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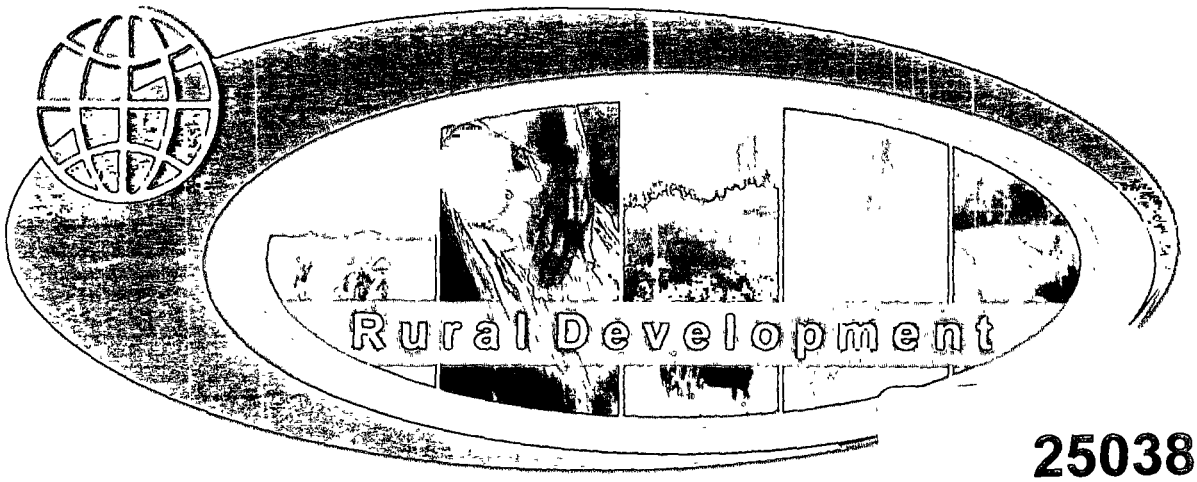


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# The Role of Agriculture in Economic Development and Poverty Reduction

## An Empirical and Conceptual Foundation

**Alexander Sarris**

*The World Bank*
*Rural Development Family*

**Rural Development Strategy**
**Background Paper #2**

# The Role of Agriculture in Economic Development and Poverty Reduction

## An Empirical and Conceptual Foundation

**Alexander Sarris**

*Work in Progress*

*The World Bank*
*Rural Development Family*

This report is one in the series of background studies prepared for the 2001 update of the World Bank's Rural Development Strategy. This series was created to disseminate findings of work in progress and to encourage the exchange of ideas among Bank staff and all others interested in development issues. This paper carries the name of the author and should be used and cited accordingly. The findings, interpretations, and conclusions are the author's own and should not attributed to the World Bank, its Board of Directors, its management, or any member countries.

This paper has been reviewed for publication by the Rural Development Strategy Background Paper Series Editorial Committee: Robert Thompson (Chair), Jock Anderson, Shawki Barghouti, Csaba Csaki, Cees de Haan, Gershon Feder, Sushma Ganguly, and Kees Van Der Meer.

# Contents

# Acronyms

| | |
|---|---|
| ADLI | Agriculture Demand Led Industrialization |
| CGIAR | Consultative Group on International Agricultural Research |
| DES | Dietary Energy Supply |
| GDP | Gross Domestic Product |
| GMO | Genetically Modified Organisms |
| IFAD | International Fund for Agricultural Development |
| IPR | Intellectual Property Rights |
| PFI | Prevalence of Food Inadequacy |
| OECD | Organization for Economic Cooperation and Development |
| TFP | Total Factor Productivity |
| WDR | World Development Report |

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# Foreword

Poverty reduction is the overarching objective of the World Bank, and with 75 percent of the world's poor living in rural areas, rural development is a key element in achieving progress in this objective. At President Wolfensohn's request, the rural family has prepared a revised rural development strategy, *Reaching the Rural Poor*. This has been done in close cooperation with the regions and the other sectoral units active in the rural space. The objectives of the new strategy are to revitalize the World Bank's activities in the rural areas by: (a) adjusting the strategic framework; and (b) formulating a program of concrete and implementable actions.

The new rural development strategy addresses a rural situation which is different from the past, and a rural population which confronts many new problems, especially the challenges and opportunities facing the poor with regard to globalization. The new vision and articulation of a development strategy builds upon the strengths of past efforts as well as incorporates new ideas from other models. In this context, our priorities are geared to fulfill World Bank poverty reduction objectives in the rural sector. We are convinced that the following critical components of a rural development strategy will contribute most to accelerated growth in rural economies and, consequently, to measurable poverty reduction: crafting efficient and pro-poor policies and institutions; facilitating broad-based rural economic growth; improving access to, and management of natural, physical, and human assets; and reducing risk and vulnerability for the rural poor.

A number of studies on both global and regional issues, as well as a broad portfolio analysis were commissioned to support the development of the new strategy. These studies provided a rich foundation for both the regional action plans and the corporate strategy. This study is one of the selected number of background papers which have been published in the Rural Development Strategy Background Paper Series to provide Bank staff and others with a more in-depth look at some of the issues surrounding rural development, beyond what is covered by the strategy document itself. This paper, and others in the series are available on line at: www.worldbank.org/ruralstrategy. Additional information on obtaining other papers from this series can also be found at the end of this report.

*Robert L. Thompson*
Director of Rural Development
The World Bank

# Executive Summary

The purpose of this paper is to provide a review of the issues related to the question of the role of agriculture in promoting overall growth and poverty reduction. The major questions investigated are the following. Under what conditions does additional or disproportional support for agriculture will be both overall growth enhancing as well as poverty reducing? Is there a trade-off between faster growth and poverty reduction in the context of agricultural development? Given that overall support for agriculture as an efficient growth enhancing and poverty reducing strategy can be justified, what are the most appropriate ways to support agriculture so as to maximise the effectiveness of such support in generating growth and reducing poverty?

Sustained growth in an economy requires the continuous improvement in total factor productivity (TFP), and this requires public expenditures for infrastructure and human capital developments. At early stages of development, the economy needs an engine of growth. Such an initial engine of growth can come from a variety of sources, such as the development of domestic or export agriculture, industry, tourism, etc., and the key issue for development is what is done with the increased incomes and savings that come about from the initial engine of growth.

While in the now developed countries it appears that the major stimulus to early growth was industrial innovations, accompanied but not led by agricultural innovations, there have been some developing countries in the recent past, notably India, China and Taiwan, where growth was led by agricultural broad based productivity changes. In these countries it seems that the major source of the demand for the increased product of the agricultural sector was domestic, as there were substantial levels of initial poverty. Hence improved agricultural incomes directly led to increases in the domestic demand for the larger quantities of food produced domestically. Consequently the domestic terms of trade for the increased agricultural product did not decline so as to negate the improvements in TFP. A substantial part of the cost of their agricultural productivity improvement was shouldered by external donors, including the major contributions of the international agricultural research centers, that are members of the CGIAR. Finally, it appears that given the substantial rural population densities in these countries, the cost per agricultural producer of improving agricultural productivity was relatively low, as there was no need for experimentation in too many climatically different locations.

The situation may well be different in many of the late developing countries, such as those in many parts of Africa, in the sense that the cost per beneficiary of agricultural productivity improvement may be high because of low farm population densities. At the same time that overall donor support is declining, necessitating a larger contribution to domestic productivity improvement by the state. Can agriculture play a leading role in the settings of the late developing countries, and should cash strapped governments devote a substantial share of their meager resources to agricultural TFP improvements?

The paper first examines the way in which agriculture grows. The basic ingredients that make up for faster agricultural TFP growth are known, and include agricultural R&D, extension, rural infrastructure, and human capital such as education, and health. However, it was pointed out that while we know the variables affecting agricultural TFP, the profession is much less sure about the magnitudes of the elasticities of TFP with respect to the various factors above, the as well as the ways in which these elasticities are affected by other conditions. Both structural parameters

such as distributional variables, as well as institutional factors, such as the degree of market imperfections may impinge on these elasticities. While considerable partial knowledge on these issues exists at the micro level for several developing countries, their contribution to agricultural TFP growth or to the magnitude of the elasticities of TFP growth with respect to other variables is much less well analyzed. This set of issues then is an area of considerable lack of knowledge, where more research would have a high pay-off.

The review revealed that there is by no means an unequivocal theoretical argument for agricultural development as an engine of growth. If any, recent theoretical contributions tend to rely on different structural properties between agriculture and non-agriculture concerning external effects, notably learning by doing, to argue against agricultural productivity developments as engines of growth in an open economy. It was noted in the review, however, that such treatments rely on asymmetric assumptions about the economic characteristics of agriculture and non-agriculture. Hence they cannot be utilized as guides to policy, unless one has more information at the sectoral level about the nature of external effects and learning by doing properties of the various sectors.

An important contribution of recent theoretical research has been to point out that the way in which domestic incomes, are affected by the improved agricultural productivity, or any other stimulus by another leading sector, and the consequent consumption and saving-investment patterns are crucial for determining the pattern of growth. If improved agricultural productivity leads to higher incomes of the poor who spend it on domestic non-tradables, then agricultural growth will induce non-agricultural rural growth and via employment multipliers to decreases in poverty. If, on the other hand, the fruits of agricultural development or other leading sector economic development lead to increases in the incomes of the rich, then the important determinant for growth will be where the additional savings are spent. If they are spent for domestic labor intensive investments, then there may still be growth, and the poor may well benefit from employment creation. If, however, they are spent on imported luxuries, or invested abroad, there will be little growth stimulus. Thus the pattern of the distribution of increased incomes from the initial stimulus is the most important determinant of subsequent growth. Agricultural development can contribute to both growth and poverty reduction if the fruits of the initial productivity stimulus is concentrated on those who respend it domestically (through consumption or investment) on labor intensive products with low import dependence.

There may be both direct and indirect contributions to poverty reduction from agricultural development, depending on the structure of the incomes of the poor. It was noted that while recent empirical literature has highlighted the important role of agriculture for poverty reduction in labor abundant agrarian countries like India and China, the relationship is not universal. In fact a major contribution of the recent empirical growth literature has been to point out that the elasticity of poverty with respect to agricultural productivity improvements depends on initial distributional variables. This is consistent with the literature on the role of agriculture for growth, which highlights precisely the distributional dependence of the contribution of agricultural TFP growth to overall growth. However, it seems that the elasticity of poverty reduction should not depend only on distributional variables. A variety of institutional and other features, which may be of importance, cannot be captured precisely in cross-country growth analysis, and need to be studied through specific country case studies.

The review revealed that there seem to be a set of conditions that make agricultural development both growth enhancing as well as poverty reducing. These conditions involve the following:

- Agriculture must account for a large share of aggregate employment.
- Initial distribution of land must be equitable and property rights must be well specified.
- The technological improvements must not be risk increasing, nor should they require substantive private capital to be implemented.
- The marginal expenditure shares (both from consumption as well as from investment) of the direct beneficiaries of agricultural growth for labor intensive local nontradables must be large.
- There must be an excess supply of underutilized local labor resources.
- There must be complementary improvements in the provision of human capital assets at the local level (education and health), as well as improvements in marketing infrastructure (e.g. roads).
- There must an income and price elastic source of demand for the increased product of agricultural, wither domestically (in the case of food crops), or internationally (in the case of exports).

What if the above conditions that make agricultural productivity growth have a beneficial impact on overall growth and poverty reduction do not hold? The literature is moot on this point. The following points were, nevertheless, raised in this context. First, if agriculture does not account for a large share of aggregate employment, then it cannot easily be a leading sector for growth or poverty reduction. Investments in agricultural productivity growth must then be judged by comparison with investments in productivity growth of other sectors. Perhaps the best policies under such circumstances maybe investments in human capital, so as to allow agricultural producers to adapt more efficiently to technological changes. Second, if it is difficult to change the initial conditions in the short run, then, while working toward changing them in the medium to long run, one may want to avoid the types of productivity growth that may favor adversely factors that are unequally distributed. For instance, if the land distribution is skewed, then public research in agricultural development may be better targeted towards labor intensive techniques rather than land augmenting ones. Third, if there is no large local excess supply of labor, that could be mobilized when the demand for rural non-tradables increases, then perhaps it is prudent to concentrate on improving the marketing infrastructure, and hence lower the marketing cost between rural and urban areas. This would prevent the prices of local non-tradables from increasing too much from any agricultural stimulus, by essentially making such products more tradable. The above points are not easily generalized, and the presence of only a subset of the above conditions implies that agricultural development policy in such circumstances must be judged on an individual country basis.

The paper highlighted some important emerging issues concerning agricultural development. Globalization can create opportunities, for instance through improved agricultural terms of trade, or improved market access for a country's agricultural exports. However, it may also pose additional risks, such as increased domestic price instability. The point made is that globalization must be accompanied by domestic market enhancing policies in order to produce positive overall results from agricultural growth and for poverty reduction.

Biotechnology was also seen to pose risks and opportunities. Participation by developing countries in the still to be shaped international rules of the game concerning technology transfer

and IPRs seems the best avenue for developing countries in order not to be left out of these developments.

The increasing role of the private sector in both developing countries was seen to pose new challenges for the public sector in the context of agricultural development. Joint private-public financing and responsibility for infrastructure, and research may open opportunities that were not previously available. The role of the public sector in the provision of some type of price and/or income insurance seems to be particularly important in this context.

The elaboration of a two-sector theoretical model of agricultural growth, based on external effects of public infrastructure investments, and the ensuing empirical simulations, suggested some tentative conclusions concerning the role of agriculture in growth enhancement and poverty reduction. First it was shown that maximum growth involves the provision of adequate public infrastructure, financed by higher levels of taxation. However, it was shown that there is a negative relationship between agricultural and non-agricultural taxation for optimum growth. It was seen that higher elasticities of agricultural TFP with respect to public expenditures imply faster real income increases for the poor, while lower overall rates of growth. This trade-off is rather surprising and needs further study and elaboration. It was also seen that the optimum share of public investment expenditures devoted to agricultural TFP improvement depends of the degree of trade dependence of the economy and the non-agricultural sector, increasing with higher degrees of trade dependence. This is contrary to earlier theoretical results. Finally it was shown that the labor intensities of the agriculture, as well as the non-agricultural sectors, and the aggregate saving rates are important in determining the maximum possible growth under a strategy of agricultural development.

The implications of the above review and analysis for the rural development strategy of the World Bank, are the following. First, it should be clear that the relative importance of the agricultural sector as a leading sector for growth and poverty alleviation depends on country specific geographical and economic structure variables. There can be no single agricultural growth and poverty reduction strategy to fit all developing countries. It rather seems that the emphasis on agriculture as a leading sector should depend on a set of criteria of the type mentioned above. Country specific strategy and policy work could then concentrate on the presence of the conditions that may be conducive to making agriculture a growth and poverty alleviation pole. Some of these conditions were elaborated above, but it seems that there needs to be more organized analysis of these criteria and conditions, combined with specific indicators, to provide specific empirical and country relevant guidance.

Second, there is no doubt, given the considerable externalities involved in agricultural TFP growth, that external assistance should concentrate on creating an environment that facilitates the productivity of any attendant domestic investments. For instance, if the government of a developing country is keen on rural infrastructure, perhaps, external resources could support the development of the other necessary ingredients for growth and poverty reduction, such as rural education and health, with emphasis, of course, on sustainability of investments. This can be justified under the notion that there are complementarities between various types of agriculture related public interventions. It must be noted in this context that there seems to be considerable lack of knowledge concerning the dependence of elasticities of both growth, as well as poverty reduction to different types of agricultural development spending, on institutional, as well as other structural factors. This seems an area where more country specific, as well as cross-country research is needed.

Another point has to do with the type of agricultural research that is supported. In many developing country agrarian settings, the reservation unskilled wage for the economy is close to the average product of labor in agriculture. This for instance seems to be the case in many land abundant but labor constrained economies in Africa. This implies that in such settings, agricultural research and productivity enhancement, in order to be both growth enhancing, as well as poverty reducing, must aim at increasing the average productivity of labor in agricultural production, without making production more labor intensive. This is different from settings with labor abundance, and land scarcity, where the reservation unskilled wage may be close to the marginal product of labor in agriculture. In such settings, agricultural research should try to increase the productivity of land, so as to increase the marginal product of agricultural labor.

A major strategic issue has to do with the efficacy of agricultural productivity growth as an engine of growth, as a function of rural population density. In settings of low rural population densities, the cost of agricultural productivity enhancement may be very large relative to the benefit per affected household. In such settings the elasticity of TFP growth, as well as the elasticity of poverty reduction with respect to various types of public expenditures may be low. The empirical simulations of the model suggested that low values of the agriculture TFP elasticities imply low shares of public capital devoted to agriculture TFP enhancement. This underscores the fact that the factors that determine the size of the elasticities of agricultural TFP with respect to public spending must be clearly understood, before recommendations about a rural development strategy are made.

There are several areas where additional empirical cross-country work is needed by institutions such as the World Bank. First, it is not clear how many contemporary developing countries fulfill the conditions that were identified as necessary for a win-win (growth promoting and poverty reducing) agricultural development strategy. While for some conditions the verification is relatively easy, examples being the share of agriculture in total employment, the initial land distribution, and the existence of under-utilized rural labor resources, for others the verification is by no mean straightforward. This may well be a worthwhile empirical project for the World Bank Rural Development and/or Research Departments.

Second, even if all conditions can be empirically checked, it will most likely be the case that not all of them are satisfied in any one developing country. Does this mean that agricultural development policies should take second priority? Or is it the case that there is a core subset of the conditions that if satisfied can justify a vigorous agricultural development strategy? This poses the problem of agricultural development policy under a second best world. For instance, should development effort concentrate on setting the initial conditions for agricultural development right as a prerequisite for public investments in agriculture, or should the two proceed simultaneously? Unfortunately, very little is known about this.

Thirdly, are all conditions identified of equal importance? For instance is the provision of adequate roads more important than the provision of human capital? Should rural education be enhanced before investments in agricultural research and extension are made? The answers to these and other related questions are not easy, and are not universal, as they are intimately tied with the historical and institutional context of any given country, as well as on an appraisal of the speeds with which any one policy can be implemented and have an impact. Little, however, is known about the types of conditions that should be considered as part of the core needed for agricultural development to be effective.

Given this rather inconclusive state of affairs regarding the role of agriculture in growth and poverty reduction, one way to proceed for the Rural Development Department of the World Bank to augment its practical and relevant knowledge, would be to conduct a cross-country comparative review of agricultural sector strategies and performances over the past twenty or thirty years. Such reviews have been done at the initiative of the World Bank in the past, but with very different focus, and have produced wide ranging policy relevant results. The new focus should be the relationship between agricultural productivity growth and overall economic growth and poverty reduction performance.

# 1. Introduction

Two of the major themes in the development literature as well as thinking, that have received additional emphasis in the 1990s, have been growth and poverty reduction. The new endogenous growth theory has highlighted the importance of several factors conducive to faster economic growth, such as human capital, infrastructure, sound monetary and fiscal policies, democracy and political stability, trade openness, corruption, and others, while considerable effort has been given to exploring relationships between growth and inequality as well as poverty. This essentially macroeconomic approach to growth, has placed much less emphasis on sectoral aspects of growth and poverty reduction. This, lack of sectoral emphasis, however, gives little practical guidance to policy makers who have to make decisions about the allocation of public resources, as well as sources of funds to finance public expenditures. Similarly the latest World Bank Development Report for 2000/2001 titled "Attacking Poverty," that emphasizes three themes, opportunity, empowerment, and security, is notable for the relatively limited discussion of sectoral priorities in reducing poverty and enhancing growth.

It is well known that the majority of the world's poor live in rural areas. Of the about 1.2 billion people in the world that are estimated to live on less than one dollar a day, about three quarters work and live in rural areas, and depend to a large extent on agriculture. This would seem to be good reason for support of rural poverty reduction strategies, and labor intensive agricultural growth. Yet, since the mid-1980s, aid in support of agriculture has fallen sharply in both absolute as well as relative terms, inducing slower growth in staple food yields and lower elasticity of poverty to overall growth. The recent IFAD Rural Poverty Report 2001 (IFAD 2001) mentions that real net aid disbursements to developing countries have fallen from 2.7 percent of their GDP in 1992 (or 0.33 percent of OECD GDP) to 1.4 percent of their GDP in 1998 (or 0.24 percent of OECD GDP). Over the same period, of this smaller aid disbursements, the proportion of sectorally allocated aid going to agriculture, forestry and fisheries has declined from 20.2 percent to 12.5 percent.

It is not clear why there has been such a decline in support for agriculture. Lipton (2000) suggests that this could be justified under the following arguments:

- if public action were more cost-effective in reducing urban poverty;
- if the role of agriculture and the rural sector in supporting and advancing poor people in low income countries has declined;
- if rural people gained more from urban poverty reduction than vice versa;
- if rural anti-poverty spending deterred successful urbanization;
- if rural anti-poverty spending induced less economic growth than urban poverty reduction; or
- if labor-intensive methods for small farmers and orientation of support for staple food production has disadvantages in the context of more globalized markets.

Lipton suggests that none of these arguments holds true and some of his and other arguments why this is so will be considered later.

Nevertheless, in the context of public resource allocation, the major questions that policy makers may ask concerning support for agriculture are the following. Under what conditions does additional or disproportional support for agriculture will be both overall growth enhancing as well as poverty reducing? Is there a trade-off between faster growth and poverty reduction in the

context of agricultural development? Given that overall support for agriculture as an efficient growth enhancing and poverty reducing strategy can be justified, what are the most appropriate ways to support agriculture so as to maximize the effectiveness of such support in generating growth and reducing poverty? These questions will form the basis of the review and discussion of this paper.

The discussion will start in chapter 2 with a brief review of the factors that contribute to agricultural growth. Then the role of agriculture in enhancing overall growth is considered in chapter 3. In chapter 4 the relationship between agricultural growth and poverty reduction is reviewed. Chapter 5 reviews the channels through which agriculture contributes to poverty reduction. Chapter 6 discusses some emerging issues in the context of agricultural development Chapter 7 presents a simple two-sector theoretical model of agricultural growth and poverty, in order to highlight some of the relationships discussed in the review. Chapter 8 summarizes the conclusions. The effort throughout is be to identify the conditions that make agriculture a leading sector for development and growth.

