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China's Entry into the WTO:
ICT Sectors, Innovation, Growth and Distribution

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Abstract:

During the debate about PRC's entry into the WTO, it was assumed by the proponents of joining the WTO that the export-led growth will continue and under WTO regime it will also lead to the modernization of the economy along the lines of the other newly industrialized economies(NIEs) of Asia. If examined rigorously, such an assumption can be seen to entail the goal of creating further technological capabilities. In particular, China seems to be firmly committed to the creation of a largely self-sustaining innovation system as part of a knowledge-based economy of the future . Such innovation systems, called *positive feedback loop innovation systems* or POLIS have been created by advanced countries, and NIEs such as South Korea and Taiwan are proceeding to create these as well. Can China do the same? And will China's entry into the WTO help or hinder such efforts?

Using an economy wide model it is found thatThe entry into WTO can create an opportunity for technological learning and new technology imports. The challenge is to learn quickly and develop domestic capability before costs become too high. Thus, subsidizing domestic ICT firms can become an even more attractive strategic trade and technology policy. However, developing an interactive sustainable innovation system with virtuous positive feedbacks will require strategic complementarity between capital expenditures such as R&D and human resources.Therefore, upgrading education and training and developing ICT infrastructure quickly become urgent policy objectives. Also, precompetitive support of innovation needs to be separated from the actual development and marketing. In this area, clear guidelines and incentives for both the state and non-state enterprises will be necessary. A well-defined competition policy is a *sine qua non* for this purpose. In the Chinese case, openness can lead to increased competition under a rules-based trading regime. The challenge will be to build competitive world class ICT firms in such an environment. Even as competitive policies are pursued along with further structural reforms in China, the fact that such policies are to be pursued in an environment of incomplete information and other market imperfections mean that excess capacity, and consequently, unemployment may persist for sometime. Therefore, the role for appropriate macroeconomic policies to pursue the goal of reducing excess capacity without creating inflationary pressures need to be considered carefully.

1. Introduction:

China's entry into the WTO will have diverse consequences for its economy. The best overall assessment from the Chinese perspective is that although the short run adjustment costs--- for example, the increase in unemployment in the agricultural sector--- may be high, the long run economic benefits from integration into the world trading system are likely to be considerable. In particular, it is assumed that the export-led growth will continue and will also lead to the modernization of the economy along the lines of the other newly industrialized economies(NIEs) of Asia. If examined rigorously, such an assumption can be seen to entail the goal of creating further technological capabilities. In particular, China seems to be firmly committed to the creation of a largely self-sustaining innovation system as part of a knowledge-based economy of the future (Simon,1996; Simon and Goldman,1989; Lu, 2000). Such innovation systems, called positive feedback loop innovation systems or POLIS(Khan, 1998; 2001a,b) have been created by advanced countries, and NIEs such as South Korea and Taiwan are proceeding to create these as well.[1] Can China do the same? And will China's entry into the WTO help or hinder such efforts?

It is impossible to answer such questions in detail in a brief paper. My intention here is to examine an important part of the Chinese strategy for the transition to the modern technology system by focusing on the information and communications technology(ICT) sectors. The implications of China's joining the WTO for these sectors are significant for future technology acquisition , use and development, not just for these particular sectors, but also for the Chinese economy as a whole. Even within the narrower concerns in the ICT sectors, I will focus on the area of foremost significance for all the important actors--- the Chinese policy makers, the foreign governments, businesses and the WTO as an international organization. This is the area of intellectual property rights(IPRs) where the complex issues raised by the Trade- Related Aspects of Intellectual Property Rights or TRIPs require serious economic analysis that so far seems to be conspicuous by its absence.

In what follows, I will begin by identifying the most important aspects of the ICT sectors and their relevance for China in terms of its own

[1] A formal and complete description of POLIS as an innovation system ,and contrasts with NIS(national innovation system) of which POLIS is both an extension and an extended critique, is outside the scope of this paper. Khan (2001a) gives a formal description and two existence theorems in topological spaces. Technically, non-linearities and multiple equilibria are at the heart of a formal proof of POLIS and its properties. Khan (2001b) presents both a conceptual and concrete critique of NIS by comparing and contrasting the national innovation system (NIS) with POLIS in the context of Taiwan.

economic development goals. I will then discuss the main aspects of TRIPs that China must adhere to and the implications of such adherence for developing a POLIS for China. Finally, I will raise some questions about the strategic and structural policy reforms of the Chinese economy that are closely related to the above issues. In particular, the need for thinking about the relevance of the ICT sectors for growth, income distribution and poverty alleviation in a comprehensive manner will be emphasized in the context of such reforms.

