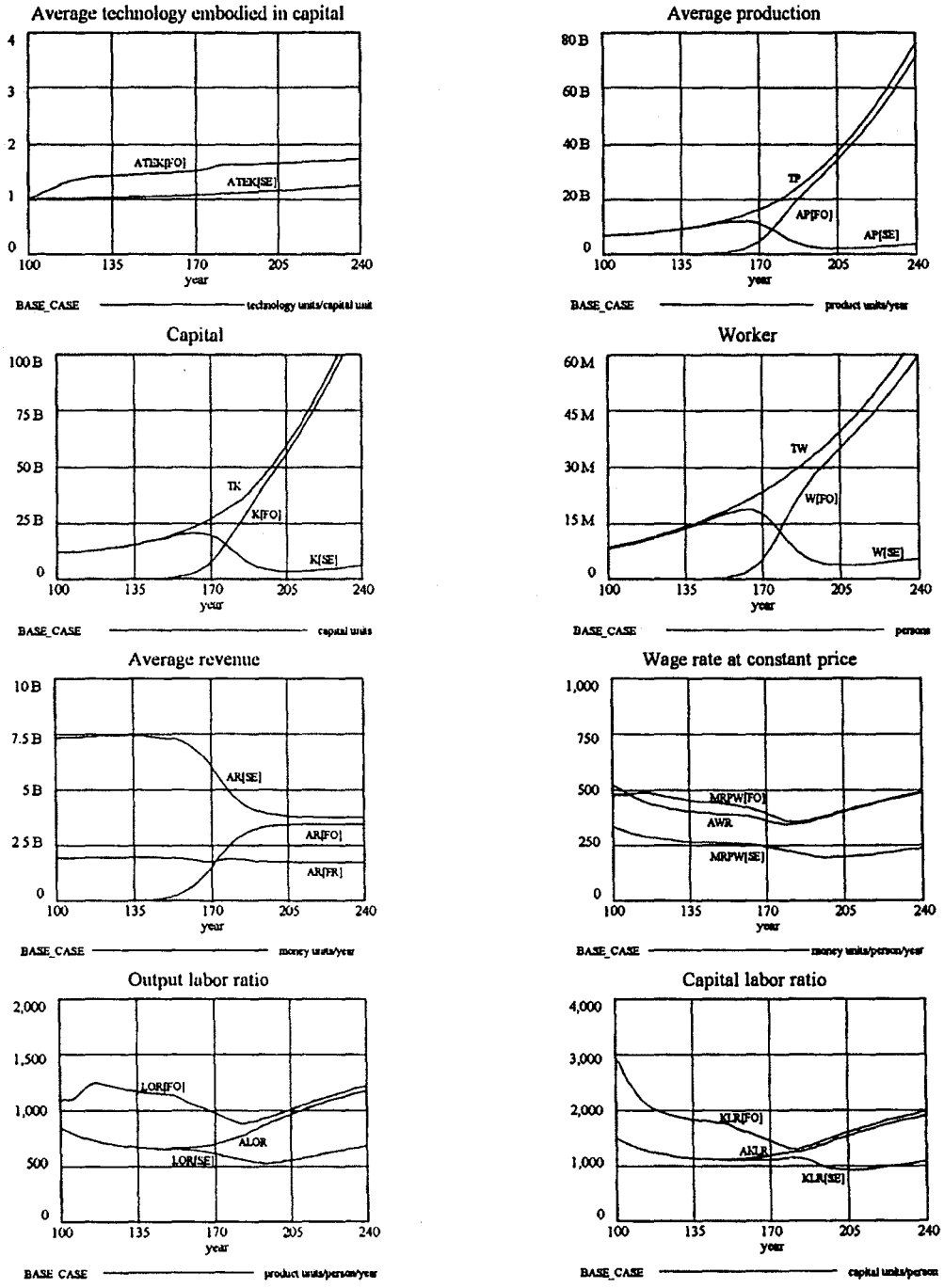

Figure 3 The emergence of a dual economy: the base case

The policies for mobilizing funds for technology-related investments (3, 4) translate into providing loans for technological investment through special banks and financial ins tions mobilizing venture capital. This policy is simulated in the model by relaxing liquidity co raints on technological investments of the production sectors. The policies to increase pressure on the production sectors to improve technology (5, 6) represent measures to promote market competition. In practice, this is accomplished by facilitating market entry through investment promotion in certain industries, providing market information to the consumers and educating consumers on product specification. These policies can increase the pressure on the production sectors to improve their technology, for which they must increase their investment in technological activities. This policy is simulated in the model by increasing the pressure to innovate and the pressure on worker learning rate of each production sector.