# 2. How Does Agriculture Grow?

Before we discuss the role of agriculture in poverty reduction it seems appropriate to review the process through which agriculture grows. Concerning agricultural growth and its components, early research (Binswanger et. al. 1987) showed that the major determinants of agricultural supply are physical capital, infrastructure, human capital, research, extension, and rural population density. Prices were found to be weak determinants of agricultural supply, consistent with earlier studies of aggregate agricultural supply response to price (Bond, 1983). Similarly Antle (1983) showed that the major determinants of total factor productivity (TFP) in agriculture in cross-country regressions is education, research and infrastructure. More recent research (Mundlak, Larson and Butzer, 1997, Mundlak, 1999) has confirmed these results and has specified that technological change in agriculture is incorporated into increased agricultural production through the increases in physical capital stock. In cross country regressions that incorporate both country specific and time effects, the result is that constant returns to scale cannot be rejected, and that the shares of capital, land, labor and fertilizer are respectively 0.37, 0.47, 0.08 and 0.08. These are different when time effects are included, which is the way most cross-country production functions have been estimated. In such regressions the elasticity of capital is lower (around 0.34), that of land is practically nil, the elasticity of labor is 0.26, and that of fertilizer is 0.43. In other recent analyses without time effects (Craig et. al (1997) the production elasticity of land was found to be around 0.35, that of labor was 0.25, and that of fertilizer 0.04. Capital elasticities were quite low in this study, but quite significant were the contributions of infrastructure, human capital and research variables.

The various estimates are considerably hampered by the inaccuracy of aggregate data for inputs such as labor and capital. Similarly the interpretation of the contribution of several variables such as those of human capital (usually proxied by variables such as adult literacy, and life expectancy) or infrastructure (proxied for instance by variables such as road density), is problematic, as they may be providing indirect information on the role played by conventional inputs, such as physical and human capital.

The changes in the total factor inputs appear to account for only about half of the total growth of agricultural output (Mundlak, 1999). The rest is accounted for by the "residual", namely what is normally termed total factor productivity (TFP), which is basically technical change. Mundlak (1999) suggests that the empirical evidence points to the fact that the major way technology is incorporated into agricultural production is through physical capital. The different rates of growth of physical capital among sectors in turn can lead to differential sectoral growth rates along standard Rybczynski theorem logic (for an analysis of such supply side factors see Martin and Warr, 1993). Changes in technology, however, especially those involving new discoveries in production techniques, come irregularly, and hence cannot be planned.

There are not many studies that explore the contribution of different factors to agricultural TFP growth. A recent monograph by Evenson, Pray and Rosengrant (1999) has estimated the contributions of various factors to India's TFP growth in agriculture. They find that public research and extension are the two most important factors accounting for TFP growth, with irrigation coming next. The internal rates of return to public agricultural research in particular are

estimated to be higher than 50 percent, which is fairly impressive. Fan, Hazell, and Thorat (1999) similarly show, using an econometric model estimate with Indian data, that public expenditures for research and extension have had the largest impact on agricultural productivity growth, with rural roads, education and irrigation following with a distance. Finally, Fan, Zhang, and Zhang (2000) found that in China the largest contribution to agricultural productivity has come from research and development public expenditures, followed by education, rural telephones, rural roads, and electricity. It is interesting that irrigation investments in that setting had the lowest impact on agricultural productivity.

It thus appears from these few recent exercises that publicly financed research and extension, and rural infrastructure in the form of rural roads, electricity, irrigation, etc., are major contributors to agricultural TFP growth, with investments in human capital also a significant factor. This is all in line with the conclusions of the endogenous growth theory. All these papers, however, deal only with agricultural TFP growth. Hence they do not answer the question of whether the same funds if invested by the public in non-agriculture could have achieved larger TFP growth there. As Evenson and Westphal (1995) point out there are significant differences between agriculture-related research and industrial research, with the former much more circumstantially sensitive, namely sensitive to local conditions. Thus, to make agricultural research have a high payoff, the large fixed cost of establishing and running technological facilities must be geared to producing results that can possibly be adopted by a large number of producers. This explains, for instance why returns to agricultural R&D have been so high in densely populated agrarian countries such as those in Asia, while they are lower in sparsely populated agrarian economies, such as those of Africa. Evenson and Westphal (1995) in their survey of many returns to agricultural R&D studies find that in Africa of 10 reviewed studies 4 (40 percent) reported rates of return higher than 50 percent, while among 77 reviewed studies in Asia, the number was 48 (63%). Nevertheless, if returns to agricultural research are as high as they appear to be, the question arises as to why they do not attract further funds devoted to such research. Perhaps the reason may have to do with constraints on public investment budgets, or the long term nature of such investments.

The most surprising result of recent research in total factor productivity in agriculture and manufacturing, is that across a variety of studies it appears that the rate of growth of total factor productivity (TFP) in agriculture has been greater than the rate of growth of TFP in industry (Bernard and Jones, 1996, OECD, 1995, Martin and Mitra, 1999). Martin and Mitra, in particular, in the most complete study to date, found that the average annual growth rate of TFP in manufacturing in developing countries varied between 0.62 and 0.92 percent over the period 1967 to 1992 depending on the methodology of estimation used, while in developed countries the range was between 1.91 and 3.29. On the other hand in agriculture the average rate of growth of TFP in developing countries ranged between 1.76 and 2.62 percent, while for developed countries the range was between 3.35 and 3.46 percent. For the low-income developing countries, the average rate of TFP growth in agriculture was between 1.44 to 1.99, while in manufacturing it was between 0.22 to 0.93 percent. Clearly the rate of growth of TFP in agriculture seems to be higher than that of manufacturing.

The study, furthermore, found that there seems to be convergence of the growth rates of TFP in agriculture between all countries both developed and developing ones. The same was found also for the growth rates of TFP in manufacturing. The authors interpret their results as suggesting that they weaken the case for policies that discriminate against agriculture in favor of the

supposedly more dynamic manufacturing sector. The results suggest that the high rates of TFP growth in agriculture reflect effective systems of developing and disseminating internationally innovations in agriculture, and this seems to be related to the establishment in the early 1960s of a large-scale system for international agricultural research. Thus a hypothesis is that the "globalization" of agricultural research, has contributed to faster TFP growth in agriculture, compared to that of manufacturing, for which a large portion of applied research is privately funded and appropriated.

While these results are very interesting, it is not clear whether they are due to disproportionally high public investments in agriculture, or other policies discriminating against other sectors. If, for instance, the contribution to infrastructure or education to TFP growth is similar across sectors, it would be no surprise if higher TFP growth in one sector is due to higher shares of public expenditures on these factors devoted to this sector. In fact Byerlee (1996) exhibits data that show that developing countries have invested proportionally more in agricultural research recently than developed countries, and this would be consistent with the above results.

Also it may be the case that technological improvements in agriculture are reflected more in increased quantities of capital in the developed countries, compared to the developing countries, hence masking the impact of technical changes on TFP. Hence the assessment that larger TFP growth in agriculture implies that agriculture should not be discriminated against is incomplete without the analysis of the sectoral utilization of public growth enhancing expenditures, as well as analysis of the elasticity of capital inputs with respect to technological improvements.

Concerning factor supply, the data in Mundlak (1999) suggest the following:

- The share of agriculture in total investment, and in total capital is smaller than its shares in output and the labor force. This is an indication of lower capital-labor ratios in agriculture compared to non-agriculture.
- Average labor productivity growth in agriculture has exceeded that of non-agriculture.
- The share of agriculture in total investment has been declining since 1970.
- The share of manufacturing in total investment has also been declining. This indicates that other sectors, probably services have attracted increasing shares of investment.
- The capital-output ratio in agriculture seems to have increased over the last thirty years (indicating capital deepening).
- In most countries the capital-labor ratio has grown over time in the economy as a whole as well as in agriculture.

Mundlak interprets this evidence as suggesting that demand is the dominant determinant of agricultural growth. Sluggish agricultural demand growth, due to low-income elasticity of demand for agricultural products, implies low growth in agricultural output and investment. Similarly the increasing capital labor ratio in agriculture reflects the out-migration of farm labor, as well as a shift to more capital intensive techniques.

An aspect that has not been appreciated in the above literature is the contribution of the institutional environment to agricultural growth. Of course, the reason for such neglect is that for most of the countries studied with data before 1985-90, there had not been any institutional change in the structure of agricultural production, to justify any attribution of growth to such

factors. However, the institutional changes in China (Lin, 1992) as well as in Eastern and Central Europe (Sarris, et. al., 1999), have alerted researchers to the likelihood that institutional changes may be instrumental in accelerating agricultural growth. Apart from major institutional changes such as those that have occurred in China and Eastern Europe, one can think of other institutional reasons that may contribute to fast productivity growth. These include the development of agricultural extension, and the improvement in the functioning of input and output markets.

Other factors that have not been considered in these analyses are structural ones. For instance does the structure of land ownership matter in the efficiency with which research and extension, or other public investment policies like infrastructure or education enhance agricultural growth? Does the structure of production (in terms for instance of the division between crops and livestock, or between food and non-food crops) matter?

The above studies do not consider the contribution of the policy environment for agricultural TFP growth. Early research did tend to show that policies affected the pace of agricultural growth (Lele, 1989), and the review of agricultural price policies in 18 developing countries by Schiff and Valdes (1991) tended to support the view that anti-agriculture price policies are associated with slower agricultural growth. However, it was not clear from these studies whether it was the result of the decline in overall resources to agriculture that slowed down agricultural growth (and this is consistent with the sources of agricultural TFP growth literature), or the decline in the elasticity of TFP growth to specific inputs resulting from bad policies.

The above studies suggest that while the standard inputs (capital and labor) enhance agricultural growth, it is public expenditures for agricultural research and extension, rural infrastructure, and rural education that are important for agricultural TFP growth. They do not, however, make the case for disproportional public expenditures on such items relative to other sectors, as a growth enhancing strategy, albeit the exceptionally high returns to publicly funded agricultural research seem to suggest that considerable public investment should be devoted there. The studies also do not consider how institutional and structural factors affect the effectiveness of these types of policies. In other words, while by now we know the factors that affect agricultural growth and TFP growth, and in some cases we even know the elasticities of TFP with respect to these factors, we do not know how the elasticities of agricultural TFP growth with respect to the various variables identified above are affected by structural and institutional features of an economy. While country specific effects in cross-country regressions have taken account of country heterogeneity, and isolated the net contributions of the indicated variables to growth, their inclusion has not answered the more interesting question about what influences the elasticities of TFP with respect to the standard variables. This is a ripe topic for research.

Another issue that has arisen in recent research is the lag between technological innovations in agriculture and overall TFP improvements. Murgai (1999) has shown that during the period of India's Green revolution TFP growth was surprisingly low, but increased in later years after adoption was basically complete. She attributed this pattern to three major factors. First, the technical innovations appear to have increased the elasticity of output response to modern inputs, and hence a large part of the increased inputs should be attributed to the Green revolution, but is not captured in TFP figures. Second, learning by doing effects were slow in the short run, as the major impetus of the technological developments in the short run was fast capital accumulation to facilitate adoption. Third, it seems that there were differences in development of accompanying infrastructure like irrigation, and these have accounted for the differences in the rates of productivity increases.

# 3. Agricultural Development and Overall Growth

What is the role of agriculture in economic development? Can agriculture be a leading sector to induce faster growth, and under what conditions? These questions are very important for development strategy, and the choices of policy makers. What do the theoretical and empirical literature have to say on these issues?

On the relationship between agricultural and overall growth, Stern (1994) has presented a summary of the empirical evidence concerning correlations between agricultural and non-agricultural or overall growth. The historical pattern supports the view that in the course of development the share of agriculture in both output, as well as labor falls. This is the outcome of an initial disparity between labor productivities between agriculture and the non-agricultural "the modern" sectors, that leads resources, especially labor to move out of agriculture. Simultaneously the capital intensity in both sectors rises.

The empirical evidence across countries points out to close positive correlations between agricultural and non-agricultural growth rates for the period before 1980, and little or no correlation between the same growth rates after 1980. Stern hypothesizes that after 1980 there were considerable exogenous shocks for many countries that may have slowed down the growth of their non-agricultural sectors, and weakened the correlation between sectoral growth rates. The associations highlighted by Stern suggest some complementarity between agricultural and non-agricultural growth, and this can be supported by simple theoretical models based on demand. For instance, rising income in a closed economy would lead to rising food consumption at a positive but slower rate than that of non-agriculture, because of the fact that the income elasticity of demand for food is smaller than one. This thinking would then suggest a positive association between agricultural and non-agricultural growth rates, but with the latter larger than the former. Of course, in open economies production and consumption can differ, and it is not clear whether such conclusions and associations can be justified. The association between agricultural and non-agricultural growth does not, of course, say anything about any causal relationship between the two, and similarly does not say anything about a strategy for agriculture in the course of development.

Early development writers such as Rosenstein-Rodan (1943), Lewis (1954), Hirschman (1958), Jorgenson (1961), Fei and Ranis (1961) regarded agriculture only as a reservoir and source of abundant labor and transferable product and financial surplus. The role of agriculture was seen as ancillary to the main strategy of growth, which was accelerating industrialization. Hirschman (1958) in particular was negative on agriculture as a source of growth on the basis of its weak forward and backward linkages needed for development. By contrast Kuznets (1968) pointed out that in a successful development strategy, technological progress must support both industrialization and agricultural productivity. The basis of this view is the observation that the stylized shift of employment away from agriculture and toward industry is the consequences of technological changes in both agriculture and industry. The revolution in agricultural productivity, according to Kuznets, is an indispensable base of modern economic growth. A similar view was expounded by Kalecki (1960, 1971), who based his position on the idea that balanced growth in both wage goods and capital goods forms the basis of sustainable long run growth. Since agriculture is the main sector producing food, the key wage good in a developing

economy, agricultural development is essential for a successful industrialization strategy for developing countries.

Development thinking and practice in the 1960s and 1970s tended to neglect agriculture as a leading sector, with its emphasis on import substitution industrialization and export promotion. This thinking was aided by the literature concerning the terms of trade of agriculture. Concerning the terms of trade for agriculture, which can summarize the "price bias" and the rate of taxation on agriculture, and which can be considered as a policy instrument, there is extensive literature on its pattern in the course of development, starting with the Soviet industrialization debate of the 1920s (Preobrazhensky, 1965). Under the assumption that agricultural production would not suffer, given the inelasticity of aggregate agricultural supply with respect to price, and the further assumption that industrial investment gives higher rates of return, the idea was to "force" savings, food, and labor out of agriculture through explicit and implicit taxation in order to finance industrial growth.

Such thinking provided the intellectual basis for policies that were applied in many countries in sub-Saharan Africa and other regions in the 1960s and 1970s, that taxed explicitly and implicitly agriculture. The results of such policies were disastrous for growth, leading to the adoption of structural adjustment programs that aimed at reversing such policies (for a summary of the issues and debate concerning agricultural taxation see Sarris, 1994). Sah and Stiglitz (1984, 1987) have provided a framework for thinking about the agricultural terms of trade in its relation to the overall "investible surplus" of the economy, defined as the difference between the total production and consumption of the non-agricultural product.

The logic of their argument is fairly straightforward. Assuming that agricultural or industrial laborers do not produce much saving for investment, and that foreign savings are constrained, the major sources of domestic savings are private profits from non-agricultural production and public tax revenues from exports or imports. Since the major part of non-agricultural production cost is labor, and since wages in a developing country seem to respond to the cost of food, non-agricultural profits can be raised by keeping the price of food and hence wages down. Also if most of exports are agricultural, while imports are non-agricultural, the government can increase public revenue by taxing exports and/or imports. Both of these policies imply a reduction in the terms of trade for agriculture.

In their later work Sah and Stiglitz (1987) widened the framework and clarified further the logic of the above argument. They showed that suppressing the terms of trade of agriculture below the levels dictated by international prices, increases the domestic investible surplus of the economy. In other words the agricultural sector must be taxed, or equivalently the non-agricultural sector must be subsidized vis-à-vis world prices, in order to raise the level of aggregate domestic investment. There is a critical level of the domestic agricultural terms of trade, which is below the international terms of trade, and which maximizes the total level of domestic surplus. Furthermore, the suppression of the internal terms of trade does not have to impoverish urban workers. Similar results about the agricultural terms of trade were obtained in earlier research dealing with growth in dual economies such as the works by Hornby (1968) and Bardhan (1970, chapter 9), under different assumptions.

In all of the above literature the basic assumption is that the major source of domestic savings is non-agricultural profits. This is basically a functional view of savings and income distribution. Translated to personal income distribution this view assumes that the recipients of agricultural

incomes are subsistence farmers with little savings for investment, and that recipients of non-agricultural profits are different from the recipients of agricultural and wage incomes. This, however, neglects the possibility that the bulk of income recipients in developing countries have joint income from agriculture and non-agriculture, and that rural agricultural producers may generate considerable investible savings. In any case, the source of savings and investments is an issue that must be dealt with in the design of a development strategy.

None of the above works deal with the issue of the allocation of investment among sectors. Furthermore, they all neglect the issue of technical change, and its relation to investments and growth. They also all seem to neglect the welfare of agricultural producers. Finally, they all deal with growth towards some steady state growth rate that, like the standard neoclassical Solow model (Solow, 1956), is independent of endogenous growth generating factors.

It was only in the late 1970s and early 1980s that the role of agriculture as a leading sector was re-emphasized in the development literature by authors such as Mellor (1976) and Adelman (1984). These authors emphasized the importance of agricultural growth in generating demand for locally produced non-tradable products, and thereby stimulating overall production and growth. Such a strategy was termed Agriculture Demand Led Industrialization (ADLI) by Adelman (1984).

Timmer (1988) has observed that research to date relating to the different views about agriculture in the course of development, suggest three sharply different paths for appropriate policies toward agriculture if the goal is to speed up overall growth.

The first path, grows out of a view that markets, if left alone, will function properly, and that economic decision makers are rational and respond efficiently to economic signals. As the long run tendency is for a decline in the proportions of agricultural output and labor, the best way to speed up growth is to accelerate this natural tendency. Rapid technical change and declining relative prices for agricultural products (arising out of a faster growth of supply compared to demand) in a world of little government interference will accomplish this.

The second path associated with Mellor and Johnston (1984), is the "interrelated rural development strategy". This strategy advocates a unimodal, namely broad based, pattern of economic development that improves incomes, nutrition, and income distribution, while promoting overall growth. Agricultural growth not only satisfies the criterion of growing food for the poor smallholders to meet nutritional requirements, but also promotes a favorable employment-oriented demand structure. Mellor and Johnston advocate considerable government intervention to promote extension and research aimed primarily at rural smallholders.

This strategy is heavily influenced by closed economy considerations. Three key elements are suggested as essential to meeting all objectives of agricultural development, namely massive investment in human capital through nutrition, health and family planning services in the countryside, creation of a complex rural organizational structure (like the ones observed in Taiwan and Japan) for providing services to small farmers, and investments in rapid technical change appropriate to small farmers in order to raise agricultural output and incomes simultaneously.

The third approach to agricultural development realizes the important links of agriculture and the macro-economy, as well as the importance of market signals and incentives, elements that are relatively underemphasized in the second strategy. It calls for government policy intervention

into domestic markets, but uses markets and the private sector as vehicles for these interventions. This approach can be termed "price and marketing policy" approach, and recognizes widespread market failures in agriculture, as well as government failures in implementation of policies. The dilemma is how to cope with segmented and/or poorly functioning or absent rural labor, land, and credit markets, the pervasive lack or imperfect nature of information, and the absence of many important markets notably those for risk.

All three approaches recognize the importance of government investments in infrastructure and agricultural research. However, the approaches differ in their emphasis among these government interventions. The free-market approach would put greater emphasis as well as budget share on research, the rural development strategy on human capital investments, while the price and marketing approach on rural infrastructure to lower marketing costs. As Timmer properly concludes, the issue is not one versus the other, as all three elements should be part of a successful agricultural growth strategy. The real issue is one of where should scarce resources be invested, and with what priority at different stages of development.

The above strategic approaches, however, all avoid the major issue of allocation of resources between agriculture and non-agriculture. They deal with the issue of how a given amount or share of investment resources should be allocated among different types of investments within agriculture to achieve a given growth rate. They do not deal with the issue of whether agriculture should receive a larger or smaller share of overall investment resources relative to non-agriculture, and whether this would speed up or slow down overall growth.

The real issue from a growth perspective, however, is how to accelerate growth. The role of agriculture must be examined in such a context if some guidelines for strategy and policy are to be derived. Unfortunately, however, there seems to be very little research focusing on such a problem, and then only partially. In an early paper Krishna (1982) observed using data from the period 1960-80 that non-agricultural growth not only was correlated with that of agricultural growth, but, furthermore, that the growth rate of agriculture was usually lower than that of non-agriculture. He also noted based on the research of Kuznets (1961) that the incremental capital-output ratios for agriculture are higher than those of mining and manufacturing. Since such ratios are often used to plan investments, the implication is that to achieve a similar growth rate for agriculture and manufacturing, a larger share of investment should be devoted to agriculture, relative to the share of agriculture in GDP.

Another paper that also examines the allocation of investment among agriculture and non-agriculture is the one by Das (1982). He utilizes a simple two sector (agriculture and non-agriculture) model, with externally fixed prices, and asks the question of the optimal saving rate and optimal investment allocation among the two sectors, so as to maximize the per capita consumption in the steady state. Under perfect labor mobility and no sectoral wage differentials he finds that the optimal savings ratio (the golden rule savings ratio) is equal to the share of capital in total income, and that the optimal share of investment in each sector is equal to the proportion of total capital earnings generated in the sector. Hence, if agriculture generates a small share of the economy's capital income, then this rule implies that the optimal share of agriculture in total investments is correspondingly low.

If, on the other hand, the wage in the non-agricultural (urban) sector is fixed exogenously at a higher level than that in agriculture, and if the labor market behaves in a Harris-Todaro (HT) fashion, namely equating the marginal product of labor in agriculture with the expected marginal

product of labor in non-agriculture, then Das (1982) finds that the optimal savings ratio is higher than the full-employment golden rule ratio. Furthermore, the optimal share of investment for a sector is higher (lower) than its contribution to capital income if and only if the proportion of the total labor force in the sector is greater (or less) than its share of capital income. Given that in developing countries the labor market is likely to behave in a HT fashion, and that normally the proportion of labor in agriculture is higher than the proportion of capital income generated in agriculture, the above result implies that the optimal investment share for agriculture is higher than agriculture's share in capital income.