2. ICT, Innovation and Growth in China:

Before discussing the relation between ICT sectors and economic growth and innovation it is first necessary to have a clear definition of the ICT sectors. The most widely accepted definition so far is the one agreed to at the April 1998 meeting of the Working Party on Indicators for the Information Society (WPIIS) and subsequently endorsed at the September 1998 meeting of the Committee for Information, Computer and Communication Policy of OECD. The following principles underlie the definition.

For *manufacturing industries*, the products of a candidate industry:

- Must be intended to fulfill the function of information processing and communication including transmission and display.
- Must use electronic processing to detect, measure and/or record physical phenomena or to control a physical process.

For *services industries*, the products of a candidate industry:

- Must be intended to enable the function of information processing and communication by electronic means.

Based on these principles the ICT sectors are identified within the revised classes of the International Standard Industrial Classification (ISIC). In manufacturing and services the following four digit sectors are included:

Manufacturing

- 3000-Office, accounting and computing machinery
- 3130-Insulated wire and cable
- 3210-Electronic valves and tubes and other electronic components
- 3220-television and radio transmitters and apparatus for line telephony and line telegraphy
- 3230-Television and radio receivers, sound or video recording or reproducing apparatus, and associated goods
- 3312-Instruments and appliances for measuring, checking, testing, navigating and other purposes, except industrial process equipment
- 3313-Industrial process control equipment

Services

- 5150-Wholesaling of machinery, equipment and supplies
- 7123-Renting of office machinery and equipment (including computers)
- 6420-telecommunications

- 7200-Computer and related activities

In short, roughly there are three broad categories of the new ICTs: (1) computing (2) communicating (3) Internet-enabled communication and computing.

An examination of the recent Chinese input-output tables and sectoral data in the 1990s shows that while the ICT sectors are still small by international standards, they are nevertheless growing rapidly. According to the calculations at the OECD, the ICT market in China is growing at over twenty percent average annual rate. This is second to only that of Brazil among the non-OECD countries and is much higher than the already high average growth rate of 15.4 percent for this group of countries. [2] The ICT-intensity(ICT expenditures as a percentage of GDP) likewise shows a robust growth. This trend is consistent with the earlier observation about the Chinese strategic commitment to creating a POLIS and a knowledge-based economy in the 21st century. In fact, this trend emerged as early as the mid-1980s. As one student of Chinese technological development, Qiwen Lu has commented:

> In the mid-1980s, when I was a graduate student in Beijing University, the Zhongguancun area surrounding the campus witnessed, in 'Silicon Valley' fashion, the emergence of new high-tech firms, mostly in computer electronics. The most notable example was the Stone Group.
> (Lu, *China's Leap into the Information Age*,Oxford University Press, 2000, p.xiii)

The preliminary results I have obtained from modeling the ICT sectors in China in an economy-wide framework indicate that Lu's impressionistic and intuitive insights may actually be valid. Each million yuan of investment in the ICT sector will have a social return of 200,000 yuan per year, or an undiscounted rate of return of 20 per cent. Each million yuan increase in demand for the products and services of ICT sectors will have an own multiplier value of about 1.7, leading to an output expansion of 1.7 million yuan. Although the total economy-wide linkage effects will take some years to develop fully, even at the current stage the economy-wide multiplier is about 2. In other words, an expansion of demand for

[2] Lu(2000) points out that the PC market in China has grown to be second only to Japan in Asia. The share of indigenous producers has risen from 30 per cent in 1991 to almost 70 per cent recently. It is not certain that joining WTO will open up export markets further in this area. So, China may have reached a plateau in terms of market share in this sub-sector.

the ICT sectors already spills over and generates demand for other sectors as well.