Policy runs 7, 8, 9 represent experimentation with fiscal instruments found critical to changing income distribution in Saeed (1988). These include taxation of rent income, with and without applying the collection to the worker-run activities. The rent income tax policy is simulated in the model by deducting a tax equal to 20 % of the rent income from the revenue of the formal renting sector, which reduces the rate of return on renting activity. Policy run 10 combines the policy to tax rent income with the financing of the technological investment and upgrading technological capability of the self-employed production sector. Finally, policy run 11 simulates the financing of the technological investment and upgrading technological capability of the self-employed production sector through an income rather than a rent tax in an effort to explore the efficacy of selective technology development policy without penalizing unearned income. Table 1 summarizes the results of the experimentation.

Table 1 End conditions (at time 240) of policy runs compared to base case run

Policy run	Output labor ratio (units/person/year)		Capital labor ratio (units/person)		Fraction worker	Wage rate	Average production (billion units/year)			Worker income share
	(fo)	(se)	(fo)	(se)	self-emp.		(fo)	(se)	Total	
Base case	1217 (1.00)	673 (1.00)	1965 (1.00)	1073 (1.00)	.08	486 (1.00)	71.3 (1.00)	3.6 (1.00)	74.9 (1.00)	.42
1.Upgrading technological capability of formal production sector	1309 (1.08)	644 (0.97)	2081 (1.06)	1019 (0.95)	.07	521 (1.07)	77.8 (1.09)	2.8 (0.78)	80.6 (1.08)	.41
2.Upgrading technological capability of self-employed production sector	1284 (1.06)	879 (1.31)	2069 (1.05)	1394 (1.30)	.15	509 (1.05)	70.0 (0.98)	8.2 (2.28)	78.2 (1.04)	
3.Mobilizing fund for technology related investment of formal production sector	1229 (1.01)	669 (0.99)	1980 (1.01)	1066 (0.99)	.08	485 (1.00)	72.1 (1.01)	3.5 (0.97)	75.6 (1.01)	
4.Mobilizing fund for technology related investment of self-employed production sector	1892 (1.55)	1476 (2.19)	2850 (1.45)	2352 (2.19)	.32	742 (1.53)	80.8 (1.13)	30.2 (8.39)	111.0 (1.48)	.50
5.Increase pressure to improve technology of formal production sector	4097 (3.37)	385 (0.57)	5359 (2.73)	589 (0.55)	.03	1536 (3.16)	247.7 (3.47)	.8 (0.22)	248.5 (3.32)	.41
6.Increase pressure to improve technology of self-employed production sector	1217 (1.00)	673 (1.00)	1965 (1.00)	1073 (1.00)	.08	481 (0.99)	71.3 (1.00)	3.6 (1.00)	74.9 (1.00)	.42
7.Taxing rent income	1315 (1.08)	639 (0.95)	2121 (1.08)	1012 (0.94)	.07	524 (1.08)	78.2 (1.10)	2.8 (0.78)	81.0 (1.08)	.43
8.Taxing rent income and giving the tax collected to the workers	1572 (1.29)	672 (1.00)	2541 (1.29)	1042 (0.97)	.22	634 (1.30)	78.0 (1.10)	9.5 (2.64)	87.5 (1.17)	.47
9.Taxing rent income and financing the technological investment of the self-employed production sector	1932 (1.59)	1460 (2.17)	2946 (1.50)	2325 (2.17)	.31	782 (1.61)	83.3 (1.16)	29.3 (8.14)	112.6 (1.50)	.51
10.Combination of policies: Taxing rent income and financing the technological investment of the self-employed production sector and increasing the technological capability of the sector	5188 (4.26)	4204 (6.25)	7494 (3.81)	6174 (5.75)	.76	2174 (4.47)	78.2 (1.10)	198.0 (55.00)	276.1 (3.69)	.70
11.Combination of policies: Taxing all income and financing the technological investment of the self-employed production sector and increasing the technological capability of the sector	4782 (3.93)	4021 (5.97)	6838 (3.48)	5921 (5.52)	.84	1975 (4.06)	47.6 (0.67)	210.0 (58.33)	257.6 (3.44)	.72

(The numbers in the brackets are the relative magnitude to the base case)

Table 1 shows both the actual values and those relative to the base case. Many of the policies experimented with do not cause much improvement by the defined criteria when compared to the base case . The ineffective policies include attempts to upgrade technological capability of either production sector (1,2), mobilization of funds for technology-related investment for the formal production sector (3), increasing pressure on the self-employed production sector to improve technology (6), taxing rent income (7), and taxing rent income and transferring the collection to the self-employed (8). The table shows that the output labor ratio, the average production, the worker income share, and the wage rate are not improved much in these cases except in policy run (8) that creates some rise in the wage rate and the income share of the workers, although with a stagnating output.