The above results are interesting, and give some kind of yardstick that can guide total investments in agriculture and non-agriculture. However, the conclusion concerns all investments and not just public ones. Furthermore, the complete exogeneity of prices makes demand not to play any role.

On the relationship between agricultural and non-agricultural growth there is very little research as already mentioned. A major exception is the paper by Adelman (1984) that advocated an Agriculture-Demand-Led-Industrialization (ADLI) strategy for middle income developing countries. This strategy that resembles in some ways the "interrelated rural development" strategy of Mellor and Johnston (1984) basically consists of building a domestic mass-consumption market by improving the productivity of agriculture and letting farmers share in the fruits of improved productivity. The demand linkages generated by farmers, especially the small low income ones, are stronger with domestic industries and other non-tradables, and domestic low capital intensity non-agricultural sectors. The strategy advocates higher shares of investment going to agriculture, in response to higher rates of return there. Thus, investment allocations are made functions of the relative rates of return, and the ADLI strategy is based on the observation that investment returns are higher in agriculture than in non-agriculture at some stages of development. This is, of course, a key observation that has also been made by Lipton (1977, chapter 8).

The importance of agriculture for growth in the context of the ADLI strategy has been recently demonstrated by Vogel (1994), who computed forward and backward SAM multipliers for agriculture and non-agriculture for a variety of developing and developed countries, and plotted them as a functions of the GDP per capita. He showed that the backward multipliers of agriculture are much larger than the forward multipliers at all development levels, and furthermore, that they grow across different countries, from those with low GDP per capita, until the GDP per capita reaches middle development levels (around 2500-3000 USD). The backward multiplier works by examining the implication of an additional unit of income for agricultural households. It implies increased expenditures of agricultural households on non-agricultural products, and hence increased incomes to non-agricultural households, and through a secondary effect, further expenditures on non-agricultural goods. The forward multiplier works thorough the demand by agriculture of inputs from non-agriculture, and attendant income effects.

The finding that the agriculture backward multiplier is quite large, supports the view that agricultural growth contributes considerably to overall economic growth through the demand linkage effect. The author argues that the fact of strong backward and weak forward linkages make agriculture a candidate to be the leading sector in an economic growth strategy. This point of course has been made repeatedly by authors working in the "growth linkages tradition," such as Haggblade and Hazell (1989), Haggblade, Hammer and Hazell (1991), Hazell and Roell (1983), and more recently Delgado, Hopkins, and Kelly (1998). These authors have emphasized

the importance of non-tradable non-agricultural products in the demand of rural low-income residents that are recipients of agricultural income. However, the logic of this approach depends considerably on the assumption of elastic labor supply by agricultural households, or rural residents. While this assumption may be reasonable in some labor abundant developing countries, it may not be so in others.

Recently, in relation to the revival of discussion about growth rates, in the context of the "endogenous growth literature", there has been a small number of papers dealing with agricultural growth, the terms of trade, and overall economic growth. An early paper by Thirlwall (1986), provided a simple two sector framework, that related the internal terms of trade for agriculture to the equilibrium growth rates of the two sectors (agriculture and industry), which in the steady state are assumed equal, and hence equal to the overall growth rate of the economy.

He showed that for a closed economy, the equilibrium growth rate will be larger, the higher is the productivity of investment in industry and agriculture (namely the incremental output capital ratio), the higher is the agriculture savings rate, and the lower are industrial wage costs per unit of output. In such a steady state, and under the assumption of unitary income elasticities of demand, the equilibrium terms of trade are constant, and, furthermore, the ratio of outputs in the two sectors is constant and dependent only on the agricultural sector savings rate, and the wage bill per unit of output in industry (namely the industrial labor share).

Thirlwall showed with his model that the basic constraint on growth is technical change in agriculture, and that the steady state rate of agricultural growth is independent of the terms of trade. Technical progress in agriculture (assuming no discovery of new land, which affects the growth rate in the same way as technical progress) will relax the constraint on industrial growth, and it is only this that will do so. In other words technical progress in industry only affects the internal terms of trade, but not the long run equilibrium growth rate of the economy.

International trade in Thirlwall's model acts so as to provide, through exports, an additional source of demand for industrial output, in addition to domestic demand that comes from agricultural growth. Thus the rate of growth of demand for industrial output becomes a weighted average of the rates of growth of domestic and export demand. As export demand comes to dominate domestic demand for industrial output, the rate of growth of industry becomes externally constrained at a rate that is independent of the rate of growth of demand coming from the agricultural sector, and this is a turning point in the country's history. Thus the model that Thirlwall analyzes points out that "...in the course of development we expect a healthy agricultural sector to be the driving force behind industrial growth in the early stages, superseded by export growth in the later stages. In this sense the model reinforces the belated recognition of agriculture's importance in the early stages of development, and lends support to export led growth theory in the later stages."

While Thirlwall's model emphasizes the role of capital productivity and the agricultural savings rate in growth, it does not discuss how these can be raised, or affected by intersectoral labor movements or investment allocations or technical change. In his model the gross productivity of investment in the two sectors is a constant, and this seems unrealistic, as reallocations of labor in the course of development significantly change the sectoral marginal products of capital. Also it views investment in each sector as determined by the savings of each sector, a very restrictive assumption that omits the possibility of inter-sectoral reallocation of savings. The domestic

agricultural terms of trade in the model are endogenous and constant in the steady state. This is the result of the assumption of unitary income elasticities for the products of the two sectors. Finally, if one assumes neoclassical production functions for the products of the two sectors, and if one assumes that in the steady state there is no intersectoral labor movement, then Thirlwall's model implies in the steady state zero growth rate of per capita incomes in both sectors, just like the neoclassical Solow model.

Another model by Canning (1988) is more in the spirit of the endogenous growth literature. Canning considers a closed economy that produces three products, namely agricultural goods destined for consumption, manufactured goods also destined for consumption, and manufactured goods, destined for investment. He builds a general equilibrium model of the economy, in which demand for agricultural goods is subject to Engel's law, namely an income elasticity of demand smaller than one. Consumption in his model comes from labor and land ownership, and this implies a farm structure, where farmers (who may be visualized as owning their land) do not save. Savings are derived only from industrial profits, and are equal to the sum of investments in all sectors. Non-agricultural production is subject to production with increasing returns, and it is this assumption that drives the results of the model.

Under constant values for population and land, Canning shows that his model implies a constant and stable steady state aggregate capital stock. However, the per capita capital stock is an increasing non-linear function of the population, and this implies that under a growing population, there is non-zero per capita capital stock growth, and hence positive per capita income growth. Remarkably, this growth does not require technological change, but rather the continuous expansion of manufacturing. The latter, because of increasing returns technology, can produce ever-increasing amounts of output at diminishing cost.

Canning's model is compatible with a diminishing share of labor force in agriculture, as well as with declining internal agricultural terms of trade. The reason that such developments do not come into conflict with an assumption of no technological improvement in agriculture, is that the lower prices of manufactured goods allow agriculture to adopt techniques that are increasingly capital intensive, thus alleviating the constancy of land.

Canning's model does not consider foreign trade, and no policy variables. Furthermore, his "short run" is characterized by complete depreciation of all capital, something that would be more appropriate for overlapping generations models, and also by full adaptation of industrial structure (namely number of firms) to eliminate profits due to scale economies. However, both of these assumptions are more appropriate for the "long run." In this sense his model, albeit offering interesting insights is not appropriate as a guide for thinking about policy towards agriculture and growth.

A more recent model fully in the endogenous growth model tradition is that of Matsuyama (1992). Matsuyama considers a two-sector model of agriculture and non-agriculture (industry). Agriculture is characterized by traditional diminishing returns production function of labor, but industry is characterized by the accumulation of knowledge as a byproduct of aggregate production. These external economies that arise from learning by doing are external to the firms and increase industrial productivity, while there is no such knowledge accumulation in agriculture. Labor is assumed to move freely between the two sectors so as to equalize short run marginal products. There is no capital in his model. He also assumes a demand system that implies an income elasticity for demand of the agricultural products smaller than one.

His model in the short run is a simplified Ricardo-Viner (two sector three factor) model, and is used to show that, when the economy is closed, the share of employment in manufacturing (or agriculture, as the model assumes full employment) is constant over time and positively related to the level of exogenous agricultural productivity. The domestic terms of trade is a function of labor allocation and is passive in the model, namely it does not determine the rate of growth. Growth is determined by labor allocation. As the only sector that can grow is industry, because of learning by doing, the more labor that is allocated to industry the larger is the rate of growth. The share of labor that is employed in industry, in turn in the closed model is related positively to the level of agricultural productivity. Thus in the closed economy, agricultural productivity increases are crucial in inducing growth.

However, this result seems to depend crucially on the closed economy assumption. When the world is composed of two similar economies of the above type, then Matsuyama shows that there is a negative link between agricultural productivity and growth. The reason is that a more productive agriculture that employs more people, slows down the rate of labor transfer to industry, and since industry exhibits external learning effects, slows down growth.

The rather counterintuitive results of Matsuyama do not imply that an economy with more productive agriculture is necessarily worse off than one with less productive agriculture. They just imply that the rate of growth is smaller. The major contribution of Matsuyama's paper is to demonstrate that the relationship between agricultural productivity and growth depends on the openness of the economy. His model depends on the assumption of no international knowledge spillovers. It is also rather special in the sense that it does not include a non-tradable sector, and in that it assumes that both agriculture and manufacturing production depend only on labor and not on capital. Finally it depends on the assumption that learning by doing exists only for the non-agricultural sector. There is no a-priori reason why this should be so. It is more likely that learning by doing exists in sectors using technologies with economies of scale, and applying modern techniques. There are many traditional industrial sectors that are not subject to economies of scale, just as there are agricultural production technologies that are subject to modern techniques and economies of scale. A better distinction in that model would perhaps be between modern and traditional sectors.

Another theoretical work that examines the role of agriculture in the course of development is that of Taylor (1991). Taylor utilizes a structuralist model of an economy, namely one that incorporates "stylized facts" about economic behavior, rather than functions that derive from optimizing behavior of agents. His model includes two major sectors, one that is largely quantity adjusting under non-full employment in the short run and another that is price adjusting (a fix price, flex price specifications).

Taylor explores the implications of an "agriculture-first" strategy in the sense that agricultural investment is increased autonomously. Taylor attributes considerable significance to the internal terms of trade, and it is via the different changes in the internal terms of trade that the results obtain. He shows that the way in which an agriculture first strategy affects long run growth depends on whether the movement in the internal terms of trade make agriculture's income fall or rise. In the latter case growth in enhanced, while in the former it is not. Thus, the value of the various elasticities that determine the domestic terms of trade, as well as the various distributional parameters are crucial in determining the contribution of agriculture to growth. This is especially important as most of the studies of technical change in agriculture have found that the major gainers from new agricultural technology are the consumers of agricultural

products. This tends to benefit urban poor consumers as well as small farmers and rural landless. It is thus the domestic elasticities of demand for food that matter for the contribution of agricultural technological change to poverty reduction, and it is clear that these are influenced by the degree of openness of an economy (Evenson and Westphal, 1995).

Another recent model that analyzes a two sector (agriculture-industry) economy, is that of Skott and Larudee (1998). Their model assumes increasing returns to industry and non-increasing returns to agriculture. Under autarchy they show that successful industrialization requires adequately high agricultural labour productivity growth, otherwise the economy may fall into a de-industrialization trap. This is compatible to what Matsuyama (1992) showed for a closed economy, and this is no surprise as both assume increasing returns to industry. However, Skott and Larudee diverge from Matsuyama in showing that under free trade economic growth and industrialization are possible if the initial conditions are such that the economy is not in a de-industrialization trap. Such a trap, in turn is possible if the initial level of industrialization is not too high, and the wage share in industry is high. These conditions may resemble the initial conditions of some countries in Sub-Saharan Africa in the post-adjustment period and Eastern Europe in the post-transition period, and hence such a model may be helpful in understanding the stagnation in these regions during the last ten years.

The above models and theories point out that the degree of openness, especially in the presence of economies of scale, is a key factor in understanding the role of agricultural productivity growth in speeding up overall growth. They also point out that since that demand factors are crucial in determining whether agricultural productivity growth is helpful for overall growth, the distribution of income and gains from growth is a key factor in this issue. They finally point out that the composition of demand among tradables and non-tradables seems to be an important element of the agriculture-first theories. To-date, however, there has been no theory or framework integrating all the above elements. The models also do not consider the issue of how agricultural productivity growth is to be achieved and how it is to be financed.

Do policies matter in the pace of agricultural growth? The empirical work of Mundlak, Cavallo and Domenech (1989) and Coeymans and Mundlak (1993) is the most serious attempt to date to relate macroeconomic and other policies to the internal terms of trade and growth. The empirical model that they employ is a non-full employment small economy model that assumes investment functions related to sectoral profitabilities. The overall savings-investment balance in their models comes from the external sector, which is assumed to be able to provide enough "savings" to finance the investments that are desired domestically. In this sense their models are "structuralist" according to Taylor's (1991) terminology, as the two most important macroeconomic "closure rules", namely the one governing the labour market and the one that concerns the savings-investment balance are clearly non-neoclassical. A major innovation of their models is the endogeneity of the technological adaptation in agriculture. This is modeled by varying parameters of a Cobb-Douglas production function, where the parameters are made functions of various other exogenous and policy variables.

The authors find that agricultural taxation and macroeconomic policies influenced considerably the pace of agricultural and overall economic growth in Argentina and Chile. They also show that the degree to which macroeconomic policies affect agricultural and overall growth depends on the extent of "tradability" of the sectors, namely the shares of products produced by various sectors that are tradable. Taxation of agriculture, both direct and indirect has slowed down the adoption of better technologies in production, and hence slowed down growth. They also find

that government investment influences positively private investment, as one would expect, but the financing of investment makes a difference, as deficit financing via domestic borrowing crowds out private investments.

# 4. Agriculture, Growth, and Poverty Reduction

Is growth in agriculture conducive to reducing overall poverty? If yes, is it more likely to do so than growth in non-agriculture? What are the conditions that make agricultural growth a major contributor to poverty reduction? These are the major questions that policy makers may be interested in when thinking about development strategies that are pro-poor. What does the literature say on these issues, and are there clear answers?

The ways in which agriculture can affect the overall poverty level in a country can be direct and indirect. The direct way implies that agricultural growth lowers directly the degree of poverty in rural areas and the whole economy. The indirect way implies that the way agricultural growth contributes to overall poverty reduction is through the contribution of agriculture to overall growth, and through the latter's contribution to poverty reduction.

Consider the contribution of overall growth to poverty reduction. This issue can be investigated by examining the relationship between growth and income distribution, or directly via the relationship between growth and poverty reduction. On the former, there is considerable recent literature that re-examines the Kuznets inverse U hypothesis, namely the proposition that starting at a low level of income, the income distribution worsens at early stages of growth, before it improves. This hypothesis received support in the 1970s (e.g. by Ahluwalia, 1976), but recent research has weakened the earlier results and has shown that much of the earlier results were due to omitted country-level effects (Anand and Kanbur, 1993, Bruno, Ravallion and Squire, 1996). In fact the review of Bruno, Ravallion and Squire (1996) showed that the income distributions in most countries tend to be stable over time, while they vary considerably across countries. Similarly Ravallion and Chen (1997) find that aggregate income growth in 43 countries did not associate itself with reduced inequality.

This suggests that the major influence on poverty reduction is broad-based overall growth. This seems to be supported by a variety of other recent studies, such as the ones by Fields (1989), Squire (1993), Lipton and Ravallion (1995), and Deininger and Squire (1996). The last one of these studies, shows that in periods of aggregate growth, the income of the poor increased in 88 percent of the cases. Birdsall, and Londono (1997) similarly find that the elasticity of income growth of the poor with respect to aggregate income growth is 1.3.

The fact that country specific effects seem to be important in explaining the differences among income distributions in different countries has given rise to some work trying to explain these cross country differences in more detail. A recent paper by Bourguignon and Morrisson (1998) suggested that a major explanatory factor in cross-country differences in income distribution is the degree of dualism in economies, measured by the relative labor productivity between agriculture and non-agriculture. Other important explanatory factors in cross country differences in income distributions were also agriculture related, namely the amount of land per capita and the share of land cultivated by small and medium farmers. Bourguignon and Morrisson interpret their findings as suggesting that "...in many countries increasing the level of productivity in traditional agriculture may have become the most effective way of reducing inequality and poverty."

The fact that recent research points out that general growth improves all incomes and hence under a constant distribution reduces absolute poverty, does not mean that the pattern and

structure of growth do not matter. A paper by Ravallion and Datt (1996), that used time series of income distribution data from several Indian states, showed that while urban income growth contributed to urban poverty reduction, it did not contribute to rural poverty reduction, or overall national poverty reduction. On the other hand rural income growth contributed to both urban and rural poverty reduction, as well as national poverty reduction in India. These results, that are compatible with the Bourguignon Morrisson findings, provide the strongest evidence to date that rural growth is more pro-poor than urban growth. The Ravallion Datt analysis showed that 85 percent of the large reduction in poverty in India during the period of analysis was due to agricultural growth, and this is very strong evidence that agricultural growth is pro-poor. The finding of Ravallion and Datt is contrary to the earlier finding of Quizon and Binswanger (1986, 1989), who showed, using a partial equilibrium multimarket model for India, that the agricultural growth effects of the Green revolution did not benefit the rural poor. The analysis of Quizon and Binswanger, however, only considered agricultural incomes and did not consider spillover effects to non-agricultural incomes. The authors in fact showed that the main way to help the poor, were rises in non-agricultural incomes (of both rural and urban residents). The issue then is, whether initial rises in agricultural incomes help increase the non-agricultural incomes that eventually help the poor. These authors did not go into this subject.

Another paper by Ravallion and Datt (1999) showed, using the same state level Indian data as in Ravallion and Datt (1996), that the factors that were instrumental at reducing poverty were higher average farm yields, higher state development spending, higher non-farm output (both rural and urban), and lower inflation. The elasticities of poverty reduction with respect to the various variables above were the same across states, except those with respect to non-farm output. Thus, while differences in agricultural output growth had the same impact on poverty irrespective of state, the degree of non-farm output growth had different impact on the poor depending on the state. Yet another paper by Datt and Ravallion (1998) found that rural absolute poverty is negatively related to the real rural wage and the average farm yield, and positively related to the relative price of food. Thus lower food prices were in that case poverty reducing, largely because a large number of the Indian rural poor are landless, and hence net food buyers. They estimated both short run and long run elasticities of various poverty measures to average agricultural yields, and found that while the short run total (direct and indirect) elasticities were negative and between -0.18 and -0.41, the long run elasticities were substantially larger (from -0.88 to -1.93), implying that increases in farm agricultural productivity have substantial effects in the long run, namely after the rural agricultural and non-agricultural labor markets have had time to adjust.

While the number of studies investigating the structure of growth and its impact on poverty reduction is small and concentrated on India, they all seem to point out that agricultural growth is poverty reducing, and more so than other types of growth. Is this a result that can be generalized across countries? The evidence suggests that this is not so. For instance Timmer (1997) finds that the impact of agricultural growth on poverty reduction depends on income distribution. Timmer utilizes the concept of the "elasticity of connection" between growth in the overall economy and growth in the per capita incomes of the poor, specified as either the bottom twenty or forty percent of the income distribution. If growth is uniform for all incomes, then this elasticity should be equal to one for all income groups. He finds by simple regression of the log of per capita income of a given income quintile on the log of average income per capita (including fixed effects), that these elasticities for the poorest quintiles are smaller than one, while those for

the top quintiles are larger than one. He then tries to account for these differences by permitting the elasticities to vary as functions of distributional variables.

He finds that the overall income inequality, measured by a variable intended to capture the relative income gap, between rich and poor[1], does not affect much the estimated aggregate elasticities of connection. He then goes on to investigate whether differences in sectoral labor productivities matter. He finds that income inequality affects considerably the elasticity of poverty reduction with respect to different types of sectoral growth. For instance in countries where the relative income inequality is large, the elasticity of connection between agricultural labor productivity, and the per capita income of the bottom quintile is very small and not statistically different from zero. The same holds for the elasticity of connection with respect to non-agricultural labor productivity. The elasticities for the top quintile, by contrast are larger than one. For countries with small relative inequality, the elasticity of connection is close to one for both types of income, and slightly higher for agriculture. This basically says that the contribution of agricultural productivity to poverty reduction is a function of the inequality in the country, with unequal countries having a low elasticity of connection.

Timmer uses his results to estimates the impact on the poor and non-poor from a uniform aggregate economic growth of 5 percent in per capita terms. Assuming that the composition of growth is such that agriculture grows by 3 percent, while non-agriculture grows by enough to keep the overall 5 percent growth rate, he finds that over a 25 year period, in low inequality countries the per capita incomes of those in the bottom quintile grow by 241 percent, while the incomes of those in the top quintile grow by 211 percent, thus narrowing the income distribution. By contrast with the same assumptions the per capita incomes of the poor in a high inequality country would grow by only 73 percent, while those of the top quintile would increase by 273 percent, worsening substantially the income distribution.

DeJanvry and Sadoulet (2000) find results similar to those of Timmer (1997), as far as the impact of distributional variables on the elasticity of poverty reduction to overall growth. Using data on rural and urban poverty from Latin American countries, they find that the elasticity of urban poverty to overall income growth is -0.95, and they also find that agriculture related variables do not affect urban poverty. On the other hand they find that the degree of income inequality does affects this elasticity, with low inequality increasing considerably the absolute value of this negative elasticity, while high inequality almost erases the ability of income growth to reduce urban inequality. Concerning sectoral aspects, they find that growth in the service sector is important in reducing urban poverty, but growth in agriculture or manufacturing is not.

Concerning rural poverty, they find that the elasticity of rural poverty reduction to overall growth is smaller at -0.75. They also find that high levels of initial rural poverty make the absolute value of this negative elasticity very small, while low levels of initial rural poverty increase its absolute value considerably. Hence the elasticity of poverty reduction with respect to overall growth depends on distributional variables. In contrast to Ravallion and Datt's (1996) work, however, they do not find significant impact on either rural or urban poverty reduction from agricultural growth. They find instead that it is only service sector growth that reduces rural poverty. It thus appears that the role of overall income growth in poverty reduction depends on the distribution

[1] The variable Timmer utilizes is a dummy, which is equal to one if the difference between the average per capita income of the top quintile and the bottom quintile is larger than twice the average per capita income of the economy.

of income in the economy, and the role of agriculture in reducing poverty depends on the country context.