According to Lu, and other observers, a state-private sector partnership is developing in China through financial, infrastructural and other supporting relationships in the computer and related sectors. At the same time, the control of telecommunications sectors by the state remains tight. Both the government and the non-state actors emphasize the fundamental importance of technological learning. In the computer sector the Chinese enterprises started with product redesign with plans to ultimately move to own designing that require scientific knowledge and technical/higher education. This supports the view that the strategy (as suggested in Soete, 1985) is not one of incremental imitation but of leapfrogging, at least in the computer and, more broadly, microelectronics sectors. Given this ambitious strategy, joining WTO will bring some new opportunities and challenges. In particular, the TRIPs requirements will need to be taken fully into account. I now turn to a discussion of these requirements.

3. TRIPs, China's ICT Sectors and some Policy Issues:

The TRIPs agreement with its seven parts and seventy three articles is the most important international attempt to harmonize IPRs globally. The coverage is intended to be comprehensive and contains, for example, integrated circuits designs, biotechnology and software protection in addition to the standard copyright, trademarks, patents and other related areas.There are enforcement provisions requiring civil and criminal measures and border enforcements that are likely to be costly for developing countries including China. Institutionally, China's entry into the WTO will also mean agreeing to be monitored and reviewed by the TRIPs council and accepting the TRIPs dispute settlement mechanisms.There is a transition period of five years for developing countries to enable them to adhere to all the TRIPs requirements.

It should be pointed out that China has been (at least publicly) quite eager to embrace the IPRs reforms in the last decade. As Maskus (2000) points out:

> Beginning from a situation of near absence, China erected laws covering patents (including pharmaceutical patents), trademarks, integrated circuits, plant varieties, unfair competition, and copyrights….China joined nearly all major international IPRs conventions and is also now a member of international procedural treaties on the classification of patents and trademarks and the deposit of microorganisms….China has also made considerable progress in establishing education and training programs in IPRs and in upgrading its administrative and legal enforcement systems. (p. 94)

However, problems remain, particularly from the point of view of the outsiders who observe massive product counterfeiting and doubt the effectiveness of enforcement mechanisms(LaCroix and Eby-Konan,1998).

Economics of Innovation and the Dilemma of IPRs: Policy Options for China

It may seem that the basic problem of IPRs in China is simply one of enforcement; but that characterization of the basic problem will be simplistic and misleading. The markets for intellectual properties are not the same as markets for simple commodities like apples and oranges. There are serious economic tradeoffs involved here that arise from externalities and consequent market failures. Intellectual property is based on knowledge and information, and therefore has characteristics like those of public goods. Therefore, efficient use requires wide access to all users at the marginal social cost, which may be quite low. At the same time, dynamic efficiency requires ensuring innovation over time. Here the social value of innovation may exceed private development costs. IPRs are intended to alleviate the dynamic inefficiency problem; but even when they are successfully implemented, the static problem of distributing the good widely remains and can, in fact, be exacerbated. Economists sometimes call this problem the **dual distortion** of intellectual property markets. Virtually all the ICT sectors in China are plagued with this double distortion.However, software development and use may be the almost paradigmatic example.

The provisions of WIPO(World Intellectual Property Organization) earlier and of TRIPs more recently can solve partially the dynamic inefficiency problem, but mainly from the point of view of foreign firms and governments. The pace of innovation in the world as a whole may be accelerated, but China and other developing economies mainly pay higher rents in the short-term to foreign firms and governments.

The entry into WTO can create an opportunity for technological learning and new technology imports. The challenge is to learn quickly and develop domestic capability before costs become too high. Thus, subsidizing domestic ICT firms can become an even more attractive strategic trade and technology policy. However, developing an interactive sustainable innovation system with virtuous positive feedbacks will require strategic complementarity between capital expenditures such as R&D and human resources. [3]Therefore, upgrading education and training and developing ICT infrastructure quickly become urgent policy objectives. Also, precompetitive support of innovation needs to be separated from the actual development and marketing. In this area, clear guidelines and incentives for both the state and non-state enterprises will be necessary. However, as Stiglitz (1994) has correctly pointed out, even if resolving the ownership debate is not by itself crucial, a well-defined competition policy[4] nevertheless is a *sine*

[3] For a non-technical description of such strategic complementarity, see Asian Development Outlook(1998, part III) and Deolalikar et. al. (1997). Khan(1998) gives a formal description.