Attempts to increase the technological ability are defeated for the formal producti sector by its lack of competitiveness (1) and for the self-employed sector due to its financial co raints

(2). Since, liquidity is not a constraint for the formal sector, financial assistance for its technological activity (3) does not accomplish much. Likewise, since self-employed lack finance rather than motivation to fuel technological activity, pressuring them further to invest in technology (6) is pointless. Taxing rent income appeared to be critical to changing income distribution in Saeed's original model in which he defined the technological differential between the two sectors exogenously but its effect is much diluted in policy run (7) of the modified model which endogenizes technological growth process. This is not surprising in view of Saeed's extended experimentation with the parameters representing technological differential between the two sectors which appeared to dilute the impact of this policy on income distribution [Saeed 1994]. When technological development is endogenized, penalizing unearned income will cause adjustment in the technological differential between the two sectors while maintaining status quo in income distribution. The policy to tax rent income and subsidize the workers with the collection (8) increases liquidity of the self-employed production sector, but cannot fuel technological development substantially since that sector has a priority for maximizing consumption rather than making technological investments.

The promising policies include mobilization of funds for technology-related investment of the self-employed production sector (4), increasing pressure on the formal production sector to improve technology (5), and taxing rent income and using the collection to finance the technological investment of the self-employed production sector (9). These policies result in significant improvements in all criteria, namely output-labor ratio, average production, wage rate and worker revenue share, except in policy run 5 where the worker revenue share is slightly decreased when compared to the base case. The policy to mobilize funds for technology related investment of the self-employed production sector (4) is effective since it relaxes the financial constraint on the technological activity of the competitive sector. The resulting increase in the productivity of the self-employed sector also gives the workers a greater bargaining power which leads to an increase in the wage rate. At the same time, an increase in the technology used by the self-employed also increases the pressure on the formal production sector to innovate and improve the technology used in its own production. In the end, labor productivity and capital intensity rise in both sectors.

The policy to increase pressure on the formal production sector to improve its technology (5) significantly improves all criteria except the worker income share since it largely stimulates the growth of the formal sector, without affecting wage rate, ownership distribution or worker income share. The policy to tax rent income and finance the technological investment of the self-employed production sector (9) significantly affects both economic growth and income distribution by increasing competitiveness as well as changing income distribution.

Policy run 10, which combines policy runs 2 and 9, shows that the former policy further facilitates the changes set into motion by the later although by itself, policy 2 is ineffective. An increased pressure on the self-employed to innovate in the presence of reduced financial constraints on technological investment yields significant improvements. The taxation of rent income alone (7) did not appear to be effective for redistributing ownership in the extended model since adjustments in technological differential were able to maintain existing ownership pattern, while instruments providing preferential incentives and facilitation for technological development created the primary forces for change. This led to experimenting with policy package 11 which is similar to policy package 10 except that it finances the self-employed through a tax on aggregate income instead of one penalizing unearned income.

The performance of Policy Package 11 is almost as good as policy package 10, which confirms that technology policy instruments might be as effective as fiscal incentives and disincentives for affecting changes in income distribution. It should be added that there might appear considerable resistance to implementation of fiscal instruments selectively penalizing economic actors in view of the interest group involvement in the decision process [Burki 1971, Alavi 1976]. On the other hand, technology-related instruments may not arouse as much adversarial response since these may not be seen to be directly linked with the various forms of income generation activities.

Conclusion

The developing country economies have been observed to incorporate two equally significant production modes: a profit maximizing formal sector and a consumption maximizing self-

employed sector. Yet, only their formal sectors have been targeted for much of the economic and technological development effort. On the other hand, although the developed country economies consist predominantly of profit maximizing firms but their small self-employed sectors are often targeted for assistance for technological development.

Having accounted for a significant part of economic growth in the industrialized countries, technological development instruments offer a good promise also for the developing countries for accelerating economic growth and affecting income distribution. These instruments, however, remain underutilized. Even when used, they often disregards the dual structure of the developing country economies whose relations must be understood for creating any effective policy designs.

This paper has attempted to explore the efficacy of technology policy for the developing countries using a system dynamics model of economic growth, income distribution and technological growth building on an earlier model developed by Saeed. Experimentation with this model shows that technological development related instruments might offer a promising alternative to the traditional direct and indirect policy levers used for fostering economic growth and influencing income distribution.

It is observed, however, that for a technological development initiative to successfully facilitate growth and influence income distribution, it must attempt to promote competition among the monopolistic formal firms while providing positive assistance to the competitive informal firms.

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