That asset inequality can affect the poverty impact of growth is relatively easy to visualize. If, for instance agricultural land distribution is highly skewed and agricultural productivity growth favors the products produced by the large landowners, then it is not hard to see that agricultural growth would not be poverty reducing. Such a conclusion is supported by data analyzed by Adams and He (1995), who find that increases in agricultural crop income tend to be inequality increasing in Pakistan because of the skewed distribution of land, while increases in livestock income are equalizing. It thus appears that unequivocal agricultural growth, may not always be poverty reducing, and that initial asset distribution, in particular with respect to land, may matter, coupled with the particular way agricultural growth is stimulated.

The relationship between initial income or asset distribution and subsequent growth has been the subject of considerable recent research (for a thorough review see Aghion, Caroli and Garcia-Penalosa, 1999). The main links that the literature has identified, through which inequality can affect the rate of economic growth are credit market imperfections and political economy considerations that may affect the voting behavior of the "median voter." Empirically it seems that there is strong association between more equitable income or asset distribution and subsequent growth (for recent empirical analyses see Deininger and Squire, 1998, and Ravallion, 1997). The aspect of this literature that is relevant for our discussion here is that initial inequitable land distribution makes the relationship between agricultural growth and overall growth much weaker. The other question that it raises is whether agricultural growth under inequitable land distribution can worsen the income distribution, and hence make subsequent growth slower. In such a case agricultural growth could slow down overall growth. There do not appear, however, to be studies to deal adequately with these issues.

It thus appears that the evidence reviewed suggests that agricultural development is associated with overall and rural poverty reduction, but the relationship maybe conditioned by initial asset and income distribution, as well as country characteristics.

# 5. The Channels Via Which Agricultural Development Reduces Poverty

There are basically three ways through which the poor (or anyone else for that matter) can improve their real incomes. First is through increases in the productive assets they own. This can be done either through their own investments, out of their own savings or borrowing, or through increases in publicly provided but privately appropriated assets, such as health and education. The second mechanism is by improved employment and returns to the assets the poor already own. Such improved returns could obtain, for instance, through increased utilization of unused land, profits from increases in prices for the products the poor produce and sell, or increases in employment and wages. The final channel is through increased productivity of the assets the poor own. This could involve, for instance, increased land or labor productivity, namely increased output per unit of land or labor at unchanged prices. How does agricultural development contribute to these three channels?

The answers to the above question depend on the structure of assets of the poor, on the structure of their income sources, on the structure of various institutions that mediate between the poor and the rest of the economy (such as markets, family networks, etc.), and on the dynamic economic and social processes that create and maintain poverty. In other words they depend on the static and dynamic profile of poverty. Concerning the sources of income of the different classes of the poor in a country, it is useful to classify them as income from agriculture (normally divided by income from crops and livestock, or as income from food and non-food, or income from tradable and nontradable products depending on the data and context), income from farm and non-farm labor employment, profit income from own enterprise activity, income from land rentals, and income from various other sources such as transfers, remittances, dividends etc.

The profiles of the poor differ considerably in different countries and regions. For instance many of the poor in South-East Asia are rural smallholders, with substantial portions of their income coming from agriculture, but also many others are rural landless, relying primarily on farm and non-farm labor income. In much of Sub-Saharan Africa, the poor are mainly rural with the bulk of their incomes from agriculture. In Latin America a large part of the poor are urban based, relying for income on informal enterprise activity and non-farm labor.

Another differentiating aspect across countries is the existence of different farming systems in different agro-ecological zones and parts of the world. The recent FAO farming systems study, done for the World Bank (FAO, 2000) exhibits the heterogeneity in farming systems across the world, but also highlights the fact that even within the same agro-ecological zone there may be several farming systems that coexist.

Along with the static description of poverty, of significant importance are the dynamic poverty processes, namely institutional features that create and, more importantly, maintain poverty. An early description of a variety of such mechanisms, as they apply to the rural sector, is given by Jazairy, et. al (1992), based on the experiences of IFAD in dealing with rural poverty related projects. They include dualism, population pressures, resource management and environmental degradation in fragile settings, natural production cycles inducing production risk, social

marginalization of women, cultural and ethnic factors, and exploitative intermediation mechanisms. In that volume an attempt was made to indicate the importance of these various mechanisms in different countries. Overall they managed to characterize the rural poor as falling largely into the following functional classes.

- Smallholder farmers
- Landless rural residents
- Nomadic pastoralists
- Ethnic indigenous groups
- Artisanal fishermen
- Displaced or refugee populations
- Households headed by women

It should be clear from this characterization that agricultural growth has different poverty reducing and growth implications under different settings, and for different poor groups.

Consider increases in private productive assets. One mechanism through which such assets can be augmented, and especially benefiting the rural poor, is land distribution, land reform, or general enhancement of property rights to land. There are considerable issues concerning land relations in agricultural development, and they have taken new dimensions in the context of the transition of many countries in Central and Eastern Europe (for useful surveys see Binswanger et. al, 1995, Swinnen, 1997, de Janvry et. al., 2001). They will not concern us here, as they form a major subject on their own. For this survey it will be assumed that the landed poor own or have access to given amounts of land, through some form of tenure. The landless poor, of course, do not have agricultural land.

However, a major issue, which is related to agricultural development and its role in reducing poverty, is security of land ownership or tenure rights. These rights are far from secure in many developing countries, and this may be a major impediment to land augmenting technical change, that will enhance the value of land. This could be, for instance, a major problem in most African countries, where the land tenure systems are such that they provide very weak private ownership rights. Access to land has many advantages for poverty reduction, and often for achieving efficiency gains. For instance access to farm land can give value to many factors that are underutilized otherwise by poor (e.g. family labor), can lower the cost of using household factors of production (e.g. family labor through the lower transactions and supervision costs), can provide food security and insurance when food prices rise, etc. (for a complete discussion see deJanvry et. al., 2001).

Thus the poverty and growth implications of any land augmenting technical change in agriculture will depend considerably on the existing land tenure system, because it is the appropriation of the benefits of technical change that is at issue. As Adams and He (1995) showed, agricultural development concentrated on technological change in crop production tended to worsen income distribution in rural Pakistan, as most of the poor were landless, and as increased crop income tended to favor the owners of land. Hayami (2000) illustrates vividly the different growth paths of agricultural development since the nineteenth century in the Philippines, Indonesia and Thailand, and attributes the different agricultural growth trajectories to the evolution of agrarian structures in these countries. In the Philippines, bimodal and dual agrarian structures, while initially efficient due to the early substantial expansion of the land frontier, eventually turned into a disadvantage because of the inefficiencies of large-scale

agriculture with its monitoring needs for hired labor. On the contrary, in Thailand and Indonesia, despite similar early vent-for-surplus agrarian development, the agrarian structure that was maintained was largely unimodal and smallholder based, that facilitated later agricultural growth and development. More research on this issue is needed.

Consider increases in private productive assets through investment. It is well known that most poor people face credit constraints, hence most of their investments are made using own funds out of personal savings. To have savings, of course, implies that households can meet their basic food and other needs first, out of whatever income they have. The evidence from household surveys suggests that the poor do have savings, often of the order of 20-30 percent of their gross incomes. If there are variations in the incomes of the poor, and of a magnitude that can reduce basic needs satisfaction below some minimum acceptable levels, then there is vulnerability. That there is considerable vulnerability among the poor around the world is well documented in WDR2000, in chapter 8.

Under vulnerability the poor may devote a considerable portion of whatever savings they have into liquid forms of non-productive assets, as insurance. Such assets can take the form of grain stocks or animals in rural areas, gold and jewelry in non-farm households, etc. This has been documented in several analyses of microeconomic behavior (see references in page 143 of the WDR2000). The poor, in response to external risks, may devote a disproportional portion of their savings to such unproductive self-insurance and hence reduce their investments in more productive activities. Thus, the need for precautionary savings may reduce the growth opportunities of the poor, and may create poverty traps. For instance, Rosenzweig and Wolpin (1993) found that in rural semi-arid India, poor farmers are less likely to invest in irrigation equipment than in bullocks, despite the fact that the return to the former is higher than the return on the latter, because bullocks can be sold in times of need, while pumps cannot. Similarly Fafchamps and Pender (1997) showed using similar panel data from ICRISAT that the indivisibility of profitable investments, such as wells, coupled with the need to have cash on hand for insurance purposes, made it very difficult for poor households to undertake such investments. In the same vein, in many parts of the world, the need to maintain some income when adverse shocks occur, induces parents to pull children away from school (an acknowledged profitable investment) and send them to work. This clearly prevents human capital accumulation and leads to persistent poverty across generations. It is clear that under such conditions, what is needed is some institutional mechanism to provide in a reliable and credible way cheaper insurance to the poor, in order to let them utilize in a more productive way their own savings.

The second major way in which poor can expand their own assets is through acquisition of human capital such as education and better health. The role of the government in provision of such assets is crucial and has been reviewed extensively in WDR2000 (chapter 5). It will not be discussed further here, as it does not pertain directly to action to improve agricultural growth. However, it must be mentioned that human capital assets by households such as education can make for more efficient use of other productive services. An example is the use of irrigation equipment, which was found in Vietnam to be more efficient by better educated farmers (Van de Walle, 2000). Thus it appears that there are complementarities between human capital variables and the productivity of physical capital. This implies that agricultural productivity enhancing measures, such as provision of infrastructure and new technologies, will produce higher returns when implemented by more educated producers, or when accompanied by action to strengthen the education of those affected. Another aspect of public sector provision of human capital

services is that it appears that the poor do better with some of all, rather than with a lot of one type of service and little or none of the others (Lipton, 2000).

Agricultural development involves productivity increases, and this can occur through either new techniques of production, or through productivity enhancing infrastructure and human capital investments. These are the main mechanisms identified earlier in section 2 that create agricultural growth, and it is these mechanisms that must be considered in their possibility to alleviate rural and urban poverty. There are direct as well as indirect ways in which agricultural development can contribute to poverty alleviation. The direct way involves direct improvement in the incomes of the rural poor, through adoption of improved techniques, or increases in the productivity of their agricultural assets such as land. Such increases in productivity can come about through agriculture-related research, and extension, as well as agriculture related infrastructure investments, such as irrigation, and rural electrification. The extent to which such agricultural productivity improvements lead directly to income increases of the poor depends on the extent to which the poor produce the products for which improved techniques become available, as well as the degree of adoption of the new techniques by the rural poor.

Consider new techniques of agricultural production. These normally involve the possibility of higher crop or animal yields. For crops this can involve improved yields for food or non-food crops. While both can lead to improved incomes, increased yield of staple foods has the advantage that a portion can be consumed directly by poor producing households since the income elasticity of demand for staples is normally larger than zero. This implies that the increase in marketed surplus out of increased production of foods by poor rural producers will be smaller than the increase in production, and this avoids large price declines of staples when the products are not perfectly traded, the markets are imperfect, or the price elasticity of demand in the rest of the economy is small. That such imperfections are prevalent in the rural areas of developing countries is by now well accepted, and a substantial part of development economics research over the past twenty years has been devoted to examinations of the implications of such imperfections (for useful surveys see Bardhan and Udry, 1999, Bell, 1989, Stiglitz, 1989, Besley, 1995).

Concerning adoption, it is not at all assured that the poor agricultural smallholders will adopt the improved techniques so as to benefit directly. The major reasons involve uncertainty and risk about the new technology (for a survey of agricultural technology adoption see Feder, Just and Zilberman, 1985), plus issues involving the availability of the minimum initial capital that may be needed to implement the new techniques. Under conditions where adoption is perceived as risky, and in addition requires capital outlays, it is quite likely that the early adopters are the better off farmers. This may create initially adverse consequences for the poorer farmers if the increased production of the progressive farmers depresses domestic prices. This may either marginalize the poorer farmers or may accelerate their tendency for adoption. In any case historically the Green Revolution seems to have had negative initial effects on the smaller farmers, but the later impacts were positive (Byerlee, 1996).

Binswanger and Von Braun (1993) have reviewed the issues of agricultural technological change and poverty alleviation. They note that country experience suggests that agricultural yield increasing technological change, coupled with better infrastructure to improve commercialization of the increased production has been crucial to expanding agricultural growth, food supply and employment, all of which are crucial to the poor.

While there are cases that may be cited where technological change and commercialization has been blamed for the decline of welfare of the poor, they show that in all such cases there are other factors that have been responsible for these adverse effects. They note that uneven regional agricultural development, while it may lead initially to adverse consequences for the residents of the regions that have not adapted, due to the treadmill effect, will probably benefit the poor through consumption improvements. They also showed that late adoption by the poor, something that may be expected in view of the higher relative risks faced by the poor, does not necessarily put them in a disadvantage. They also cite examples from Ethiopia and Sudan, where agricultural technological change led to substantial increases in the returns to land, and led to eviction of tenants, thus marginalizing the poor. However, the impoverishment in such cases was not due to the development of agricultural technology, but rather to other accompanying anti-poor policies. Binswanger and Von Braun also review the issue of targeting technological change to the poor, and they find that the scope of targeting technological change to the poor is limited.

The major way, however, through which the poor may benefit from agricultural technological change is indirect. Mellor (1999) makes the point that while recent empirical evidence, such as in the papers reviewed above, "...make a powerful case that it is agricultural growth and essentially only agricultural growth that brings about poverty decline in low income countries with a substantial agricultural sector", the explanation for this relationship is older and associated with the work of Johnston and Mellor (1961), Mellor (1961, 1976, 1995), Mellor and Johnston (1984), and Mellor and Lele (1973). Mellor (1999) has reiterated this explanation, pointing out that the main channels through which agricultural productivity increases impact on poverty reduction are non-agricultural employment generation, increases in staple food output through yield increases so as not to increase unduly domestic prices for the foods that are the major wage goods, and shifts towards more high valued labor intensive agricultural commodities, that stimulate demand for agricultural labor.

Concerning employment generation of agricultural productivity increases, Mellor (1999) makes the point that agricultural employment is not likely to be very much stimulated by improvements in land or labor saving technology of production of staple foods, because the elasticities are rather low, normally much smaller than one. He suggests that a much more likely contributor to agricultural employment generation is the stimulation of production of high value labor intensive commodities such as fruits and vegetables. However, such a stimulus must come from increases in demand for these products, that are in turn stimulated by higher incomes. Thus, one needs higher incomes to generate such rural employment growth. He then goes on to suggest that the major stimulus to rural employment is not from agriculture, but from rural based non-agricultural activities. He suggests that employment elasticities from rural non-farm activities are close to one.

The major way that has been identified by the literature, in which agricultural growth contributes to overall growth and simultaneous poverty reduction is the stimulation of demand for non-tradable labor intensive non-agricultural activities, through the demand linkage effect mentioned earlier. Supply of such activities is normally assumed to be very elastic under the hypothesis of underutilized labor resources in rural areas of developing countries. Hence, the increase in demand is assumed to lead to an almost one-for one increase in supply, and this is what accounts for the large multipliers. The estimated multipliers from increased agricultural output to overall output are in the vicinity of 1.4-1.8 in most studies (e.g. Hazell and Roell, 1983, Haggblade, Hazell, and Brown, 1989, Delgado, et. al., 1998, ), and can reach values as high as 3. However,

in cases where the price elasticity of supply of labor is not infinite, then these multipliers are smaller (Haggblade, Hammer, and Hazell, 1991).

Mellor (1999) also makes the point that development of urban-based formal sector manufacturing in the absence of agricultural growth is not likely to reduce poverty. The reason is that formal sector manufacturing growth through borrowed techniques from abroad, is most likely to be capital intensive. This implies that while the wages of some lucky formal sector employees may be high, the reservation wage of those who supply the pool of potential employees, namely the average product of labor in agriculture will not rise. The consequence is that more rural people may migrate to the cities in search of high paying formal sector employment, with the result of larger urban unemployment, lower urban wages, and higher urban poverty. This is a pattern that seems to have been followed in many Sub-Saharan Africa countries.

Of course, the demand stimulus for higher valued agricultural products, and for rural based non-agricultural activities does not have to come strictly from the agricultural sector. Broad-based increases in urban incomes can also lead to a stimulus for rural incomes, especially if the marketing margin from rural to urban areas is small. This indicates the two conditions that must be fulfilled so that urban based growth can stimulate poverty reducing rural income growth, namely the broad based nature of urban growth, and the reduction of the cost of rural-urban marketing.

The channels through which agricultural growth and public investments in agriculture contribute to overall income growth and poverty reduction have been made the object of empirical analysis by two recent studies by Fan, Hazell and Thorat (1999) for India, and Fan, Zhang, and Zhang (2000) for China. In both studies an econometric multiple equation model is estimated that attempts to explain rural poverty, total factor productivity in agriculture or simply agricultural production, rural wages, rural non-farm employment, the agricultural terms of trade and several infrastructure variables. It is found in both studies that rural poverty is negatively and significantly associated with agricultural total factor productivity (or growth in agricultural production), rural wages, and non-farm rural employment. Agricultural total factor productivity is explained by a sequence of infrastructure related variables, such as irrigation, rural roads, literacy, electrification, as well as by expenditures on agricultural R&D. Wages and non-farm employment in turn are determined by both agricultural and non-agricultural production variables, as well as infrastructure spending variables. The most important variables in these empirical analyses in terms of both TFP improvements, as well as rural poverty reduction are investments in agricultural R&D, and investments in rural roads, followed by education. The elasticities differ by country, which attests to the fact that local conditions and institutional specificities matter. The results are, nevertheless, compatible with the view that it is not only agricultural productivity growth that is important for poverty reduction, but also complementary human and nonhuman infrastructure investments. The results also tend to corroborate the view that it is through the stimulation of non-farm rural non-tradable activities that agricultural growth helps to reduce poverty and at the same time enhance overall growth. It is clear that more studies of individual countries are needed to generalize these findings.

All the above raise the question of the conditions that are conducive for agricultural growth to have beneficial impact on overall growth. Delgado, et. al (1998) have outlined these conditions. The first condition is that agriculture must account for a large share of aggregate employment. The second is that agricultural growth must be equitable and evenly distributed. In other words it

must allow a large number of rural people to increase their incomes and hence demand. This condition will be fulfilled when agricultural growth is targeted to products that are produced with labor intensive technology and by a broad range of rural producers. Initial asset distribution, especially for land matters. The third condition is that the consumption patterns of the direct beneficiaries of agricultural growth must be such that large shares of the increments to income are spent on labor-intensive local nontradable goods and services. In other words the growth multipliers are likely to be larger the less open the rural economy is, in the sense that the bulk of the local economy consists of production and consumption of nontradables. The final condition is that there must be a supply of underutilized local resources to make the supply of local nontradables elastic, so as not to choke the increased demand for local nontradables by undue increases in prices.

Note that one of the key conditions is that agricultural growth must be broad based, in the sense of benefiting a large share of the rural people. It is in this sense that agricultural growth is poverty reducing. In order for such a condition to hold the productivity changes induced by whatever interventions are made must be such as to touch a large share of the rural producers. Nevertheless, Mellor (1999) points out that an initial skewing of the benefits of agricultural growth towards the higher income rural producers is not in conflict with poverty reduction. He points out that if these producers spend a large portion of their extra incomes on local nontradables, then eventually the poor will benefit through local employment creation. This, however, may take some time. Another aspect of the relationship between agricultural development and poverty reduction is the relationship between agricultural development and nutritional improvements. At low levels of income, rural households in developing countries are not very well nourished, they spend a large share of their income on own produced staples, and the income elasticity of demand for such staples is high. Thus agricultural productivity growth, especially for staples, apart from improving incomes, can improve the nutritional status of many of these households. Better nutritional status can in turn improve overall labor productivity, as suggested by a variety of micro studies (see for instance Strauss, 1986, Behrman and Deolalikar, 1988). Better labor productivity can have growth implications. In a recent empirical analysis Arcand (2000) finds a significant relationship between the initial level of the prevalence of food inadequacy (PFI) or the dietary energy supply per capita (DES), and subsequent overall growth. Given that these two nutritional variables are normally strongly associated with the overall levels of poverty in a country, Arcand's results suggest that the initial degree of undernutrition and poverty is detrimental to growth. Arcand subjects his results to a battery of robustness tests, which preserve a significant relationship between the level of undernutrition and subsequent growth.

Arcand further finds that there are nutritional growth traps, in the sense that at low levels of undernutrition, growth rates are sensitive to improvements in nutrition, while at higher levels of undernutrition the relationship is much weaker. This suggests that at low levels of overall nutrition it is efficient for a country to adopt policies that improve the overall nutrition level of the population. Given the normally large shares of undernourished rural populations in most of low-income developing countries[2], such policies almost invariably include agricultural productivity growth for the rural poor. It is not clear whether Arcand's nutritional variables are

[2] Arcand's tests identify 54 countries where nutritional improvement is likely to be helpful in improving overall growth. These countries are mostly concentrated in Africa (35 out of 54), but there are also large Asian countries included such as Afghanistan, Bangladesh, India, Philippines, and Thailand.

proxies for the overall degree of poverty in a country. Even if they are, however, they still imply that poverty alleviation in the form of decreasing the number of undernourished is efficient, in the sense of improving growth. The results of Arcand are consistent with historical work accounting for growth in now developed countries. For instance Fogel (1994) claims that improved nutrition may have accounted for 30 to 50 percent of the growth in per capita income in Great Britain between 1790 and 1980.

It thus appears from the above review of the literature that the conditions that can make agricultural productivity growth to be both overall growth enhancing as well as pro-poor are the following.

- Agriculture must account for a large share of aggregate employment.
- Initial distribution of land must be equitable and property rights must be well specified.
- The technological improvements must not be risk increasing, nor should they require substantive private capital to be implemented.
- The marginal budget shares of the direct beneficiaries of agricultural growth for labor intensive local nontradables must be large.
- There must be an excess supply of underutilized local labor resources.
- There must be complementary improvements in the provision of human capital assets at the local level (education and health), as well as improvements in marketing infrastructure (e.g. roads).

The consequences of agricultural development for the poor can be direct, through improved agricultural incomes, or indirect, through the impacts on employment, wages, prices of products, and productivity of non-farm assets. A major contribution of the research on agricultural growth and poverty over the past decades has been to point out that the indirect impacts can be as large or even larger than the direct ones, but may take some time to be realized.