[4] It should be emphasized that the most advanced and scientifically accurate ideas of competition are far from the perfectly competitive world of Walrasian (e.g., Arrow-Debreu) models.This new view is anti-monopoly, but does not try to create a perfectly competitive market structure with atomistic firms. At the same time entry-deterrence by the incumbent firms are to be opposed by vigorously enforcing anti-trust laws. But even this more realistic competition policy may have some deleterious effects. Perhaps the most important one for the ICT sectors is that anti-trust policies may interfere with cooperative efforts to engage in R&D by leading firms. A tricky legal and economic issue will be what kind of cooperative R&D efforts may be permissible nationally and globally under WTO and further

qua non.In the Chinese case, openness can lead to increased competition under a rules-based trading regime. The challenge will be to build competitive world class ICT firms in such an environment.

Even as competitive policies are pursued along with further structural reforms in China, the fact that such policies are to be pursued in an environment of incomplete information and other market imperfections mean that excess capacity, and consequently,unemployment may persist for sometime. [5] Therefore, the role for appropriate macroeconomic policies to pursue the goal of reducing excess capacity without creating inflationary pressures need to be considered carefully. In principle, this should be possible, but the political problems of policy formulation and practical problems of policy implemention exist for both fiscal and monetary policies.

Related to the goals of creating employment and growth is the objective of alleviating poverty and reducing the increase in both intraregional and interregional inequalities in income and wealth distribution. As Quibria and Tschang(2000) have observed:

> …ICTs can be used selectively and innovatively to enhance the welfare of the poor. However, to reap the full benefits of the ICT revolution and reduce poverty, they need to address the main impediments to economic development. Improving the infrastructure, opening up markets, breaking telecommunications monopolies and improving education for all…(p. 25)

Interestingly, Quibria and Tschang found little empirical evidence of a positive relation between ICT sectoral growth and poverty alleviation. Due to data limitations, they were unable to apply any sophisticated general equilibrium models. Hence, one could conjecture that they may have missed some of the indirect forward and backward linkage effects. In order to rectify this I formulated a model (see appendices 1 and 2 for details) and applied it to China in an economy-wide context. The preliminary results obtained so far confirm their earlier findings. There doesn't seem to be any systematic connection between the expansion of

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globalizing efforts. For more theoretical details on the new view of competition domestically, see Stiglitz (1994), chapter 7. Globalizaion is another matter. There is no guarantee that the current trends will continue. Even if they do, devising global competition policies will present even more complex problems than is the case for domestic competition policies.

[5] As the most recent theoretical advances in the economics of information and imperfect competition emphasize, equilibrium credit rationing, efficiency wages, uncertain profit outlook and a number of other factors can lead to cyclical behavior on the part of private firms. During the downturn of the business cycle, excess capacity and cyclical unemployment are likely events. The view, popularly advanced in the business press, that the so-called information and knowledge-based new economy will not have business cycles is not supported by any serious economic research.

the ICT sectors(with or without China's joining the WTO) and poverty alleviation. What does happen though, is that the more skilled workers and capital can earn extra rents with the expansion of the ICT sectors.
Clearly, growth by itself will alleviate some poverty; but for ICT to have significant impact on the poor and low income groups in China, policies will have to be developed for allowing these groups access to ICT in such a way that their capabilities are enhanced rapidly. This is unlikely to happen simply as a by-product of joining the WTO.[6] Therefore, a comprehensive approach that includes both growth and distributional objectives---in particular, policies for poverty alleviation that are also growth-promoting, along with structural reform and technological modernization policies---seems to be the most reasonable course for the Chinese economy.

4. Conclusions:

Clearly, there are both costs and benefits for China's ICT sectors from adherence to the provisions of TRIPs. In the short-term the increased outflow of resources may not be balanced by the inflow of new and best practice technology without proper trade, industrial and macroeconomic policies and a set of incentives for both state and non-state enterprises. Developing both domestic technological capabilities and learning will require a judicious combination of external knowledge flows and internal institution building. Here again the appropriate investment in technology and training will require active policy intervention. The historical lessons from Japan and other NIEs are valuable, but China's ambition of leapfrogging in the ICT sectors will require even more active role by the state and more intense state-market-knowledge institutions interaction than has been the case for the other East Asian economies. Joining the WTO may open some doors, but walking through them in the right direction and at the right pace will require some quite clever maneuvering on China's part.

[6] See also Wu and Yuan(2000) for a description of the state of the digital economy and China that corroborates this argument.

