UNIVERSITY OF VICTORIA ECONOMICS

Economics of the Poor

Comparing Developing and Developed Agriculture by Comparing Factor Growth and TFP

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Special thank-you to my Mother

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Abstract

This thesis is based on comparing developing and developed agriculture across a panel of OECD and World Bank low-income countries. It is carried out by presenting data on factor growth in labour, land, livestock, machinery and fertilizer. Providing a descriptive analysis using support literature, I explain the circumstances of factor growth among the study countries and demonstrate prevalent issues in agriculture using the data. To calculate total factor productivity (TFP), I use the factor estimates provided in Fuglie (2010), which are based on a number of aggregated independent studies. What this thesis finds is that tradition measurements of TFP using growth accounting will over estimate productivity growth due to limitations on measure mechanization in agriculture. More appropriately, comparing factor growth and TFP using a relative set of factors provides this thesis with an enhanced perspective on the state of agriculture across developing and developed countries.

Introduction 1.1

The importance of total factor productivity (TFP) and agricultural development in determining reasons for international income inequality and persistent stagnation has prompted many economist to study agricultural growth as providing an base for long-term economic growth (see Sachs, 2005; Restuccia et al., 2007; Fuglie, 2010). The distribution of input cost shares tend to favor traditional and less profitable means of production. The more profound effects of a labour-intensive agricultural sector on employment is that other sectors suffer the loss of infrastructure, and human capital development, as many farm employees remain on the farm and lack opportunities for employment elsewhere (Ploeg, 2008). The data presented here shows developing agriculture growing at a much lower rate than developing countries, thereby increasing the TFP gap between them.

This study will develop an applicable model to compare agricultural growth between of a panel of developed, OECD (Organisation for Economic and Cooperative Development) countries, and a panel of developing countries as identified by the World Bank[1]. This thesis will ask: *How does agricultural growth in developed countries compare to that of developing countries? How is factor utilization and total factor productivity changing over time in these countries?* I use the Solow Model infused with factors of labour, land, livestock, machinery, and fertilizer to look at the period from 1980 to 2006. The magnitudes of growth for each country are calculated based on direct statistics and indexes provided by the Food and Agriculture

[1] "Developing countries are defined according to their Gross National Income (GNI) per capita per year. Countries with a GNI of US $11,905 and less are defined as developing (specified by the World Bank, 2010) (International Statistic Institute, 2015, List of Developing Countries).

Organization, the World Bank, and EconStats™ [2](EconStats™, 2015, WB, WDI). Input cost shares are provided by Fuglie's (2010) study on global agriculture productivity, which categorizes the cost-share distribution by region according to a number of independent region and country based agricultural studies. My growth data on the included factors can be weighted and categorized according the Fuglie's findings and provides a basis for comparison by determining the trending growth rates of TFP. By modelling the change in factor utilization, change in output, and change in the TFP, I can explain that constant or inconsistent streams of growth in developing countries leads to lower levels of TFP for agricultural sectors in low income, developing countries. This cycle leads to increasing relative gaps in production.

Studies have shown the TFP accounting for up to 64% of annual GDP growth per capita in some countries, where as physical capital accounts for 25% at most (Easterly & Levine, 2001, p. 9; see also Dougherty, 1991; Young, 1994; Lagos, 2006). Easterly (2001) tells us the driver of economic growth is not factor accumulation, but rather total factor productivity (TFP). Total factor productivity can be explained as the statistic gap between similar levels of inputs and investment which lead to in higher levels of production. As Comin (2006) states, "[TFP] is the portion of output not explained by the amount of inputs used in production. As such, its level is determined by how efficiently and intensely the inputs are utilized in production" (p.1). The increase in production is attributed to the diffusion of technological innovation, education, and improved practices reaching the producer. In agriculture, as in other sectors, there are various forms of capital inputs included in production (such as mechanized capital, fertilizer, land expansion, and protections for livestock and crops), which make it difficult to accurately measure many capital factors. In some circumstances innovations occur under certain types of conditions (climate, soil type, etc.) and are not applicable elsewhere. This often stifles measurement models and has led researchers to seek alternatives to the use of a mechanized capital factor (Restuccia et al., 2007). Determining the growth of TFP also relies on large and consistent bodies of statistics in order develop reasonable estimates of the input costs and are especially difficult to find in the case of developing countries.