DeJanvry et. al (2000) have shown that the shares of direct and indirect effects on poverty reduction from agricultural TFP growth are vastly different in different institutional and economic settings. They note that in an Asian context the indirect effects are likely to be much larger than direct effects, and this implies that most of the benefits from agricultural TFP growth on the poor arise from increased employment and unskilled wage increases, as verified by the various studies of agriculture and poverty reduction in India. In Africa, the direct effects are much more important, and this suggests that targeting technological change on poor farmers is essential for poverty reduction. In Latin America by contrast the indirect effects are much larger than the direct effects, but there the benefits to the poor from technological improvements are likely to come through the declines in food prices.

What if the above conditions that make agricultural productivity growth have a beneficial impact on overall growth and poverty reduction do not hold? Should one abandon agriculture and public investments that favor it? Should one adopt policies to set the initial conditions right before investing in agricultural development? The answers to the above questions are certainly not clear-cut or generalizable, as they imply a real world where only second best policies can be applied, but certain points may be made. First, if agriculture does not account for a large share of aggregate employment, then it cannot easily be a leading sector for growth or poverty reduction. Investments in agricultural productivity growth must then be judged by comparison with investments in productivity growth of other sectors. Perhaps the best policies under such circumstances maybe investments in human capital, so as to allow agricultural producers to adapt

more efficiently to technological changes. Second, if it is difficult to change the initial conditions in the short run, then, while working toward changing them in the medium to long run, one may want to avoid the types of productivity growth that may favor adversely factors that are unequally distributed. For instance, if the land distribution is skewed, then public research in agricultural development may be better targeted towards labor intensive techniques rather than land augmenting ones. Third, if there is no large local excess supply of labor, that could be mobilized when the demand for rural non-tradables increases, then perhaps it is prudent to concentrate on improving the marketing infrastructure, and hence lower the marketing cost between rural and urban areas. This would prevent the prices of local non-tradables from increasing too much from any agricultural stimulus, by essentially making such products more tradable. The above points are not easily generalized, and the presence of only a subset of the above conditions implies that agricultural development policy in such circumstances must be judged on an individual country basis.6. Historical lessons from country experience[3]

Agricultural development played different roles in growth and poverty reduction in the now developed countries. The development paths of developed countries like the United Kingdom and the United States, relied primarily on capital intensive industrial development in the early phases that induced slow growth in labor demand. As at the same time the labor supply was increasing, the real wages of unskilled workers, the primary factor determining incomes of the poor, grew slowly and hence there was little impact on poverty. During the early phases of industrialization of these countries, namely from the late eighteenth to the mid-nineteenth centuries, agricultural productivity increased only a little. In the United Kingdom, the early agricultural technological improvement of the eighteenth century, consisted of the development of an integrated crop-livestock system of husbandry, which was more labor intensive than the traditional one, but increased the productivity of land, while the increases in net returns to labor were small. However, the total employment increased, and this gave work to many underemployed workers. The English agricultural revolution did not supply surplus labor for industry, but rather food for the rapidly rising population from which both agricultural and industrial labor was recruited. Hence real wages did not rise. It is only since 1840 that the incidence of poverty in the United Kingdom started declining, and this because of a decline in the overall labor force growth that led to real wage increases.

The expansion of the land frontier in the United States induced labor saving technological change, and increased overall production. The increase in agricultural productivity and consequent expansion of production, led to slow secular declines in the prices of food, and it is this, along with the slowdown of the growth rate of labor supply that induced real wage increases and consequent declines in poverty. It is also only since the mid-nineteenth century that in the US agricultural technology and labor productivity in agriculture started improving, thus inducing a more balanced pattern of growth, and favoring more labor intensive techniques.

By contrast in countries like Japan development in the nineteenth century occurred through a broad based strategy to improve subsistence-oriented agriculture, a strategy that led to both reduced poverty as well as improved growth. The Japanese model was transplanted to Taiwan, which under the Japanese colonial administration, by the 1920s had a well established agricultural research system, irrigation infrastructure, availability of chemical fertilizers, and a

[3] This very brief description is taken mainly from Hayami and Ruttan (1971) and Mellor (2001), and is not meant to be comprehensive.

well developed transportation and marketing system, so as to facilitate the provision of marketed surplus to Japan. The introduction of new rice varieties in the 1920s induced large increases in fertilizer use, and increased yields considerably. In contrast to the English agricultural revolution, in Taiwan, labor productivity and the labor earnings of individual cultivators rose concurrently with the rise in land productivity, which resulted from the introduction of modern biological technology. The increased incomes of farmers permitted the transfer of resources to non-agriculture, primarily small rural based industries, as well as to government through taxation. However, the government helped the agricultural transformation by improving rural infrastructure, and heavily investing in rural education and rural public health. The consequence was not only fast agricultural and non-agricultural growth, but also a decline in poverty.

The success of the green revolution in India and other Asian countries has been well documented and needs no further discussion. In India, for instance, in the twenty year period since the introduction of the new varieties, poverty levels dropped nearly to half. This occurred partly due to increased employment of the poor in agriculture, but mostly because higher farm incomes led to increments of expenditures in local employment intensive goods and services, which in turn spurred the creation of many rural small scale enterprises to provide these goods with labor intensive techniques, in a setting with abundant and underemployed labor.

The story of China has already been mentioned. The Chinese success story relied heavily on agricultural development, spurred by both broad based agricultural technological improvements, as well as local infrastructure investments and rural education. The increase in rural incomes led to increases in demand for other products that were also provided largely by rural-based small-scale labor intensive industries. The number of absolutely poor as a consequence declined substantially from 250 million in 1978 to 125 million in 1985 and to less than 100 million in the mid-1990s.

The experience of Bangladesh is similar. Rapid broad based agricultural technological change, in conjunction with improvements in rural infrastructure, and coupled with the provision of a food security system for the poor, has made Bangladesh much less vulnerable to floods, and has reduced poverty (Mellor, 2001).

Mellor (2001) cites the example of Malaysia, a country with physical agricultural resources similar to those of Western Africa, as a success story of agricultural development and poverty reduction. The agricultural growth of Malaysia came from exportable cash crops like rubber and palm oil, rather than food crops. However, Malaysia adopted a policy of support for research and rural infrastructure that led to considerable yield increases that induced large income increases from the many small producers of these products. The intensification of rice production also led to increases in rural incomes that were translated to increased non-farm employment. The multipliers from such agricultural development strategy have been documented by Hazell and Roell (1983) and they were large.

Mellor provides other examples of successful agriculture led growth and poverty reduction stories. These include Kenya, Costa Rica, and Indonesia. In all cases the major impetus to success has been agricultural broad-based growth, with spillovers to non-agricultural sectors. Also in all cases the agricultural transformation has been aided by infrastructure investments and rural education. These are examples that reinforce the points made earlier about the conditions that are conducive to agriculture led growth and poverty reduction.

# 6. Emerging Issues of Agricultural Development and Poverty Reduction

In this chapter we discuss some issues that are bound to become more important in the future, as they pertain to agricultural development and poverty reduction.

## 6.1 Globalization

Globalization implies both fewer trade restrictions, as well as that the various trading countries may be less insular in the future, allowing for lower protection, better transmission of international prices and general market signals to domestic markets, but also allowing domestic shocks to be absorbed through international transactions. There are several issues that arise in this context. First, the general tendency towards trade liberalization is likely to lead to increased average international prices for most products (Goldin and van der Mensbrugghe, 1995). While agricultural trade liberalization has been the subject of discussion mostly among developed countries, there are implications for developing countries. These involve significant average rises in prices for cereals like wheat, rice, feedgrains, and sugar. Many of these products are of import or export significance for developing countries. Sadoulet and deJanvry (1992) found that increases of world prices for cereals and animal products are likely to have detrimental welfare impacts on the landless and small farmers, as well as the urban poor in African and Asian archetype economies, representative of countries with high levels of poverty.

Second, there may be implications about the instability of international prices. While theory suggests that more trade liberalization implies more stable prices, there were concerns expressed during the 1995-96 cereal price rise that international price instability might have increased as a consequence of agricultural trade liberalization. This, however, does not appear to be the case (Sarris, 2000).

Third, general liberalization of marketing in many developing countries since the onset of structural adjustment programs, has led to the abolition or restructuring of most marketing parastatals, abolition of pan-territorial prices, abolition of other marketing controls, etc. Such measures, while removing the price biases against several products, have also removed the previous stability of prices. They also may have led to more realistic incorporation of regional marketing margins into producer prices, a process that may have led to secular price declines and greater price instability for producers located in regions that are not well integrated with the main domestic and international markets.

Thus the consequences of trade liberalization and globalization for the poor agricultural producers depends on the types of products they produce, and on their location, and it is likely that there are gainers and losers among the poor within any given country. Nevertheless, if better response to the signals generated by increased globalization is to be sought, then it appears that more emphasis must be placed on rural infrastructure so as to lessen the cost of marketing, and make remote regions more integrated with the rest of the economies.

## 6.2 Biotechnology

The developments in biotech research suggest that both the structure of research as well the ownership of research will be different in the future. Biotechnology is based on the understanding of how biological organisms function at the molecular level, and manipulation of the DNA molecules from which genes are made to achieve desirable outcomes. The introduction of intellectual property rights (IPRs) has led to substantial new research with extensive applications to agriculture.

There are considerable potential benefits of agro-biotechnology for poverty reduction (de Janvry et. al. 2000). These include:

- Yield increase in staple food crops produced in tropical and semi-tropical environments, and in peasant farming systems.
- Area expansion towards less favored lands.
- Multiple cropping and shorter maturation periods.
- Cost reductions via resource savings.
- Risk reduction via lower susceptibility to pests and viruses, as well as to frosts, droughts, etc.
- Improved storability via insect resistance, delayed maturation, etc.
- Nutritional improvements as food and feed.
- Environmental benefits, like reduction of chemical pesticides.

There are also risks for poverty reduction such as:

- Staple food crops produced in tropical and semi-tropical environments are bypassed by research.
- Labor displacement by diffusion of herbicide tolerant plant varieties.
- Production in developed and middle level developing countries of substitutes for crops previously produced by developing countries.
- Tailoring of research towards products not fit for poor consumers.
- Terminators genes to enforce IPR may raise costs by preventing reproduction of seeds.

De Janvry et. al. (2000) suggest that new biotech research results in traits that can be usable over a wide range of local conditions, and this implies that if the institutions and information are available developing countries do not need to engage in fundamental research. However, the access to new technology may be impaired by the increasing tendency towards patenting of new gene technologies by biotechnology firms, and the wider enforcement of IPRs. This may result in improved seeds that are more expensive, incorporating the cost of innovation, as well as patent protection. If the adoption of such seeds requires more initial working capital, the adoption of genetically modified seeds (GMOs) may become more difficult for the poor. Other studies surveyed by Perrin (1999) also suggest that developing countries may not benefit from the strengthening of IPRs. Hence, the way in which biotech is applied to developing country agriculture may be very important for the poor. De Janvry et. al. suggests a variety of institutional measures to make the benefits from biotech research filter more easily towards the poor.

## 6.3 Changing Roles of the Public and Private Sectors

There are three important ways in which the role of the public sector has been changing in the agriculture of developing countries. The first concerns the role of the public sector in providing price stability and market insurance in agriculture. It has already been mentioned that structural adjustment has reduced the role of monopolistic public marketing agencies, and has increased price and possibly income instability for all agricultural producers, and most likely also for the poor. While there is no doubt that the better functioning of markets, through wider participation of market agents, for products, inputs, labor, and capital are bound to benefit all, and especially the poor, the increased market uncertainty may make it even more difficult for the poor to escape poverty. The reason may have to do with the level of precautionary savings that need to be held by poor households to buffer undesirable income variations in the presence of incomplete insurance and credit markets. If this amount depends on the degree of risk faced by households (Paxson, 1992), then the increased market uncertainty implied by the disengagement of the state from marketing may induce more precautionary savings by the poor, and hence limit the savings available for more profitable productive investments. This suggests that the role of the public sector in the context of more open markets must be redefined more as having an insurance function, rather than a direct marketing function.

The second aspect where the role of the public sector is changing involves the provision of infrastructure and community services such as health, education, sanitation, etc. While in the past the provision of such services was envisioned almost exclusively as the domain of the public sector, the new thinking sees a more mixed approach where both public and private provision are involved. There are considerable issues involved in both the financing of infrastructure and service projects, as well as the pricing of the services (for a review see Jimenez, 1995). Given the proven contribution of infrastructure investments on productivity of rural residents, and the generally redistributive role of most infrastructure investments, it is important that the new mixed approach does not end up making the poor shouldering a larger relative burden for infrastructure provision.

The third role involves research. It was already seen above that the private sector is much more involved in new biotech research compared to earlier periods. It has also been observed that there is increasing concentration of patents in these new fields (de Janvry et. al. 2000). The current patenting system on life forms allows private appropriation of knowledge on genomics, the basic material of biotech research (Wright, 1998), and this may prevent access of relevant materials for research in developing countries. However, the patenting system in this field is still evolving.

There may also be undue concentration of knowledge in few firms through the concentration in the ownership of the many patents involved in the production of a final product. De Janvry et. al. 2000 note that in 1999 75% of the patents obtained by the largest 6 agro-biotech firms were obtained through acquisitions of smaller biotech and seed companies. This may prevent open rights to the use of some biotech products by institutions of developing countries. Finally, enforcement of IPR legislation leads to more incentives for innovative activity, but at the same time may make the cost of new products higher for the poor. Thus there may be a trade-off between stronger enforcement of IPR laws and poverty reduction.

# 7. Modeling Public Policy Towards Agriculture in the Context of Growth and Poverty Reduction

In the previous chapters it was seen from the literature review that while there are some theoretical attempts to model agriculture in the contest of growth and poverty alleviation, they have not incorporated the issue of how productivity growth is to be implemented and financed. To explore these issues, a simple two-sector model of agriculture and growth was built, that incorporates explicitly both TFP growth as well as financing of TFP improvements in agriculture and non-agriculture. The idea is to obtain general results about the tradeoff between taxation of the two sectors, as well as allocation of public capital to the two sectors. As far as the author is aware this is the first such model that has been analyzed in the literature. The details of the model structure and the theoretical and empirical results are exhibited in the appendix. Here we only discuss the structure and the highlights of the results.

The model considers a small open economy with two sectors, agriculture and non-agriculture. The economy is assumed to export the agricultural product, while the non-agricultural product is non-traded. However, a non-domestically produced intermediate product is imported and used in the production of the non-agricultural sector. The non-agricultural sector is the only one producing investment goods. Such an economy, resembles many of the poor economies in Africa, as well as in some other parts of the world.

The model assumes that infrastructure or other development spending (e.g. for research, human capital, etc.) improve the total factor productivities of the two sectors, with different elasticities. However, the expenditures for these productivity enhancements must be financed, and this is done by taxation of both the agricultural as well as the non-agricultural sectors, at different rates. It is assumed that the government devotes a fraction of its total public resources for investment in the agricultural sector. Full employment of labor is assumed, and this makes the growth linkages of the model smaller than what they would be under a non-full employment structure. The dynamics of the model assume that capital allocation is more sluggish in the short run, compared to labor. Capital accumulation occurs through the saving of private agents, while the government is assumed to have a balanced budget.

The dynamic accumulation equations of the model imply a growth rate that is a function of the share of public capital devoted to agriculture, the labor productivities of the two sectors, and the degree of trade openness of the economy. However, the resulting expression for the growth rate is too complicated for general results, and some simulation exercises are performed and tabulated in order to obtain an idea of the contribution of different factors to economic growth. Under some assumptions about the structure of poverty, it is also possible to assess the contribution of agricultural TFP growth on poverty reduction.

The first conclusion that obtains is that for optimal, namely maximum under the various constraints, growth there is a negative relation between the two sectoral tax rates. A high agricultural tax rate implies a low non-agricultural tax rate and vice-versa. Also a zero agricultural tax rate necessitates a positive non-agricultural tax rate. This is necessary, as by assumption the existence of public capital is essential for production in both sectors, and hence at

least one of the sectors must be taxed to generate revenues to maintain public capital. In fact for every agricultural tax rate one can compute the optimum non-agricultural tax rate that maximizes the growth rate of the economy. Hence, one only needs to consider the agricultural tax rate as a policy instrument.

A second empirical result is that at any given degree of openness, higher values of the agricultural TFP elasticities, namely greater ease with which agricultural public sector investments enhance agricultural production, imply lower rates of overall growth. However, they imply higher rates of growth of the real incomes of the poor. Hence it appears that variations of agricultural TFP elasticity imply a tradeoff between higher overall growth rates and higher rates of real income growth of the poor.

A third conclusion is that in order to maximize overall growth, the rate of agricultural taxation is a decreasing function of the degree of trade dependence of the non-agricultural sector. Hence, an economy with high trade dependence in the production of its non-tradable good, does not need high degrees of agricultural taxation, in order to maximize growth. The opposite is true for countries with low degree of trade dependence. The optimum share of public capital going to agriculture is smaller than the share of agriculture in GDP, or the share of labor in agriculture. However, the optimal share of public capital going to agriculture is a positive function of the degree of trade openness.

Finally, it is appears that low labor intensities in both sectors imply low rates of growth, but high shares of public capital in agriculture. On the contrary, high labor intensities in both sectors imply high growth rates in steady state, and low shares of public sector capital in agriculture. Interestingly, going from low to high degrees of labor intensity of agriculture, the implied steady state rate of growth rate of the economy increases, but the real income of the poor first declines and then increases.

The conclusion from the simulations is that the parameters that matter a lot in determining the usefulness of agricultural development as an engine of growth as well as poverty reduction are the degrees of labor intensities of the two sectors, the degree of trade openness, the elasticity of agricultural TFP with respect to public capital, and the rate of domestic savings.

Concerning policy, the conclusions of the simulations are that some agricultural taxation certainly helps the overall rate of growth in small open economies, with an agricultural sector that produces the bulk of exportables. The appropriate non-agricultural tax rate is inversely proportional to the agricultural tax rate. The share of public sector capital that must be devoted to agriculture is not related to the share of agriculture in GDP, or the share of labor employed in agriculture, but is rather a function of the labor shares of the two sectors, the import intensity of non-agriculture, and the elasticity of agricultural TFP with respect to public capital.

# 8. Conclusions and Implications for the World Bank

Sustained growth in an economy requires the continuous improvement in TFP, and this for a developing country requires public expenditures for infrastructure and human capital developments Such improvements allow private agents to obtain higher levels of income, and this makes possible higher levels of consumption and investments. However, it appears that at early stages of development, in order for an economy to move from a situation where it is "...saving and investing 4 or 5 percent of its national income or less, to a an economy where voluntary saving is running at about 12 to 15 percent" (Lewis, 1954), which Lewis regards as the central problem of economic development, the economy needs an engine of growth. Such an initial engine of growth can come from a variety of sources, such as the development of export agriculture, industry, tourism, etc., and the key issue for development is what is done with the increased incomes and savings that come about from the initial engine of growth.

While in the now developed countries it appears that the major stimulus to early growth was industrial innovations, accompanied but not led by agricultural innovations, there have been some developing countries in the recent past, notably India, China and Taiwan, where growth was led by agricultural broad based productivity changes. In these countries it seems that the major source of the demand for the increased product of the agricultural sector was domestic, as there were substantial levels of initial poverty, and hence improved agricultural incomes directly led to increases in the domestic demand for the larger quantities of food produced domestically. Hence the terms of trade for the increased agricultural product did not decline so as to negate the improvements in TFP. Another important historical characteristic of these economies is that a substantial part of the cost of their agricultural productivity improvement was shouldered by external donors, including the substantial contributions of the international agricultural research centers, members of the CGIAR. Finally, it appears that given the substantial rural population densities in these countries, the cost per agricultural producer of improving agricultural productivity was relatively low, as there was no need for experimentation in too many climatically different locations.

The situation may well be different in many of the late developing countries, such as those in many parts of Africa, in the sense that the cost per beneficiary of agricultural productivity improvement may be high because of low farm population densities, at the same time that overall donor support is declining, necessitating a larger contribution to domestic productivity improvement by the state. Can agriculture play a leading role in the settings of the late developing countries, and should cash strapped governments devote a substantial share of their meager resources to agricultural TFP improvements?

The review made in this paper first examined the way in which agriculture grows. It was seen that **the basic ingredients that make up for faster agricultural TFP growth are known, such as agricultural R&D, extension, rural infrastructure, education, etc.** However, it was pointed out that **while we know the variables affecting agricultural TFP, the profession is much less sure about the magnitudes of the relevant elasticities, as well as the ways in which these elasticities are affected by other factors.** For instance it may well be that both structural parameters such as distributional variables, as well as institutional factors, such as the degree of

market imperfections may impinge on these elasticities. While considerable partial knowledge on these issues exists at the micro level for several developing countries, their contribution to agricultural TFP growth or to the magnitude of the elasticities of TFP growth with respect to other variables is much less well analyzed. For instance how does the contribution of the provision of rural roads to agricultural TFP is affected by other market imperfections? This set of issues then is an area of considerable lack of knowledge, where more research would have a high pay-off.

The review also revealed that there is by no means an unequivocal theoretical argument for agricultural development as an engine of growth. If any, recent theoretical contributions tend to rely on different structural properties between agriculture and non-agriculture concerning external effects, notably learning by doing, to argue against agricultural productivity developments as engines of growth in an open economy. It was noted in the review, however, that such treatments rely on asymmetric assumptions about the economic characteristics of agriculture and non-agriculture, and hence cannot be utilized as guides to policy unless one has more information at the sectoral level about the nature of external effects and learning by doing properties of the various sectors.