Appendix 1: Growth Impacts of the ICT Sectors--- A simple SAM-based Model

Fixed Price Modeling in a SAM-based Framework:

In this section the Social Accounting Matrix is presented as a data gathering framework as well as an analytical tool for studying the effects the ICT sectors on growth. Appendix two presents the methodology for estimating the impact of growth generated by the ICT sectors on poverty alleviation. The origins of social accounting can be traced as far back as Gregory King's efforts in 1681, but more recent work stems from the attempts by Richard Stone, Graham Pyatt, Erik Thorkbecke and others. [7]

In the methodological framework of this study the SAM is used for mapping production and distribution at the economy wide level. In this section, first a general SAM is described. Then it is shown how the method for studying the effect of growth within this framework follows logically from its structure. The model used is a simple version of a class of SAM-based general equilibrium models.[8] It summarizes succinctly the interdependence between productive activities, factor shares, household income distribution, balance of payments, capital accounts, etc. for the economy as a whole at a point in time. Given the technical conditions of production the value added is distributed to the factors in a determinate fashion. The value added accrued by the factors is further received by households according to their ownership of assets and the prevailing wage structure. In the matrix form the SAM consists of rows and columns representing receipts and expenditures, respectively. As an accounting constraint receipts must equal expenditures.

As is elaborated further in Khan and Thorbecke (1988), the SAM framework can be used to depict a set of linear relationships in a fixed coefficient model. For deciding the question of determination, the accounts need to be divided into exogenous and endogenous ones. For instance, in the China SAM, there are three endogenous accounts. These are factors, households and production activities, leaving the government, capital and the rest of the world accounts as exogenous.[9]

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[7] For a description of SAM as a data gathering device, see G. Pyatt and E. Thorbecke, *Planning Techniques for a Better Future* (Geneva: ILO, 1976). Khan(1997) also has a chapter on this alone.

[8] In Walrasian general equilibrium models the flexible price vector determines the equilibrium. In a Keynesian (dis)equilibrium model in the short-run the quantities vary while the price vector remains fixed.

[9] See Khan and Thorbecke, op.cit., Ch. II for more theoretical details and empirical examples. The presentations here follow the cited work closely.

Table 1: Simplified Schematic Social Accounting Matrix

				Expenditures				
				Endogenous Account			Exog.	Total
				1	2	3	4	5
Receipts	Endogenous Accounts	Factors	1	0	0	$T_{1.3}$	x_1	y_1
		Households	2	$T_{2.1}$	$T_{2.2}$	0	x_2	y_2
		Production Activities	3	0	$T_{3.2}$	$T_{3.3}$	x_3	y_3
	Exog.	Sum. Of other accounts	4	l_1'	l_2'	l_3'	t	y_x
		Total	5	y_1'	y_2'	y_3'	y_x'	

Looking at Table 2, which represents a SAM, we can see immediately that

$$y = n + x \qquad (1)$$
$$y = 1 + t \qquad (2)$$

Now if we divide the entries in the matrix Tnn by the corresponding total income (i.e. y_n), we can define a corresponding matrix of average expenditure propensities. Let us call this matrix A. We now have:

$$y = n + x = Ay + x \qquad (3)$$
$$y = (1-A)^{-1}x = Mx \qquad (4)$$

M has been called the matrix of accounting multipliers by Thorbecke, for these multipliers, when computed, can account for the results (e.g. income, consumption, etc.) obtained in the SAM without explaining the process that led to them. Let us now partition the matrix A in the following way.[10]

[10] Ibid.

$$A = \begin{bmatrix} 0 & 0 & A_{13} \\ A_{21} & A_{22} & 0 \\ 0 & A_{32} & A_{33} \end{bmatrix} \qquad (5)$$

Table 2: Schematic Representation of Endogenous and Exogenous Accounts in a SAM

		Expenditures				
		Endogenous	Sum	Exogenous	Sum	Totals
Receipts	Endogenous	T_{nn}	n	Injections T_{nx}	x	y_n
	Exogenous	Leakages T_{xn}	1	Residual Balances T_{xx}	t	y_x
Totals		$y_n/$		$y_x/$		

<u>Source</u>: H.A. Khan and E. Thornbecke, <u>Choice and Diffusion of Technology in a Macroeconomic (SAM) Framework</u>

Given the accounts factors, household and the production activities, now we see that the income levels of these accounts (call them y_1, y_2, y_3 respectively) are determined as functions of the exogenous demand of all other accounts. In this respect, what we have is a reduced-form model which can be consistent with a number of structural forms. This is quite satisfactory as far as tracing the effects of a certain injection in the economy is concerned or for prediction purposes when the structural coefficients are more or less unchanged.