To provide consistency to my own study, I was able to use a single body of statistics which provides similar data across all the countries included in the panel. In cases where data was not available, the country was either exempt from the study or, where piece data was available, represented for a subset of the study period beginning in 1980. Furthermore, the data set provides information in some direct relation to each of the factors accounted for by Fuglie (2010), allowing for both consistent and relatively accurate measuring of agricultural growth with respect to the included countries. The applying this data to the Solow growth accounting model provides a basis for comparing the growth of developed and developing agriculture. Furthermore, because of the continuity of the data collected spans over 25 years, I was able to

[2] The statistics used to calculate the growth of each factor were retrieved from EconStats™ which are gathered from the World Bank, World Development indicators, and internally (EconStats™, 2015, WB, WDI).

use an index to reflect the relative cumulative changes in factor utilization and TFP over the study period. As a result, the descriptive analysis is enhanced by allowing us to see the year to year changes in factor and TFP growth over the study period. What the index shows in many circumstances is that factor utilization remains relatively constant with significant differences among developing and developed agriculture in the use of labour, land, and fertilizer.

1.2 Review

Agriculture acts as a basis for comparing development because, as Theodore Schultz states, "Most of the world's poor people earn a living from agriculture, so if we knew the economics of agriculture we would know much more about the economics of being poor". And "Because no currently advanced country of some size became advanced without the agriculture sector first achieving substantial productivity gains in the early stages of development“(Bezemer & Headey, 2007, p. 1342). Developing agriculture is contested on the grounds that production decisions are made on the availability of labour, the level of necessity, and the possibility of entitlement (see Ploeg, 2008; Angelsen, 1999). Some researchers argue that developing countries should "stress [] demographic growth as the driving force of agricultural growth" (as cited in Ploeg, 2008, p.46, see Boserup, 1970). In contrast, Reardon et al (2003), shows that supermarkets in the developing world are "increasingly and overwhelmingly [foreign owned]" and "demonstrate a preference for working with relatively fewer, modern suppliers" (as cited in Barkley and Barkley, 2015, p.87). The expansion of Western producers reflects the classic restrictions on developing agriculture listed by Ploeg (2008): reaching "technical ceilings", suffering diminishing returns on labour inputs, and continued factor stagnation (p.46). The descriptive analysis used in this study offers support to the latter body of research by showing relatively constant factor utilization among some countries. Furthermore, stagnation or decline in the use efficient and productive factors like fertilizer and machinery may explain negative rates of TFP growth among some developing countries.

The following section (2) provides a model of measurement and the factors needed to derive a reliable result. More directly, I provide the Solow model being used for measurement, the included factors, a derivation of the growth accounting model, and the index used to demonstrate change in factors over time. In Section (3), I discuss the input factors and the associated data. In particular, I point out features displayed in the trends of each factor which suggest intuitive features of the economies being researched. For example, in the case of small developing countries, a lack of trade specialization is believed to result from unusually high levels of activity in agriculture. In section (4) I display my findings on TFP for the included countries and discuss the implications with regard to agricultural development. I found that, over the course of the study period, a majority of countries yielded sufficient data to determine relative productivity growth in agriculture. Information from the study suggests increasing productivity gaps between developing and developed agricultural economies.

Study 2.1

This study is driven by a descriptive analysis of the factors listed above and is supported by a number of literary sources with regard to the factors involved. As cited in Ludena et. al (2007) "a review of multi-country agriculture productivity studies, report[ed] a total of 17 studies in the decade between 1993 and 2003" (p. 1). In the case of Ludena et. al. (2007), a Malmquist Index[3] and data on livestock quantities provided estimated input costs which are applied to a sample of 116 countries. However, Coelli and Rao (2005) have reported that cost shares often vary widely over regions and over time. Fuglie's (2010) research on global agricultural productivity "bring[s] together several country-level case studies that have acquired representative input cost data to construct... and apply their average cost-share estimates to other countries with similar agriculture" (p.65). The approach used by Fuglie provides accurate estimates of the TFP growth by categorizing the differences in multi-factor cost according to region, but unfortunately does not account for their change over time. Similarly, my research adopts the input cost-share estimates on labour and land; livestock, machinery, and fertilizer provided by Fuglie (2010) (see Figure 2). The panel of countries selected for this study are categorized according to their region and development status (i.e., developed and developing) in Figure 1.

Modeling 2.2

The Solow Model used for the study can be shown in the Cobb-Douglas form under constant returns to scale as:

$$Y_t = BL_t^{\alpha} La_t^{\beta} Li_t^{\gamma} Ma_t^{\delta} Fe_t^{\theta}$$
$$\alpha + \beta + \gamma + \delta + \theta = 1$$

According to Fuglie (2010) "TFP is usually defined as the ratio of total output to total input in the production process" (p.66). TFP is, then, the average measure of the mean output from a given set of input. As such TFP can be given as:

$$TFP = Y/X$$

By taking the log differential equation and derivative with respect to't', we can show the growth rate of TFP as:

$$ln(TPF_t/TPF_{t-1}) = ln(Y_t/Y_{t-1}) - \sum_j S_j ln(X_{j,t}/X_{j,t-1})$$

[3] "The Malmquist index is based on the idea of a function that measures the distance from a given input/output vector to the technically efficient frontier along a particular direction defined by the relative levels of the alternate outputs" (Ludena et. al, 2007, p.2).