One important contribution of recent theoretical research has been to point out that **the way in which domestic incomes, are affected by the improved agricultural productivity, or any other stimulus by another leading sector, and the consequent consumption and saving-investment patterns are crucial for determining the pattern of growth.** If, for instance, improved agricultural productivity leads to higher incomes of the poor who spend it on domestic non-tradables, then agricultural growth will induce non-agricultural rural growth and via employment multipliers to decreases in poverty. If, on the other hand, the fruits of agricultural development or other leading sector economic development lead to increases in the incomes of the rich, then the important determinant for growth will be where the additional savings are spent. If they are spent for domestic labor intensive investments, then there may still be growth, and the poor may well benefit from employment creation. If, however, they are spent on imported luxuries, or invested abroad, there will be little growth stimulus. **Thus the pattern of the distribution of increased incomes from the initial stimulus is the most important determinant of subsequent growth. Agricultural development can thus contribute to both growth and poverty reduction if the fruits of the initial productivity stimulus is concentrated on those who respend it domestically (through consumption or investment) on labor intensive products with low import dependence.**

Chapter 5 took up the issue of agriculture's contribution to poverty reduction. It was noted that there may be both direct and indirect contributions to poverty reduction from agricultural development, depending on the structure of the incomes of the poor. It was noted that while recent empirical literature has highlighted the important role of agriculture for poverty reduction in labor abundant agrarian countries like India and China, the relationship is not universal. In fact a major contribution of the recent empirical growth literature has been to point out that **the elasticity of poverty with respect to agricultural productivity improvements depends on initial distributional variables.** This is consistent with the literature on the role of agriculture for growth, which highlights precisely the distributional dependence of the contribution of agricultural TFP growth to overall growth. However, it seems that the elasticity of poverty reduction should not depend only on distributional variables. **A variety of institutional and**

**other features, which may be of importance, cannot be captured precisely in cross-country growth analysis, and need to be studied through specific country case studies.**

The review revealed that **there seem to be a set of conditions that make agricultural development both growth enhancing as well as poverty reducing. These conditions involve the following:**

- **Agriculture must account for a large share of aggregate employment.**
- **Initial distribution of land must be equitable and property rights must be well specified.**
- **The technological improvements must not be risk increasing, nor should they require substantive private capital to be implemented.**
- **The marginal expenditure shares (both from consumption as well as from investment) of the direct beneficiaries of agricultural growth for labor intensive local non-tradables must be large.**
- **There must be an excess supply of underutilized local labor resources.**
- **There must be complementary improvements in the provision of human capital assets at the local level (education and health), as well as improvements in marketing infrastructure (e.g. roads).**
- **There must an income and price elastic source of demand for the increased product of agricultural, wither domestically (in the case of food crops), or internationally (in the case of exports).**

The review highlighted some important emerging issues concerning agricultural development. Globalization can create opportunities, for instance through improved agricultural terms of trade, or improved market access for a country's agricultural exports. However, it may also pose additional risks, such as increased domestic price instability. The point made is that globalization must be accompanied by domestic market enhancing policies in order to produce positive overall results from agricultural growth and for poverty reduction.

Biotechnology was also seen to pose risks and opportunities. Participation by developing countries in the still to be shaped international rules of the game concerning technology transfer and IPRs seems the best avenue for developing countries in order not to be left out of these developments.

The increasing role of the private sector in both developing countries was seen to pose new challenges for the public sector in the context of agricultural development. Joint private-public financing and responsibility for infrastructure, and research may open opportunities that were not previously available. Nevertheless, the role of the public sector in the provision of insurance seems to be enhanced in the new context.

The elaboration of a two-sector theoretical model of agricultural growth, based on external effects of public infrastructure investments, and the ensuing empirical simulations suggested some tentative conclusions concerning the role of agriculture in growth enhancement and poverty reduction. First it was shown that **maximum growth involves the provision of adequate public infrastructure, financed by higher levels of taxation.** However, it was shown that there is a negative relationship between agricultural and non-agricultural taxation for optimum growth. It was seen that **higher elasticities of agricultural TFP with respect to public expenditures imply faster real income increases for the poor, while lower overall**

**rates of growth.** This trade-off is rather surprising and needs further study and elaboration. It was also seen that **the optimum share of public investment expenditures devoted to agricultural TFP improvement depends of the degree of trade dependence of the non-agricultural sector, increasing with higher degrees of trade dependence.** This is contrary to earlier theoretical results. Finally it was shown that **the labor intensities of the agriculture, as well as the non-agricultural sectors, and the aggregate saving rates are important in determining the maximum possible growth under a strategy of agricultural development.**

The implications of the above analysis for international financial institutions involved in development, such as the World Bank, and other development banks, are the following. First, it should be clear that **the relative importance of the agricultural sector as a leading sector for growth and poverty alleviation depends on country specific geographical and economic structure variables**. There can be no single agricultural growth and poverty reduction strategy to fit all developing countries. It rather seems that the emphasis on agriculture as a leading sector should depend on a set of criteria of the type mentioned above. **Country specific strategy and policy work could then concentrate on the presence of the conditions that may be conducive to making agriculture a growth and poverty alleviation pole.** Some of these conditions were elaborated above, but it seems that there needs to be more organized analysis of these criteria and conditions, combined with specific indicators, to provide specific empirical and country relevant guidance.

Second, there is no doubt, given the considerable externalities involved in agricultural TFP growth, that **external assistance should concentrate on creating an environment that facilitates the productivity of any attendant domestic investments.** For instance, if the government of a developing country is keen on rural infrastructure, perhaps, external resources could support the development of the other necessary ingredients for growth and poverty reduction, such as rural education and health, with emphasis, of course, on sustainability of investments. This can be justified under the notion that there are complementarities between various types of agriculture related public interventions. It must be noted in this context that **there seems to be considerable lack of knowledge concerning the dependence of elasticities of both growth, as well as poverty reduction to agricultural development spending on institutional, as well as other structural factors.** This seems an area where more country specific, as well as cross-country research is needed.

Another point has to do with the type of agricultural research that is supported. **In many developing country agrarian settings, the reservation unskilled wage for the economy is close to the average product of labor in agriculture.** This for instance seems to be the case in many land abundant but labor constrained economies in Africa. This implies that **in such settings, agricultural research and productivity enhancement, in order to be both growth enhancing, as well as poverty reducing, must aim at increasing the average productivity of labor in agricultural production, without making production more labor intensive**. This is different from **settings with labor abundance, and land scarcity, where the reservation wage may be close to the marginal product of labor in agriculture. In such settings, agricultural research should try to increase the productivity of land, so as to increase the marginal product of agricultural labor.**

A major strategic issue has to do with the efficacy of agricultural productivity growth as an engine of growth as a function of rural population density. In settings of low rural population densities, the cost of agricultural productivity enhancement may be very large relative to the

benefit per affected household. In such settings the elasticity of TFP growth, as well as the elasticity of poverty reduction with respect to various types of public expenditures may be low. It was seen in the empirical simulations of the model (re. Table 2) that low values of the agriculture TFP elasticities imply low shares of public capital devoted to agriculture TFP enhancement. This underscores the fact that **the factors that determine the size of the elasticities of agricultural TFP with respect to public spending must be clearly understood, before recommendations about a rural development strategy are made.**

There are several areas where additional work is needed. First, it is not clear how many contemporary developing countries fulfill the conditions that were identified as necessary for a win-win (growth promoting and poverty reducing) agricultural development strategy. While for some conditions the verification is relatively easy, examples being the share of agriculture in total employment, the initial land distribution, and the existence of under-utilized rural labor resources, for others the verification is by no mean straightforward. This may well be an interesting empirical project for the World Bank Rural Development Department.

Second, even if all conditions can be empirically checked, it will most likely be the case that not all of them are satisfied in any one developing country. Does this mean that agricultural development policies should take second priority? Or is it the case that there is a core subset of the conditions that if satisfied can justify a vigorous agricultural development strategy. This poses the problem of agricultural development policy under a second best world. For instance, should development effort concentrate on setting the initial conditions for agricultural development right as a prerequisite for public investments in agriculture, or should the two proceed simultaneously? Unfortunately, very little is known about the relative importance of the above conditions.

Third, are all conditions identified of equal importance? For instance is the provision of adequate roads more important than the provision of human capital? Should rural education be enhanced before investments in agricultural research and extension are made? The answers to these and other related questions are not easy, and are not universal, as they are intimately tied with the historical and institutional context of any given country, as well as on an appraisal of the speeds with which any one policy can be implemented and have an impact.

Given this rather inconclusive state of affairs regarding the role of agriculture in growth and poverty reduction, one way to proceed for the Rural Development Department of the World Bank to obtain such knowledge, would be to conduct a cross-country comparative review of agricultural sector strategies and performances over the past twenty or thirty years. Such reviews have been done at the initiative of the World Bank in the past, but with very different focus, and have produced wide ranging and policy relevant results. The new focus should be growth and poverty reduction performance.

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# Appendix. A Two Sector Model of Public Policy Towards Agriculture in the Context of Growth and Poverty Reduction

## 1. Theoretical structure

The model is a modification and adaptation to the context of this study of the model analyzed by Sarris (1999), which in turn was based on the model analysed by Mas-Collell and Razin (1973), using ideas from Taylor (1991, chapter 9). Consider an economy that consists of two sectors, agriculture, denoted throughout by the subscript "a" and non-agriculture (industry for short), denoted throughout by a subscript "n". The economy will be considered as small and open for simplicity. Trade can be introduced in many ways. For instance we could assume that both goods are traded, and the economy is small in international trade. Such an assumption would impose the domestic terms of trade (barring tariffs) from abroad, and this is unrealistic, as all economies have a substantial non-traded sector. Another way would be to assume that only one of the two goods is traded and exported, and in return the economy imports an imperfect substitute in consumption with the non-traded good. The approach followed is similar to this latter one, except it makes the assumption that the imported good is incorporated into the non-traded one before it is consumed domestically. This is made purely for analytical simplicity. The economy as defined is meant to emulate an archetype African economy in the sense, for instance, illustrated by Sadoulet and deJanvry (1992).

Suppose that the economy is a small open economy that exports the agricultural product and imports a non-competitive intermediate product, which is used in the production of the non-agricultural sector. Suppose that the international prices of the exported agricultural product and the imported intermediate are given and by choice of units are both equal to one. Define as numeraire the non-agricultural price and set it equal to one. Define by e the nominal exchange rate, which given that the non-agricultural sector is non-traded, and is assumed to be the numeraire, is equal to the domestic relative price of the agricultural product faced by consumers[4].

Let the production functions of the two sectors be given by the following Cobb-Douglas formulas.

$$Y_a = AL_a^{\alpha} K_a^{1-\alpha} \qquad (1)$$

$$Y_n = BL_n^{\beta} M^{\gamma} K_n^{1-\beta-\gamma} \qquad (2)$$

where $Y_i$ (i=a,n) denotes the gross output of the two sectors, $L_i$ and $K_i$ (i=a,n), denote the labor and (specific) capital inputs into the two sectors, M denotes the imports of the non-competitive intermediate product, $\alpha$, $\beta$ denote the labor shares in the agricultural and non-agricultural sectors respectively, $\gamma$ is the share of the imported intermediate in the production of n, and A,B, denote the TFPs of the two sectors. It will be assumed that the total labor force is a constant fraction of

[4] An alternative assumption, and analytically identical, would be to normalise on the agricultural good, in which case the domestic relative price of the agricultural good would be the inverse of the price of the non-traded good.

the total population, and hence per-capita and per-worker magnitudes are simply related by a multiplicative constant and will be treated equivalently. The per capita outputs of the two sectors denoted by $y_i$ (i=a,n) are given by the following formulas, which can be easily derived from the level form of the Cobb-Douglas production functions.

$$y_a = A(1-\mu)kk_a^{-\alpha} \tag{3}$$

$$y_n = B\mu^{1-\gamma}k^{1-\gamma}k_n^{-\beta}m^{\gamma} \tag{4}$$

where $\mu$ is the share of total capital stock that is employed in the non-agricultural sector, k is the economy wide capital-labour ratio, $k_i$ (i=a,n) are the sectoral capital labor ratios, and m is per capita imports. In other words $\mu = K_n/K$, $k=K/L$, $m=M/L$, and $k_i = K_i/L_i$ (i=a,n). The variables $\mu$ and k will be the state variables of the dynamic model. If the agricultural sector is more labor intensive than the industrial sector, then it should hold that $\alpha > \beta$.

Consider the incorporation of public infrastructure in the above simple model. The major issue from an economy-wide perspective is how does infrastructure, or other public expenditures affect the shape of the production functions. The sectoral production functions estimated, for instance, by Antle (1983), Mundlak, Larson, and Butzer (1997), and others use relatively standard functional forms, such as Cobb-Douglas, and various proxy measures for physical infrastructure or human capital, such as rural road density, irrigation density, adult literacy rates, etc., in order to estimate relevant elasticities. In models of endogenous growth, such as the ones of Barro (1990), simple forms are also used for the influence of infrastructure on the production functions.

There is no doubt that the total factor productivity of agriculture, as well as non-agriculture (the "constants" A and B in the model analyzed here) are influenced by variables such as research, extension, infrastructure, and human capital. All these variables involve an externality in the sense that the overall economic returns from expenditures in such variables are often larger than private returns. In recognition of this fact governments devote considerable expenditures to all the above productivity improving activities. Studies have found that there are substantial elasticities of TFP with respect to the above mentioned factors, and also that the same factors also contribute to poverty alleviation (Evenson, Pray and Rosengrant 1999, Fan, Hazell and Thorat, 1999, Fan, Zhang and Zhang, 2000). In the sequel we shall consider a simple way of incorporating public spending in the two-sector model in order to obtain some insights.

It will be assumed that public infrastructure or other public expenditures can affect the production of individual firms in each sector by changing the value of the TFP constant A and B. In particular assume that the two constants take the following forms.

$$A = \left(\frac{G_a}{L_a}\right)^{\varepsilon} \equiv g_a^{\varepsilon} \tag{5}$$

$$B = \left(\frac{G_n}{L_n}\right)^{\eta} \equiv g_n^{\eta} \tag{6}$$

Where $G_i$ (i=a,n) denotes the total amount of sector specific public capital, $g_i$ (i=a,n) denotes the public capital in each sector per unit of labor employed in each sector, and the parameters $\varepsilon$ and $\eta$ are the relevant elasticities. The public capital can comprise both physical infrastructure, such as roads, dams, electricity grids, etc, research, extension, as well as human capital such as health,

literacy, etc. It is assumed that the production functions are affected by the per capita availability of public capital in each sector. In other specifications, like the one in Barro and Sala-i-Martin (1995) (chapter 4), the total public capital is considered rather than the per-capita magnitudes. It is not clear which specification is better, but it does not matter that much. The key behavioral assumption in the model is that the various firms and productive entities in the two sectors consider the values of A and B as exogenous to their production decisions. Hence infrastructure and other public expenditures are assumed to have external effects.

It is also assumed that the public good is non-rival and non-excludable. In other words each firm within a sector makes use of all of the public capital available to the sector, and that use of the public good by one firm does not diminish the quantity of the public good available for the other firms within the sector. This is the standard approach to public goods, due to Samuelson (1954). Notice, however, that we are assuming some kind of congestion of public capital across sectors. This is represented by the fact that the A and B parameters are functions of per capita availability of public capital to each sector. If some policy or other effect induces intersectoral labor movement, then this, for fixed public capital available to the two sectors, induces changes in the private production of each firm, because of congestion effects. So, for instance, a labor reallocation towards non-agriculture, induces a decline in B and an increase in A, ceteris paribus.

Full employment of capital and labor is assumed. This is not a major assumption as the model is designed to trace dynamic growth relations. However, it excludes "unlimited supplies of labor" or substantial disguised unemployment. Unemployment of capital and/or labor must be specified as due to some kind of rigidities, that are assumed away here for simplicity. For instance unemployment could be due to fixed urban wages at levels above the rural wages, leading to rural urban migration a-la Harris-Todaro (HT), but if such a specification is made, then some assumption must be made about how the fixed urban wages adjust from year to year, in order to trace the model dynamically. While a variety of specifications is possible, they do not influence the major results of the dynamic model exhibited below. The assumption of full employment also makes the "growth linkage" multipliers from agricultural development small. This implies that any growth enhancing results of agricultural development can be regarded as underestimates of the true results in the presence of underemployed labor resources.

Full employment of factors implies the following relation between the variables defined above.

$$\frac{1}{k} = \frac{1-\mu}{k_a} + \frac{\mu}{k_n} \qquad (7)$$

In order to finance the public expenditures, it will be assumed that agriculture is taxed at the uniform rate $t_a$ while non-agriculture (industry) is taxed at the uniform rate $t_n$. The tax rates can be visualized as indirect tax rates on the final output of each sector's product. While it is doubtful if all agriculture or all non-agriculture can be taxed at uniform rates as assumed here, the assumption of uniform tax rates is convenient for the analysis. We do not discuss the means by which taxation on each sector is imposed. The tax rates do not have to be positive, and negative tax rates imply a subsidy for the relevant sector. The tax revenue of the government are assumed to be utilized in order to provide public capital to the two sectors. A balanced budget in every period is assumed for simplicity.

Under the assumptions concerning the international prices and the normalization mentioned above, and given that the tax rates are indirect and uniform for all output, e represents the

domestic relative consumer price of the agricultural good, while the relative producer price is $e(1-t_a)/(1-t_n)$. The latter, may then be regarded as the real exchange rate.

The marginal products of labor and the returns to capital in the two sectors, denoted by $w_i$ and $r_i$ (i=a,n) respectively are as follows, where we incorporate the influence of taxes.

$$w_a = A(1-t_a)e\alpha k_a^{1-\alpha} \tag{8}$$

$$w_n = B(1-t_n)\beta\mu^{-\gamma}k^{-\gamma}k_n^{1-\beta}m^{\gamma} \tag{9}$$

$$r_a = A(1-t_a)(1-\alpha)ek_a^{-\alpha} \tag{10}$$

$$r_n = B(1-t_n)(1-\beta-\gamma)\mu^{-\gamma}k^{-\gamma}k_n^{-\beta}m^{\gamma} \tag{11}$$

Note that $1-\beta-\gamma$ is the share of capital in the production of the n good.

The per-capita demand for the intermediate is given by the following expression, that derives from the profit maximizing condition of the typical firm in the n sector.

$$em = \gamma(1-t_n)y_n = \gamma B(1-t_n)\mu^{1-\gamma}k^{1-\gamma}k_n^{-\beta}m^{\gamma} \tag{12}$$

If we denote by g the economy-wide ratio of public capital to total labor, and if it is assumed that public capital in the two sectors is made up of the same good, which will be assumed to be the n-sector good, then we can write the per capita sectoral public capital contributions as follows.

$$g_a = \frac{\rho\frac{G}{L}}{\lambda} = \frac{\rho g}{\lambda} \tag{13}$$

$$g_n = \frac{(1-\rho)\frac{G}{L}}{(1-\lambda)} = \frac{(1-\rho)g}{(1-\lambda)} \tag{14}$$

where $\rho$ denotes the share of total public capital that is allocated to agriculture, and $\lambda$ is the share of labor employed in agriculture.

As indicated above, all domestic taxes (namely all public revenues) are utilized for public expenditures on agriculture and non-agriculture. Hence we have the following relation in level form.

$$PUB = t_a eY_a + t_n Y_n \tag{15}$$

where PUB is total domestic public spending on both sectors. If we assume that the depreciation rate of infrastructure capital is equal to $\delta$, the change per capita in aggregate public sector capital stock is as follows.

$$\frac{\Delta G}{L} = -\delta g + \frac{PUB}{L} = -\delta g + t_a ey_a + t_n y_n \tag{16}$$

where $\Delta G$ denotes the change in aggregate public sector capital stock in a year.

The per capita GDP, denoted by y, which is equal to domestic value added in domestic prices, is given by the following expression.

$$y = ey_a + (1-\gamma)y_n \tag{17}$$

Private per capita income of the economy, denoted by $y_p$ is the total value added (namely GDP) minus taxes, as follows:

$$y_p = e(1-t_a)y_a + (1-\gamma)(1-t_n)y_n \tag{18}$$

If s denotes the average private saving (and investment) rate, and θ denotes the share of private expenditure spent on food, the supply demand balance for the product of the n-sector is as follows, under the assumption that all investment is made up of n-sector products.

$$sy_p + (1-\theta)(1-s)y_p + t_a ey_a + t_n y_n = y_n \tag{19}$$

By substituting (18) in (19) we can derive an expression for e in terms of the per capita products of the two sectors.

$$e = \frac{Qy_n}{Ry_a} \tag{20}$$

where the parameters Q and R are defined for notational convenience, and are given by the following expressions:

$$Q = Q(t_n) = (1-t_n)[\theta(1-s) + \gamma(1-\theta(1-s))] \tag{21a}$$

$$R = R(t_a) = (1-\theta(1-s)) + t_a\theta(1-s) \tag{21b}$$

In the short run it will be assumed that the sector specific capital stocks are immobile across sectors, while labor is freely mobile. By substituting (20) in the labor market equilibrium condition, namely the relation that equates the marginal products of labor in the two sectors[5], as given in equation (8) and (9), we obtain a linear relation between the capital-labor ratios of the two sectors, as follows.

$$\frac{(1-t_a)\alpha k_a Q\mu}{R(1-\mu)} = (1-t_n)(\beta k_n) \tag{22}$$

Combining (22) with the full employment condition (7), we obtain expressions for the sectoral capital-labor ratios, in terms of the economy-wide state variables, as follows:

$$k_a = \frac{(1-\mu)k}{\lambda} \tag{23}$$

$$k_n = \frac{\mu k}{(1-\lambda)} \tag{24}$$

where λ, the share of labor in agriculture, is given by the following expression.

$$\lambda = \lambda(t_a) = \frac{(1-t_a)\alpha U}{(1-t_a)\alpha U + \beta R} \tag{25}$$

[5] An alternative to this labour market equilibrium condition would be to equate the average product of labour in agriculture with the marginal product of labour in non-agriculture. This would correspond to an agrarian structure of small farmers, and given our algebraic assumptions, it would not change the subsequent analysis.

In (25) the notationally convenient parameter U is given by the following expression

$$U = \theta(1-s) + \gamma(1-\theta(1-s)) \tag{26}$$

It can be readily derived from (25) by simple algebra that $d\lambda/dt_a<0$. In other words larger taxation of the agricultural sector induces labor reallocation towards non-agriculture, and hence a lower share of total labor employed in agriculture, as expected. Also it can be readily shown that $d\lambda/d\theta>0$, and $d\lambda/d\gamma>0$. The first of these relations implies that if the share of the consumers' expenditure that is devoted to agricultural products is larger, then so is the share of labor employed in agriculture. The second relation implies that if the share of imported intermediates in the production of non-agricultural non-tradables is large, then the share of labor employed in agriculture is large, and this makes sense as in such a case the country needs to produce and export larger quantities of the agricultural product to finance the imports.

By utilizing (12) and (19), the per-capita import of the non-competitive intermediate can be written as a share of the agricultural product as follows:

$$m = \frac{\gamma R}{U} y_a \equiv \Gamma y_a \tag{27}$$

where the last equality just defines the parameter $\Gamma$. It can be easily computed that $d\Gamma/d\gamma>0$, implying that a large degree of intermediate import dependence by the non-agricultural sector implies that a larger share of the agricultural product must be exported to finance the imports. It can also be verified that the above expression for m corresponds to the difference between the per capita production of the agricultural product, and the per capita quantity demanded domestically for consumption of food. This implies that $d\Gamma/d\theta<0$, as can also be directly verified by differentiating the expression for $\Gamma$ in (27).