One limitation of the accounting multiplier matrix M as derived in equation (2.2) is that it implies unitary expenditure elasticities (the prevailing average expenditure propensities in A are assumed to apply to any incremental injection). A more realistic alternative is to specify a matrix of marginal expenditure propensities (C_n below) corresponding to the observed income and expenditure elasticities of the different agents, under the assumption that prices remain fixed. The C_n matrix can be partitioned in the same way as the A matrix above. The most important difference between the two partitioned matrix is that $C_{32} \neq A_{32}$. Expressing the changes in income (dy) resulting from changes in injections (dx), one obtains,

$$dy_n = C_n dy_n + dx \qquad (6)$$
$$= (I - C_n)^{-1} dx = M_c dx \qquad (7)$$

M_c has been called a fixed price multiplier matrix and its advantage is that it allows any nonnegative income and expenditure elasticities to be reflected in M_c. In particular, in exploring the macroeconomic effects of exogenous changes in the output of different product-cum-technologies on other macroeconomic variables, it would be very unrealistic to assume that consumers react to any given proportional change in their incomes by increasing expenditures on the different commodities by exactly that same proportion (i.e. assuming that the income elasticities of demand of the various socioeconomic household groups for the various commodities were all unity). Since the expenditure (income) elasticity is equal to the ratio of the marginal expenditure propensity (MEP_i) to the average expenditure propensity (AEP_i) for any given good i, it follows that the marginal expenditure propensity can be readily obtained once the expenditure elasticity and the average expenditure propensities are known, i.e.,

$$y_i = MEP_i/AEP_i \qquad (8)$$
$$MEP_i = y_i\, AEP_i \qquad (9)$$
$$\text{and } \sum_i MEP_i = 1 \qquad (10)$$

Thus, given the matrix A_{32} of average expenditure propensities, and the corresponding expenditure elasticities of demand, y_i the corresponding marginal expenditure propensities matrix C_{32} could easily be derived.[11]

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[11]See Khan and Thorbecke (1988) for some examples.
See also G. Pyatt and J.I. Round, "Accounting and Fixed Price Multipliers in Social Acounting Matrix Framework," *Economic Journal* Vol. 89, Dec. 1979, p. 861.

Appendix 2: ICT Sectors, Growth, Distribution and Poverty. Multiplier Decomposition, Growth and Poverty Alleviation Sensitivity

Since poverty in the present context is measured by identifying a poverty line in monetary terms incomes of the various household groups are the crucial variables. In particular, sectoral growth generated by the ICT sectors must be linked to incomes of the various households in order to determine the exact extent of the alleviation of poverty through growth. The exact effect of income growth on poverty, of course, depends on the sensitivity of the adopted poverty measure to income. In this paper the Foster, Greer and Thorbecke (1984) P_α class of additively decomposable poverty measure is selected for this purpose. For α=0,1,n this measure becomes the headcount ratio, the poverty gap and a distributionally sensitive measure that gives specific weights to each poor person's shortfall, respectively.

If we apply Kakwani's (1993) decomposition to the P_α measure for specific sectors and households i and j respectively, the change in $P_{\alpha ij}$ can be written as follows:

$$dP_{\alpha ij} = \frac{\partial P_{\alpha ij}}{\partial \bar{y}_i} + \sum_{k=1} \frac{\partial P_{\alpha ij}}{\partial \theta_{ijk}} \, d\,\theta_{ijk} \qquad (11)$$

Here $P_{\alpha ij}$ is the FGT P_α measure connecting sector j to household group i, y_i is the mean per-capita income of household group i, and θ_{ijk} is the income distribution parameter. Under the unrealistic but simplifying assumption of distributional neutrality:

$$d\,\frac{P_{\alpha ij}}{P_{\alpha ij}} = \eta_{\alpha i}\left(\frac{d\bar{y}_i}{\bar{y}_i}\right) \qquad (12)$$

where $\eta_{\alpha i}$ is the elasticity of P_{ij} with respect to the mean per capita income of each household group i resulting from an increase in the output of sector j. dy_i on the right hand side is the change in mean per capita income of household group i. This can be written as (by considering the fixed price multiplier matrix)

$$dy_c = m_{ij}\, dx_j \qquad (13)$$

where dx_j is the change in the output of sector j on a per capita basis for group j. We can now rewrite the aηverage change in poverty measure as

$$d\,\frac{P_{\alpha ij}}{P_{\alpha ij}} = \eta_{\alpha i} m_{ij} \left(\frac{dx_j}{\bar{y}_i}\right) \qquad (14)$$