Per capita total private investment in this economy is given by $sy_p$. This can be written, by utilizing the expressions for $y_p$ and e in equations (17) and (19) above, as a share $\chi$ of $y_n$,, where the share $\chi$ is given by the following expression.

$$\chi = \frac{s(1-t_n)(1-\gamma t_a)}{R} \tag{28}$$

By substituting the expressions (23) and (24) in the production functions (3) and (4), and utilizing (27), we can write the per capita products of the two sectors in terms of the state variables as follows:

$$y_a = A(1-\mu)^{1-\alpha} \lambda^{\alpha} k^{1-\alpha} \tag{29}$$

$$y_n = BA^{\gamma}\Gamma^{\gamma}\lambda^{\alpha\gamma}(1-\lambda)^{\beta}\mu^{1-\beta-\gamma}(1-\mu)^{\gamma(1-\alpha)}k^{1-\beta-\alpha\gamma} \tag{30}$$

There are three dynamic equations of the system. The first describes the evolution of private capital, and is given by the following equation:

$$\hat{k} \equiv \frac{\dot{k}}{k} = \frac{\chi y_n}{k} - (n+\delta) \tag{31}$$

where $\delta$ is the rate of depreciation of private capital, which will be assumed for simplicity to be the same as the rate of depreciation of public capital, and n is the (exogenous) rate of population

(as well as labor force) growth. We could assume different rates of depreciation of public and private capital, but this would only complicate the growth expressions without adding any new insights.

By utilizing (30), as well as (5), (6), (13), and (14) we can write the private sector per-capita capital stock growth rate as follows.

$$\frac{\dot{k}}{k} = \chi\Gamma^{\gamma}\rho^{\gamma\varepsilon}(1-\rho)^{\eta}\mu^{1-\beta-\gamma}(1-\mu)^{\gamma(1-\alpha)}k^{-\beta-\alpha\gamma}g^{\eta+\gamma\varepsilon}(1-\lambda)^{\beta-\eta}\lambda^{\gamma(\alpha-\varepsilon)} - (n+\delta) \tag{32}$$

The second dynamic equation describes the evolution of the share of capital employed in the n-sector, and will be assumed to be a function of the relative rates of return to capital, as for instance specified by Mass-Collell and Razin (1973).

$$\hat{\mu} \equiv \frac{\dot{\mu}}{\mu} = \phi\left(\frac{r_n - r_a}{r_a}\right) \tag{33}$$

The final dynamic equation concerns the evolution of the public sector capital stock. By the equation for public capital (15), under the additional assumption that the difference equation can approximate the instantaneous change of public sector capital, the growth rate of public sector capital is given by the following equation.

$$\hat{g} \equiv \frac{\dot{g}}{g} = \hat{G} - \hat{L} = \frac{t_a e y_a + t_n y_n}{g} - (n+\delta) \tag{34}$$

By utilizing (19), the above growth rate can be written as follows

$$\frac{\dot{g}}{g} = \left(\frac{t_a Q + t_n R}{R}\right)\frac{y_n}{g} - (n+\delta) \tag{35}$$

The steady state of this system will involve the same returns to private capital in the two sectors, so that the private capital stocks in the two sectors grow at the same rates. By equating the two sectoral rates of return to capital in (10) and (11), and utilizing (12) and (20) we can derive the steady state value of the share of capital employed in the n-sector.

$$\mu^* = \frac{(1-\beta-\gamma)R}{(1-\alpha)(1-t_a)U + (1-\beta-\gamma)R} \tag{36}$$

Note that this value is a function of only the agricultural tax rate and not the non-agricultural tax rate. It can also be readily seen, through straightforward algebra, that $d\mu^*/dt_a > 0$. In other words a larger agricultural tax rate implies a larger share of capital employed in the non-agricultural sector in the steady state, a reasonable conclusion to expect. It can also be shown that $d\mu^*/d\theta < 0$. In other words the larger the share of food in total expenditure, the smaller the share of capital employed in the non-agricultural sector.

In this model there is no steady state where the per capita magnitudes are constant. This can be seen by noting that if the right hand sides of (35) and (31) are set equal to zero, then they imply that the ratio g/k is constant. However, by considering the right hand side of (32) it can be seen that for this value of the ratio g/k as well as the value for $\mu^*$ implied by (36), the right hand side of (32) is not equal to zero, which is a contradiction. Hence the steady state, under the

assumption of a constant food budget share and constant savings rate, is characterized be equal growth rates of all the relevant per-capita capital stocks, both private as well as public, and by consequence per-capita GDP. This implies that in steady state growth, the ratios of any two magnitudes, such as the per capita production in the two sectors, or the per capita private and public capital stocks will be constant. By reviewing the two dynamic equations (32) and (35) it can be readily seen that there cannot be a steady state in the above sense unless the following condition is satisfied among the various parameters of the model.

$$\eta+\gamma\varepsilon=\beta+\alpha\gamma \text{ or } \eta-\beta=\gamma(\alpha-\varepsilon) \tag{37}$$

This condition is a generalization of the condition that the elasticity of TFP with respect to public capital is equal to the aggregate labor share that was proposed and utilized by Barro (1990) to ensure steady state growth in the aggregate economy. In the sequel this condition will be assumed, so as to assure steady state growth.

Notice that in this model the share of agriculture in GDP, which we shall denote by $S_a$ is a function of both the tax rates, and is independent of other state variables if $\theta$ is constant.

$$S_a=\frac{ey_a}{ey_a+y_n}=\frac{Q}{Q+(1-\gamma)R} \tag{37}$$

It can be readily seen that this share is a negatively sloping function of the agricultural tax rate and a positively sloping function of the non-agricultural tax rate as is expected. Namely $dS_a/dt_a<0$ and $dS_a/dt_n>0$. It can also be shown that $dS_a/d\theta>0$, implying that a large food budget share implies a larger agricultural sector ceteris paribus, which is to be expected.

Let us now assume that in the steady state, the aggregate per capita public and private capital stocks both grow at the same rate $\zeta$. By using (35) we can obtain that the ratio of per capita output of the n-sector and the per capita public capital is constant and equal to the following.

$$\frac{y_n}{g}=\frac{(n+\delta+\zeta)R}{t_aQ+t_nR} \tag{38}$$

Similarly by using equation (31) we can derive that the ratio of per capita output of the n-sector and the per capita private capital is constant and equal to the following.

$$\frac{y_n}{k}=\frac{n+\delta+\zeta}{\chi} \tag{39}$$

Notice that as the per capita GDP can be written, by utilizing (20), as a fixed multiple of per capita output of the n-sector, the ratio of per capita GDP y to k is also a constant. This implies that y and k will grow at the same rate.

By multiplying the expression in (39) with the inverse of the expression in (38) we eliminate the variable $y_n$, as well as the growth rate variable $\zeta$, and we obtain an expression for the ratio of the per capita public and private capital stocks.

$$\frac{g}{k}=\frac{t_aQ+t_nR}{\chi R} \tag{40}$$

By substituting this expression in (40) in the growth rate equation for private capital (32), using (37), and using the steady state value of $\mu^*$ from (36), we obtain an expression for the steady state growth rate of k, and hence the growth rates of g and y as well.

$$\zeta = \chi\Gamma^{\gamma}\rho^{\gamma\varepsilon}(1-\rho)^{\eta}(\mu^*)^{1-\beta-\gamma}(1-\mu^*)^{\gamma(1-\alpha)}\left(\frac{t_aQ+t_nR}{\chi R}\right)^{\beta+\alpha\gamma}(1-\lambda)^{\beta-\eta}\lambda^{\gamma(\alpha-\varepsilon)}-(n+\delta) \tag{41}$$

As in the steady state the share of capital employed in non-agriculture, namely the variable $\mu^*$, is constant and a function of the agricultural tax rate, the overall growth rate $\zeta$ is a function of the two tax rates, as well as the variable $\rho$, namely the share of public capital employed in non-agriculture. Also note that apart from the terms that involve $\rho$ directly, there are no other terms that are functions of $\rho$. We can thus maximize the growth rate as a function of $\rho$, in order to find the share of public capital employed in agriculture that will maximize the steady state growth rate, irrespective of the tax rates. The maximization is straightforward and yields the following "optimal" share of public sector capital that must be devoted to agriculture.

$$\rho^* = \frac{\gamma\varepsilon}{\beta+\gamma\alpha} = \frac{\gamma\varepsilon}{\eta+\gamma\varepsilon} = \frac{\gamma}{\frac{\eta}{\varepsilon}+\gamma} \tag{42}$$

It can be readily seen from (42) that if there is no trade, in the sense that there is no agricultural exports, and hence no intermediate good required for non-agricultural production, then the share of public capital that needs to be devoted to agriculture, to maximize the steady state growth rate is zero. In other words for a closed economy, to maximize the steady state growth rate, under a fixed food budget share $\theta$, there is no need to devote any public resources to agriculture. The reason is basically the agricultural treadmill. Any productivity gains in agriculture are reflected in lower relative prices of the agricultural good, as can be seen from (20). When there is trade, by contrast, higher agricultural productivity is reflected in lower costs of intermediate imports, and this implies that improvements in agricultural productivity will raise growth. These results are opposite to those obtained by Matsuyama (1992).

It can be readily seen from (42) that the share of public capital that should be devoted to agriculture for maximum growth is a positive function of $\gamma$, the share of imports in the total production of the non-agricultural non-traded good. Finally the share of public capital that should be devoted to agriculture for maximum growth is seen to be a positive function of the elasticity of agricultural TFP with respect to public capital, namely the parameter $\varepsilon$, while it is a negative function of the elasticity of nonagricultural TFP with respect to public capital. This brings to the fore the importance of these elasticities, that have not been estimated very widely in an aggregative form for agriculture, and even less for non-agriculture.

Notice that the non-agricultural tax rate enters the expression (41) in only two factors, namely $\chi$ and the parenthesis that involves the variables Q and R. It is easy then to maximize the growth rate with respect to the non-agricultural tax rate while keeping the agricultural tax rate fixed (the second order condition can be checked to hold as well). The resulting expression is the following.

$$t_n^* = \frac{R(\beta+\alpha\gamma)-t_aU}{R-t_aU} \tag{43}$$

It can be easily seen that the tax rate in (43) is smaller than one, and can be negative, namely it can be a subsidy. It can also be computed by straightforward algebra that the following relation holds.

$$\frac{dt_n^*}{dt_a} < 0 \qquad (44)$$

Thus it appears that for optimal growth there is a negative relation between the two sectoral tax rates. A high agricultural tax rate implies a low non-agricultural tax rate and vice-versa. Note that a zero agricultural tax rate implies a positive non-agricultural tax rate. This is necessary as by assumption the existence of public capital is essential for production in both sectors, and hence at least one of the sectors must be taxed to generate revenues to maintain public capital. The relationship (43) describes the optimal trade-off.

If the expression for the optimal non-agricultural tax rate in (43), and the expression for the optimum share of public capital going to agriculture (42) are substituted in the growth equation (41), then we obtain an expression for the aggregate growth rate that depends only on the agricultural tax rate. From that expression one can obtain the agricultural tax rate that maximizes the overall growth rate. The expression is too complicated for analytical manipulation. Hence one must resolve to numerical computations, which are not difficult.

Notice that in the model we have assumed that the parameters θ and s, namely the economy-wide "food" budget share, and the average saving rate are constant fractions of private incomes. The first point here is that such constant shares do not require constant food budget and savings shares from all the various sources of income. For instance, if it is assumed that there are three different sources of income, namely labor income, capital income from agriculture, and capital income from non-agriculture, then if one postulates different constant food budget shares and saving shares for each one of these types of income, the net result is a model that is formally equivalent to the simpler one analyzed here, except that the various expressions have more parameters. The basic point is that one can still write an equation for the supply demand balance for the non-agricultural product (namely equation (18)), that can in turn be solved analytically for the domestic terms of trade as in (19). Under the production assumptions of the model this can always be done as long as we assume that the budget and saving shares of the different types of income sources are constant. The same results if we assumed several different income groups, each having a certain share of labour and capital incomes in the two sectors. Hence the simpler model was preferred.

The more serious assumption concerns exactly the one concerning constant food budget and saving shares from different income sources. Such an assumption assumes away one of the basic "stylized facts" about development, namely that the income elasticity of demand for food is smaller than one, known as Engel's law. The results of Matsuyama (1992), as well as those of Skott and Larudee (1998) and Taylor (1991) depend critically on this assumption. If we assume a linear expenditure system instead of the unitary income elasticity demand system we have assumed, then we could not solve explicitly for the domestic terms of trade as in (20), and we could thus not obtain closed form expressions for the sectoral capital labor ratios and the attendant growth rates.

We could rescue the analytical structure of the present model by making the assumption that the value of the food budget share θ is a decreasing function of the aggregate capital labor ratio k,

and correspondingly that the saving rate s is an increasing function of k, without otherwise changing the structure of the production and other relations. Given that we have presented the signs of the derivatives of the various key variables, such as the labor share in agriculture $\lambda$, the share of agriculture that is exported $\Gamma$, the share of capital employed in the n-sector $\mu^*$, and the share of agriculture in GDP $S_a$ , with respect to $\theta$, we can think of the changes implied by an assumption of not fixed $\theta$.

The first point that we can make in this context is that now we cannot talk about the same steady state growth rates for all the relevant state variables, such as k and g. However, we can still talk about a growth path where the returns to capital are equalized across sectors. The solution to $\mu^*$ in (36) can still then obtain, with the qualification that as $\theta$ declines (and concurrently s increases) the value of $\mu^*$ increases, as might be expected. So in this case even in the "long run" the share of capital employed in non-agriculture will be monotonically increasing, as long as the food budget share keeps declining.

The second point is that the parameter indicating the share of public capital employed in agriculture, enters the growth rate equation for private capital, as well as the growth rate equation for public capital as can be seen from (35) after substitution of $y_n$ , in a fashion that is not dependent on $\theta$. Hence these instantaneous growth rates can be maximized with respect to $\rho$ irrespective of the value of the food budget share. In other words the allocation rule for public capital (42) does not depend on the food budget share.

Third, if the food budget and the savings parameters $\theta$ and s are functions of k (the first a decreasing and the second an increasing such function), denote by $\zeta_k$ and $\zeta_g$ the instantaneous growth rates of k and g respectively. Then the following can be derived by manipulation of the growth equations for k and g, namely (31) and (35).

$$\text{If} \quad \frac{g}{k} > \frac{t_a Q + t_n R}{\chi R} \quad \text{then} \quad \zeta_k > \zeta_g \tag{45}$$

$$\text{If} \quad \frac{g}{k} < \frac{t_a Q + t_n R}{\chi R} \quad \text{then} \quad \zeta_k < \zeta_g \tag{46}$$

The right hand side of the inequalities in the left sides of (45) and (46) are functions of the parameters $\theta$ and s, which are in turn functions of k, as assumed. The above equations indicate that the growth paths of g and k will tend towards a ratio that is represented by the fraction in the right hand side of the two inequalities above. Hence the growth rate corresponding to this common ratio can be considered as the "underlying tendency" at any point in time, which in turn will be changing over time, and it is in this sense that we can interpret the steady state values of the growth rates in the context of Engel's law. Note that the two tax rates affect this steady state growth path.

Consider now poverty and distributional issues. Given the aggregated nature of our model it is not easy to specify in a general sense the structure of incomes of the poor. However, we can assume, as seems to be the case for most developing countries that the poor draw most of their income either from agriculture, or from unskilled labor. We can also assume that in terms of consumption the most important commodity they consume is food. This implies that we can write the real income of a typical poor person as follows.

$$\frac{y_{poor}}{e} = \phi\frac{(1-t_a)y_a}{\lambda} + (1-\phi)\frac{w}{e} \tag{47}$$

where the parameter φ denotes the share of income derived from agricultural production, the rest been derived from wage labor. Notice that the first term in the right hand side of (47) is agricultural production per agricultural worker net of taxes, and not per unit of labor in the economy, and this is why the per capita agricultural product is divided by the share of labor in agriculture.

By using the expressions for the per capita agricultural product and the common wage rate in (3) and (8) we can write the real income of the poor as follows.

$$\frac{y_{poor}}{e} = A(1-t_a)k_a^{1-\alpha}[\frac{\phi(1-\mu)k}{k_a\lambda} + (1-\phi)\alpha] = A(1-t_a)\left[\frac{(1-\mu)k}{\lambda}\right]^{1-\alpha}[\phi + (1-\phi)\alpha] \tag{48}$$

The last equation above is the result of applying the expression for the capital labor ratio in agriculture from (23). Under the assumptions that led to the steady state growth equations, it is apparent that faster increases in agricultural productivity, as well as faster increases in the economy-wide capital labor ratio are beneficial for the typical poor. It is clear that improvements in agricultural productivity are necessary to have faster growth of the income of the poor, or equivalently to reduce the number of the absolutely poor, as average incomes of the poor are raised. This is the result of the inter-sectoral labor market equilibrium. In other words any agricultural TFP improvements will increase the incomes of agricultural producers, and consequently, through the demand effect, increase demand for n sector goods, and hence increase the national demand for labor, and consequently real wages.

The expression in (48) can also be written, after substituting the expressions for A as follows. $\frac{y_{poor}}{e} = \rho^{\varepsilon}(1-t_a)\lambda^{\alpha-\varepsilon-1}(1-\mu)^{1-\alpha}k^{1-\alpha}g^{\varepsilon}[\phi + (1-\phi)\alpha]$ (48)

This shows clearly that an increased share of public resources devoted to agriculture is beneficial for the poor, in addition to high levels of k and g. In steady state, the growth rate of the real incomes of the poor will be a constant factor equal to (1-α+ε) of the common growth rate of k and g. If the elasticity of agricultural TFP with respect to public sector capital is larger than the labor share in agriculture, then this factor will be larger than one, signifying that the real incomes of the poor will be growing faster than those of the economy as a whole, and this will improve income distribution. Otherwise the opposite will be the case.

## 2. Empirical Simulations

Consider numerical simulations of the above model. For all experiments a population growth rate of 0.02 (namely two percent annually) and an annual depreciation rate of 0.05 common to both the private and public capital are assumed. As the population growth rate and the depreciation rate affect the steady state growth rate in an additive fashion, implications for the growth rates of different values for these parameters can be easily derived, by just adding or subtracting the

respective population and depreciation rates from those assumed above, and modifying the overall growth rate above by the total difference.

Table 1 presents the growth rates under different agricultural tax rates for a set of parameters that might characterize an agrarian developing economy under alternative values of the trade dependence parameter $\gamma$. The assumed value of the aggregate saving rate is 0.2. The values for the TFP elasticities assumed are such as to render them roughly equal. The results suggest that at low degrees of trade openness, namely low values of $\gamma$, the agricultural tax rate should be considerably high, and correspondingly the nonagricultural tax rate low, in order to achieve high overall growth rates. This is consistent with the view that at low levels of trade exposure and development, significant domestic taxation of agriculture is optimal for growth. Notice that at low levels of trade exposure, the optimum share of public capital devoted to agriculture is low, considerably smaller than the share of labor in agriculture, or the share of agriculture in GDP. The picture, however, changes considerably for high degrees of trade exposure. For large values of the parameter $\gamma$ it can be seen that the optimum rate of agricultural taxation is smaller than the non-agricultural taxation, and low, but the share of public capital going to agriculture is still smaller than the share of agriculture in GDP or the share of labor in agriculture. Thus, the first conclusion is that the rate of agricultural taxation in order to finance infrastructure and other TFP enhancing public expenditures is a decreasing function of the degree of trade dependence of the non-agricultural sector.

Table 2 exhibits the growth rates, assuming a fixed agricultural tax rate, but under different assumptions concerning openness of the nonagricultural sector, and various assumptions concerning the elasticities of agricultural TFP with respect to public capital. The aggregate saving rate is kept at 0.2. The first interesting thing to note is that at any given degree of openness, higher values of the agricultural TFP elasticity imply lower rates of overall growth. However, they imply higher rates of growth of the real incomes of the poor. Hence it appears that variations of agricultural TFP elasticity imply a tradeoff between higher overall growth rates and higher rates of real income growth of the poor. This was not observed, for instance in the figures of table 1, where both the overall income growth as well as the growth rates of the real incomes of the poor moved together as the agricultural tax rate varied. Notice also that moving down a column, toward economies with larger degrees of market openness, it appears that they dictate larger shares of public capital devoted to agriculture, for a given agricultural TFP elasticity, and imply larger rates of both overall growth, as well as real income growth of the poor. Notice that in the bottom panel of figures the share of public capital devoted to agriculture is not only larger than 50 percent, but is also almost as large as the (large) share of agriculture in GDP.

Table 3 presents alternative growth rates for different values of the food budget share parameter, as a function of the agricultural tax rates. It can be seen that while higher agricultural tax rates imply larger growth rates and larger growth rates for the real incomes of the poor, at all levels of the food budget shares, the growth rates are not very sensitive to the different tax rates at different levels of the food budget shares. Looking down any column, it can also be seen that the growth rates for given degree of agricultural taxation are not very sensitive to the different food budget shares.

Table 4 presents the growth rates for three different values of the saving rates, under a variety of food budget shares, and fixed values of the other parameters. While it can be seen that the growth rates are not sensitive to the different levels of the food budget share for given saving

rate, they are quite sensitive to different saving rates, as one might expect, with higher saving rates implying substantially larger growth rates. It can be seen also that for lower food budget shares, given a saving rate, the steady state growth rates are higher, and the growth rates of the real incomes of the poor are also higher.

The final table exhibited, table 5, presents the growth rates for different values of the labor intensity parameters in agriculture and non-agriculture, namely the parameters $\alpha$ and $\beta$. It can be seen that low labor intensities in both sectors imply low rates of growth, but high shares of public capital in agriculture. On the contrary, high labor intensities in both sectors imply high growth rates in steady state, and low shares of public sector capital in agriculture. Interestingly, also note that going from low to high degrees of labor intensity of agriculture, the implied steady state rate of growth rate of the economy increases, but the real income of the poor first declines and then increases.