By aggregating across the household groups we can arrive at the overall poverty alleviation effect

$$d\,\frac{P_{\alpha j}}{P_{\alpha j}} = \sum_{i=1}^{m} \left(\frac{dP_{\alpha ij}}{P_{\alpha ij}}\right)\left(\frac{n_i}{n}\right) = \sum_{i=1}^{m} \left(\frac{dP_{\alpha ij}}{P_{\alpha ij}}\right)\left(\frac{P_{\alpha ij}}{P_{\alpha j}}\right) \qquad (15)$$

Since we are considering a P_α measure

$$\frac{dP_{\alpha j}}{P_{\alpha j}} = \sum_{i=1}^{m} \left(\frac{dP_{\alpha ij}}{P_{\alpha ij}}\right) \left(\frac{\Sigma((z-y_k)/z)^\alpha}{\Sigma((z-y_l)/z)^\alpha}\right) \qquad (16)$$

where q_i is the number of poor in the ith group and the total number of poor $q=\sum_{i=1}^{m} q_i$

Let $s_{\alpha i}$ be the poverty share of household group i (naturally $\sum_{i=1}^{m} s_{\alpha i} = 1$)

$$s_{\alpha i} = \sum_{k=1}^{qi} \left(\frac{z-y_k}{z}\right)^\alpha \Big/ \sum_{l=1}^{q} \left(\frac{z-y_l}{z}\right)^\alpha \qquad (17)$$

We can further rewrite the expression for the average change in overall poverty alleviation.

$$\frac{dP_{\alpha j}}{P_{\alpha j}} = \sum_{i=1}^{m} \left(\frac{dP_{\alpha ji}}{P_{\alpha ij}}\right) s\alpha i \qquad (18)$$

Combining equations 14 and 18
we now have,

$$\frac{dP_{\alpha j}}{P_{\alpha j}} = \Sigma s_{\alpha i}\eta_{\alpha i}\, m_{ij} \left(\frac{d_{xj}}{\bar{y}_i}\right) \qquad (19)$$

Thorbecke and Jung(1996) separate the income increase via the modified multiplier effect from the sensitivity of the poverty measure formally in equation (19) by defining the following two entities:

1. $m'_{\alpha ij} = s_{\alpha i} m_{ij}$ gives the modified multiplier effect in terms of income of a poor group.
2. $q_{\alpha ij} = \eta_{\alpha i}(dx_j/\bar{y}_i)$ represents the sensitivity of the poverty index to the change in income. I adopt their terminology and call this the poverty sensitivity effect.

But each multiplier m_{ij} can be further decomposed:

$$m_{ij}=\eta_j d_{ij} \qquad (20)$$

where n_j gives the (closed loop) interdependency effects and d_{ij} the distributional effects of a change in demand for the product of sector j on household group i.
Thus,

$$dP_{\alpha j}/P_{\alpha j} = \sum^{m} m'_{\alpha ij} q_{\alpha ij} \qquad (21)$$

$$= \sum_{i}^{m} (r_{\alpha ij})\, (s_{\alpha ij} d_{ij})(q_{\alpha ij}) \qquad (22)$$

The d_{ij} on the right hand side can be further decomposed by multiplicatively decomposing the total distributive effects. Given the structure of C_n matrix in section 2.

$D=D_3D_2D_1$ where $D_3=(I-C_{22})^{-1}$; $D_2=C_{21}C_{13}$, and $D_1=(I-C_{33})^{-1}$

The particular element for each household i and sector j can be selected from these three matrices.

Thus the contribution of an increase in output of a particular sector j to poverty alleviation can be decomposed multiplicatively into its two components: (i) the contribution due to the change in mean income of the poor across all groups and (ii) the sensitivity of the particular poverty measure to this change in average income of the poor.

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