The conclusion from the above simulations is then that the parameters that matter a lot in determining the usefulness of agricultural development as an engine of growth as well as poverty reduction are the degrees of labor intensities of the two sectors, the degree of trade openness, the elasticity of agricultural TFP with respect to public capital, and the rate of domestic savings.

The conclusion of this section is that agricultural taxation certainly helps the overall rate of growth in small open economies, with an agricultural sector that produces the bulk of exportables. The appropriate non-agricultural tax rate is inversely proportional to the agricultural tax rate, and is negative, namely turns into a subsidy, only for large values of the rate of agricultural taxation. The share of public sector capital that must be devoted to agriculture is not related to the share of agriculture in GDP, or the share of labor employed in agriculture, but is rather a function of the labor shares of the two sectors, the import intensity of non-agriculture, and the elasticity of agricultural TFP with respect to public capital.

# Appendix Tables

**Table 1. Steady state growth rates of various economies under different agricultural tax rates**

| *Economic parameters* | *Alpha=* | *0.60 Beta=* | | *0.30 Gamma=* | | *0.10* |
|---|---|---|---|---|---|---|
| | *Theta=* | *0.50 Epsilon=* | | *0.40 Eta=* | | *0.32* |
| | | Agricultural tax rates | | | | |
| | | 0.1 | 0.2 | 0.3 | 0.4 | 0.5 |
| Variables | Symbols | | | | | |
| Nonag. tax rate | tn | 0.310 | 0.260 | 0.208 | 0.156 | 0.102 |
| Common growth rate % | percent | 5.51% | 5.77% | 6.03% | 6.30% | 6.60% |
| Gr. Rate of real incomes of poor | percent | 4.41% | 4.62% | 4.82% | 5.04% | 5.28% |
| Share of cap in n-sector | mu | 0.699 | 0.735 | 0.770 | 0.805 | 0.839 |
| Share of pub cap in agr. | rho | 0.111 | 0.111 | 0.111 | 0.111 | 0.111 |
| Share of lab. in agr. | lambda | 0.564 | 0.520 | 0.472 | 0.421 | 0.365 |
| Share of agr. In GDP | Sa | 0.355 | 0.357 | 0.360 | 0.362 | 0.365 |
| *Economic parameters* | *Alpha=* | *0.60 Beta=* | | *0.30 Gamma=* | | *0.30* |
| | *Theta=* | *0.50 Epsilon=* | | *0.40 Eta=* | | *0.36* |
| | | Agricultural tax rates | | | | |
| | | 0.1 | 0.2 | 0.3 | 0.4 | 0.5 |
| Variables | Symbols | | | | | |
| Nonag. tax rate | tn | 0.428 | 0.373 | 0.314 | 0.252 | 0.184 |
| Common growth rate % | percent | 4.28% | 4.46% | 4.61% | 4.72% | 4.81% |
| Gr. Rate of real incomes of poor | percent | 3.43% | 3.57% | 3.69% | 3.78% | 3.85% |
| Share of cap in n-sector | mu | 0.551 | 0.594 | 0.639 | 0.686 | 0.734 |
| Share of pub cap in agr. | rho | 0.250 | 0.250 | 0.250 | 0.250 | 0.250 |
| Share of lab. in agr. | lambda | 0.620 | 0.577 | 0.530 | 0.478 | 0.420 |
| Share of agr. In GDP | Sa | 0.425 | 0.433 | 0.441 | 0.449 | 0.458 |
| *Economic parameters* | *Alpha=* | *0.60 Beta=* | | *0.30 Gamma=* | | *0.50* |
| | *Theta=* | *0.50 Epsilon=* | | *0.40 Eta=* | | *0.40* |
| | | Agricultural tax rates | | | | |
| | | 0.1 | 0.2 | 0.3 | 0.4 | 0.5 |
| Variables | Symbols | | | | | |
| Nonag. tax rate | tn | 0.551 | 0.496 | 0.435 | 0.367 | 0.289 |
| Common growth rate % | percent | 5.66% | 5.77% | 5.81% | 5.78% | 5.68% |
| Gr. Rate of real incomes of poor | percent | 4.53% | 4.61% | 4.65% | 4.62% | 4.54% |
| Share of cap in n-sector | mu | 0.337 | 0.378 | 0.424 | 0.475 | 0.533 |
| Share of pub cap in agr. | rho | 0.333 | 0.333 | 0.333 | 0.333 | 0.333 |
| Share of lab. in agr. | lambda | 0.663 | 0.622 | 0.576 | 0.525 | 0.467 |
| Share of agr. In GDP | Sa | 0.496 | 0.509 | 0.523 | 0.538 | 0.554 |
| *Economic parameters* | *Alpha=* | *0.60 Beta=* | | *0.30 Gamma=* | | *0.60* |
| | *Theta=* | *0.50 Epsilon=* | | *0.40 Eta=* | | *0.42* |
| | | Agricultural tax rates | | | | |
| | | 0.1 | 0.2 | 0.3 | 0.4 | 0.5 |
| Variables | Symbols | | | | | |
| Nonag. tax rate | tn | 0.614 | 0.562 | 0.502 | 0.433 | 0.352 |
| Common growth rate % | percent | 7.88% | 7.94% | 7.92% | 7.80% | 7.60% |
| Gr. Rate of real incomes of poor | percent | 6.30% | 6.35% | 6.33% | 6.24% | 6.08% |
| Share of cap in n-sector | mu | 0.190 | 0.219 | 0.253 | 0.294 | 0.345 |
| Share of pub cap in agr. | rho | 0.364 | 0.364 | 0.364 | 0.364 | 0.364 |
| Share of lab. in agr. | lambda | 0.681 | 0.641 | 0.596 | 0.545 | 0.487 |
| Share of agr. In GDP | Sa | 0.534 | 0.550 | 0.568 | 0.586 | 0.606 |

Source. Computed

**Table 2. Steady state growth rates of different economies under various degrees of openness and agricultural TFP elasticities**

| *Economic parameters* | | *Alpha=* | *0.60 Beta=* | | *0.30 Theta=* | | *0.50* | |
|---|---|---|---|---|---|---|---|---|
| | | *S=* | *0.20 Gamma=* | | *0.20 Ag.tx rte=* | | *0.30* | |
| | | Agricultural TFP elasticities | | | | | | |
| | | 0.10 | 0.20 | 0.30 | 0.40 | 0.50 | 0.60 | 0.70 |
| Variables | Symbols | | | | | | | |
| Nonag. TFP elasticity | eta | 0.400 | 0.380 | 0.360 | 0.340 | 0.320 | 0.300 | 0.280 |
| Nonag. tax rate | tn | 0.260 | 0.260 | 0.260 | 0.260 | 0.260 | 0.260 | 0.260 |
| Growth rate % | percent | 6.99% | 6.05% | 5.43% | 5.01% | 4.73% | 4.56% | 4.48% |
| Gr. Rate of real incomes of poor | percent | 3.50% | 3.63% | 3.80% | 4.01% | 4.26% | 4.56% | 4.93% |
| Share of cap in n-sector | mu | 0.712 | 0.712 | 0.712 | 0.712 | 0.712 | 0.712 | 0.712 |
| Share of pub cap in agr. | rho | 0.048 | 0.095 | 0.143 | 0.190 | 0.238 | 0.286 | 0.333 |
| Share of lab. in agr. | lambda | 0.503 | 0.503 | 0.503 | 0.503 | 0.503 | 0.503 | 0.503 |
| Share of agr. In GDP | Sa | 0.401 | 0.401 | 0.401 | 0.401 | 0.401 | 0.401 | 0.401 |
| *Economic parameters* | | *Alpha=* | *0.60 Beta=* | | *0.30 Theta=* | | *0.50* | |
| | | *S=* | *0.20 Gamma=* | | *0.40 Ag.tx rte=* | | *0.30* | |
| | | Agricultural TFP elasticities | | | | | | |
| | | 0.10 | 0.20 | 0.30 | 0.40 | 0.50 | 0.60 | 0.70 |
| Variables | Symbols | | | | | | | |
| Nonag. TFP elasticity | eta | 0.500 | 0.460 | 0.420 | 0.380 | 0.340 | 0.300 | 0.260 |
| Nonag. tax rate | tn | 0.373 | 0.373 | 0.373 | 0.373 | 0.373 | 0.373 | 0.373 |
| Growth rate % | percent | 7.64% | 6.34% | 5.46% | 4.84% | 4.42% | 4.15% | 4.02% |
| Gr. Rate of real incomes of poor | percent | 3.82% | 3.80% | 3.82% | 3.87% | 3.98% | 4.15% | 4.42% |
| Share of cap in n-sector | mu | 0.547 | 0.547 | 0.547 | 0.547 | 0.547 | 0.547 | 0.547 |
| Share of pub cap in agr. | rho | 0.074 | 0.148 | 0.222 | 0.296 | 0.370 | 0.444 | 0.519 |
| Share of lab. in agr. | lambda | 0.554 | 0.554 | 0.554 | 0.554 | 0.554 | 0.554 | 0.554 |
| Share of agr. In GDP | Sa | 0.482 | 0.482 | 0.482 | 0.482 | 0.482 | 0.482 | 0.482 |
| *Economic parameters* | | *Alpha=* | *0.60 Beta=* | | *0.30 Theta=* | | *0.50* | |
| | | *S=* | *0.20 Gamma=* | | *0.60 Ag.tx rte=* | | *0.30* | |
| | | Agricultural TFP elasticities | | | | | | |
| | | 0.10 | 0.20 | 0.30 | 0.40 | 0.50 | 0.60 | 0.70 |
| Variables | Symbols | | | | | | | |
| Nonag. TFP elasticity | eta | 0.600 | 0.540 | 0.480 | 0.420 | 0.360 | 0.300 | 0.240 |
| Nonag. tax rate | tn | 0.502 | 0.502 | 0.502 | 0.502 | 0.502 | 0.502 | 0.502 |
| Growth rate % | percent | 13.13% | 10.77% | 9.12% | 7.92% | 7.06% | 6.48% | 6.17% |
| Gr. Rate of real incomes of poor | percent | 6.56% | 6.46% | 6.38% | 6.33% | 6.35% | 6.48% | 6.79% |
| Share of cap in n-sector | mu | 0.253 | 0.253 | 0.253 | 0.253 | 0.253 | 0.253 | 0.253 |
| Share of pub cap in agr. | rho | 0.091 | 0.182 | 0.273 | 0.364 | 0.455 | 0.545 | 0.636 |
| Share of lab. in agr. | lambda | 0.596 | 0.596 | 0.596 | 0.596 | 0.596 | 0.596 | 0.596 |
| Share of agr. In GDP | Sa | 0.568 | 0.568 | 0.568 | 0.568 | 0.568 | 0.568 | 0.568 |

Source. Computed

**Table 3. Steady state growth rates of different economies under various values of food budget shares and agricultural tax rates**

| *Economic parameters* | | *Alpha=* | *0.60 Beta=* | | *0.30 Theta=* | *0.30* |
|---|---|---|---|---|---|---|
| | | *s=* | *0.20 Gamma=* | | *0.30 Epsilon=* | *0.40* |
| | | Agricultural tax rates | | | | |
| | | 0.10 | 0.20 | 0.30 | 0.40 | 0.50 |
| Variables | Symbols | | | | | |
| Nonag. tax rate | tn | 0.447 | 0.412 | 0.374 | 0.334 | 0.292 |
| Growth rate % | percent | 4.71% | 4.74% | 4.74% | 4.70% | 4.63% |
| Gr. Rate of real incomes of poor | percent | 3.77% | 3.79% | 3.79% | 3.76% | 3.70% |
| Share of cap in n-sector | mu | 0.651 | 0.683 | 0.717 | 0.753 | 0.790 |
| Share of pub cap in agr. | rho | 0.250 | 0.250 | 0.250 | 0.250 | 0.250 |
| Share of lab. in agr. | lambda | 0.518 | 0.481 | 0.441 | 0.396 | 0.347 |
| Share of agr. In GDP | Sa | 0.320 | 0.327 | 0.335 | 0.342 | 0.350 |
| *Economic parameters* | | *Alpha=* | *0.60 Beta=* | | *0.30 Theta=* | *0.50* |
| | | *s=* | *0.20 Gamma=* | | *0.30 Epsilon=* | *0.40* |
| | | Agricultural tax rates | | | | |
| | | 0.10 | 0.20 | 0.30 | 0.40 | 0.50 |
| Variables | Symbols | | | | | |
| Nonag. tax rate | tn | 0.428 | 0.373 | 0.314 | 0.252 | 0.184 |
| Growth rate % | percent | 4.28% | 4.46% | 4.61% | 4.72% | 4.81% |
| Gr. Rate of real incomes of poor | percent | 3.43% | 3.57% | 3.69% | 3.78% | 3.85% |
| Share of cap in n-sector | mu | 0.551 | 0.594 | 0.639 | 0.686 | 0.734 |
| Share of pub cap in agr. | rho | 0.250 | 0.250 | 0.250 | 0.250 | 0.250 |
| Share of lab. in agr. | lambda | 0.620 | 0.577 | 0.530 | 0.478 | 0.420 |
| Share of agr. In GDP | Sa | 0.425 | 0.433 | 0.441 | 0.449 | 0.458 |
| *Economic parameters* | | *Alpha=* | *0.600 Beta=* | | *0.300 Theta=* | *0.70* |
| | | *s=* | *0.200 Gamma=* | | *0.300 Epsilon=* | *0.40* |
| | | Agricultural tax rates | | | | |
| | | 0.100 | 0.200 | 0.300 | 0.400 | 0.500 |
| Variables | Symbols | | | | | |
| Nonag. tax rate | tn | 0.396 | 0.306 | 0.210 | 0.108 | -0.001 |
| Growth rate % | percent | 3.82% | 4.18% | 4.48% | 4.73% | 4.98% |
| Gr. Rate of real incomes of poor | percent | 3.06% | 3.34% | 3.58% | 3.79% | 3.99% |
| Share of cap in n-sector | mu | 0.443 | 0.499 | 0.557 | 0.615 | 0.675 |
| Share of pub cap in agr. | rho | 0.250 | 0.250 | 0.250 | 0.250 | 0.250 |
| Share of lab. in agr. | lambda | 0.715 | 0.667 | 0.614 | 0.556 | 0.490 |
| Share of agr. In GDP | Sa | 0.546 | 0.554 | 0.562 | 0.570 | 0.579 |

Source. Computed

**Table 4. Steady state growth rates of different economies under various degrees of saving rates and food budget shares**

| *Economic parameters* | | *Alpha=* | *0.60 Beta=* | | *0.30 Ag.tx rte=* | *0.30* |
|---|---|---|---|---|---|---|
| | | *s=* | *0.10 Gamma=* | | *0.30 Epsilon=* | *0.40* |
| | | Food budget shares | | | | |
| | | 0.30 | 0.40 | 0.50 | 0.60 | 0.70 |
| Variables | Symbols | | | | | |
| Nonag. tax rate | tn | 0.365 | 0.332 | 0.288 | 0.227 | 0.137 |
| Growth rate % | percent | 1.17% | 1.12% | 1.07% | 1.02% | 0.95% |
| Gr. Rate of real incomes of poor | percent | 0.94% | 0.90% | 0.85% | 0.81% | 0.76% |
| Share of cap in n-sector | mu | 0.703 | 0.659 | 0.614 | 0.567 | 0.519 |
| Share of pub cap in agr. | rho | 0.250 | 0.250 | 0.250 | 0.250 | 0.250 |
| Share of lab. in agr. | lambda | 0.458 | 0.508 | 0.557 | 0.604 | 0.650 |
| Share of agr. In GDP | Sa | 0.354 | 0.413 | 0.477 | 0.546 | 0.620 |
| *Economic parameters* | | *Alpha=* | *0.60 Beta=* | | *0.30 Ag.tx rte=* | *0.30* |
| | | *s=* | *0.20 Gamma=* | | *0.30 Epsilon=* | *0.40* |
| | | Food budget shares | | | | |
| | | 0.30 | 0.40 | 0.50 | 0.60 | 0.70 |
| Variables | Symbols | | | | | |
| Nonag. tax rate | tn | 0.374 | 0.348 | 0.314 | 0.270 | 0.210 |
| Growth rate % | percent | 4.74% | 4.68% | 4.61% | 4.54% | 4.48% |
| Gr. Rate of real incomes of poor | percent | 3.79% | 3.74% | 3.69% | 3.64% | 3.58% |
| Share of cap in n-sector | mu | 0.717 | 0.679 | 0.639 | 0.599 | 0.557 |
| Share of pub cap in agr. | rho | 0.250 | 0.250 | 0.250 | 0.250 | 0.250 |
| Share of lab. in agr. | lambda | 0.441 | 0.486 | 0.530 | 0.573 | 0.614 |
| Share of agr. In GDP | Sa | 0.335 | 0.386 | 0.441 | 0.500 | 0.562 |
| *Economic parameters* | | *Alpha=* | *0.60 Beta=* | | *0.30 Ag.tx rte=* | *0.30* |
| | | *s=* | *0.30 Gamma=* | | *0.30 Epsilon=* | *0.40* |
| | | Food budget shares | | | | |
| | | 0.30 | 0.40 | 0.50 | 0.60 | 0.70 |
| Variables | Symbols | | | | | |
| Nonag. tax rate | tn | 0.383 | 0.362 | 0.336 | 0.304 | 0.264 |
| Growth rate % | percent | 7.52% | 7.46% | 7.39% | 7.31% | 7.24% |
| Gr. Rate of real incomes of poor | percent | 6.02% | 5.96% | 5.91% | 5.85% | 5.79% |
| Share of cap in n-sector | mu | 0.732 | 0.698 | 0.664 | 0.629 | 0.593 |
| Share of pub cap in agr. | rho | 0.250 | 0.250 | 0.250 | 0.250 | 0.250 |
| Share of lab. in agr. | lambda | 0.423 | 0.463 | 0.503 | 0.541 | 0.578 |
| Share of agr. In GDP | Sa | 0.316 | 0.360 | 0.406 | 0.455 | 0.507 |

Source. Computed

**Table 5. Steady state growth rates of different economies that exhibit different degrees of labor intensity among sectors**

| *Economic parameters* | | *Beta=* | *0.10 Theta=* | | *0.50 Ag.tx rte=* | | *0.30* |
|---|---|---|---|---|---|---|---|
| | | *s=* | *0.20 Gamma=* | | *0.30 Epsilon=* | | *0.40* |
| | | Labor share in agriculture alpha | | | | | |
| | | 0.30 | 0.40 | 0.50 | 0.60 | 0.70 | 0.80 |
| Variables | Symbols | | | | | | |
| Nonagr. TFP elasticity | eta | 0.070 | 0.100 | 0.130 | 0.160 | 0.190 | 0.220 |
| Nonag. tax rate | tn | -0.068 | -0.029 | 0.011 | 0.051 | 0.090 | 0.130 |
| Growth rate % | percent | 2.93% | 2.91% | 3.29% | 4.03% | 5.15% | 6.73% |
| Gr. Rate of real incomes of poor | percent | 3.22% | 2.91% | 2.96% | 3.22% | 3.60% | 4.04% |
| Share of cap in n-sector | mu | 0.603 | 0.639 | 0.680 | 0.727 | 0.780 | 0.842 |
| Share of pub cap in agr. | rho | 0.632 | 0.545 | 0.480 | 0.429 | 0.387 | 0.353 |
| Share of lab. in agr. | lambda | 0.628 | 0.693 | 0.738 | 0.772 | 0.798 | 0.819 |
| Share of agr. In GDP | Sa | 0.551 | 0.542 | 0.532 | 0.522 | 0.512 | 0.500 |
| *Economic parameters* | | *Beta=* | *0.30 Theta=* | | *0.50 Ag.tx rte=* | | *0.30* |
| | | *s=* | *0.20 Gamma=* | | *0.30 Epsilon=* | | *0.40* |
| | | Labor share in agriculture alpha | | | | | |
| | | 0.30 | 0.40 | 0.50 | 0.60 | 0.70 | 0.80 |
| Variables | Symbols | | | | | | |
| Nonagr. TFP elasticity | eta | 0.270 | 0.300 | 0.330 | 0.360 | 0.390 | 0.420 |
| Nonag. tax rate | tn | 0.196 | 0.235 | 0.275 | 0.314 | 0.354 | 0.393 |
| Growth rate % | percent | 3.12% | 3.29% | 3.79% | 4.61% | 5.77% | 7.38% |
| Gr. Rate of real incomes of poor | percent | 3.43% | 3.29% | 3.41% | 3.69% | 4.04% | 4.43% |
| Share of cap in n-sector | mu | 0.503 | 0.542 | 0.587 | 0.639 | 0.703 | 0.780 |
| Share of pub cap in agr. | rho | 0.308 | 0.286 | 0.267 | 0.250 | 0.235 | 0.222 |
| Share of lab. in agr. | lambda | 0.361 | 0.429 | 0.484 | 0.530 | 0.568 | 0.601 |
| Share of agr. In GDP | Sa | 0.481 | 0.468 | 0.455 | 0.441 | 0.426 | 0.411 |
| *Economic parameters* | | *Beta=* | *0.50 Theta=* | | *0.50 Ag.tx rte=* | | *0.30* |
| | | *s=* | *0.20 Gamma=* | | *0.30 Epsilon=* | | *0.40* |
| | | Labor share in agriculture alpha | | | | | |
| | | 0.30 | 0.40 | 0.50 | 0.60 | 0.70 | 0.80 |
| Variables | Symbols | | | | | | |
| Nonagr. TFP elasticity | eta | 0.470 | 0.500 | 0.530 | 0.560 | 0.590 | 0.620 |
| Nonag. tax rate | tn | 0.459 | 0.499 | 0.538 | 0.578 | 0.618 | 0.657 |
| Growth rate % | percent | 6.61% | 7.05% | 7.90% | 9.14% | 10.84% | 13.14% |
| Gr. Rate of real incomes of poor | percent | 7.27% | 7.05% | 7.11% | 7.31% | 7.59% | 7.88% |
| Share of cap in n-sector | mu | 0.336 | 0.372 | 0.415 | 0.470 | 0.542 | 0.639 |
| Share of pub cap in agr. | rho | 0.203 | 0.194 | 0.185 | 0.176 | 0.169 | 0.162 |
| Share of lab. in agr. | lambda | 0.253 | 0.311 | 0.361 | 0.404 | 0.441 | 0.474 |
| Share of agr. In GDP | Sa | 0.384 | 0.366 | 0.347 | 0.327 | 0.306 | 0.283 |

Source. Computed

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