Where 'R' is represented as the total revenue share and 'S' as a vector with 'j' as the number of input shares summing to one. Given constant cost-shares, the formula used for calculating TFP is shown as:

$$ln(TPF_t/TPF_{t-1}) = ln(Y_t/Y_{t-1}) - (\alpha ln(L_t/L_{t-1}) + ... + \theta ln(Fe_t/Fe_{t-1}))$$

Where the log differential with respect to't' of TFP is used to track the period to period change in TFP. In other words, for small changes, the rate of growth or decline in TFP is the difference between the growth in total output and the growth of factor inputs weighted by their cost-shares. The cost shares used to calculate the growth rate of TFP according to region are shown in Figure 2.

Indexing Factor Change

The Raw data used for this study is significantly varied in magnitudes and made it difficult to display from a relative basis. For this reason I developed a squared-adjusted index based on changes in the log differential function with respect to the time of each factor input, total output, and TFP, in order to cumulate and show the relative year to year changes. The index used here can be shown as:

$$Index_t = \sqrt{Index_{t-1} * (1 + ln(X_{j,t}/X_{j,t-1}))^2}$$
$$Index_{1980} = Index_{t-1} = 100$$

The index offers a relative perspective with respect to change in factor utilization over time. This allows us some sense of the relative change in the magnitudes of each factor across all the sample countries, rather that the direct magnitudes of input. In this regard, the index should be viewed as a level of utilization relative to the levels used during 1980, which allows us to visualize the change in utilization over the study period.

Under a constant returns to scale, growth or decline in one input factor should exhibit the opposite effect among the other factors or else be accounted for by a growth or decline in the TFP. This study does not go so far as to further implement the data on period to period change of cost-shares into the calculation of TFP, as this is limited by the amount of observations per sample country and would require aggregating countries by region while overlooking subtle country to country differences this study is comparing. Fuglie (2010) has collected a number of regional studies which use aggregate data to acquire factor estimates respective of particular countries or regions. Like Fuglie, I apply them to the calculated factor growth rates and use the index to view relative change in total factor productivity over the study period.

3.1 Labour

The most striking difference between developing and developed agriculture is the amount of labour devoted to production. The data I've collected shows the developing sample of countries commit as much as 100% and as little as 40%. Labour devoted to agriculture in developing countries also remained consistent over the study period compared to developed countries whose labour committed to agriculture continuously decreased to below 5%.
In spite of large commitments to labour, Figure 2 shows that most countries in Sub Saharan Africa commit only one third of revenue to labour, which is comparable to both North America and developed countries in Europe, yet must be distributed over a much larger agricultural labour force. Researchers have indicated that the level of labour intensity with this regard may serve as an opportunity for rapid growth by possibly increasing individual labour productivity, while others state it is an unavoidable trajectory (see Ploeg, 2008, p.48). In the context of rising population, constant levels of labour in agriculture, and the dependence of many on agriculture for employment, puts pressure on forest resources as farm land expands.

The analysis in Graph 1 contains data on the number of people active in the agricultural sector over the entire labour force. From the panel of developing countries in Graph 1.1 we can immediately see possible errors in the data collection as labour is shown to be over 100% of the labour force. Though I suspect this is due to a double-counting error in the data, such a high degree of agricultural skill adoption indicates a smaller degree of skill specialization in separate sectors of the economy. Using the Labour Index in Graph 1.3 and Graph 1.4, we can see the cumulative change in labour committed to agriculture amongst our panel of countries. With respect to equal cost-shares devoted to the labour factor among developing Sub Saharan countries and developed European countries, declining commitments to labour are indicative of increasing income gaps between our two panels. Furthermore, it supports the evidence that agricultural decisions in developing countries are based on necessity with regard to the relative availability of labour rather than production maximizing combinations of factor input.

Consistent rates of labour devoted to agriculture have prompted analysis into why this is the case. Similar to my own findings, Restuccia, Yang, & Zhu (2007) state, "despite very low productivity in agriculture, the poorest countries allocate 86% of their employment to this sector, as compared to only 4% in the richest countries" (p.235). Chayanov's (1966) micro-economic analysis of farm family decisions suggests production happens on the basis of the number of family members employable and the level of consumption needs. However, as Ploeg (2008) states, "through labour investments and... time-consuming improvement in [other factors], both the resource base and the process of production are improved. More yields results in higher earnings" (p.45). Ploeg supports an efficient redistribution of cost-shares, but at the risk over simplifying: he is aware that this must happen in the context of high unemployment, marginality among demographics, and lack of information to guide production decisions. The absence of this change among increasingly difficult conditions has led Ploeg and others to argue that developing agriculture is becoming completely alienated from the global economy.

3.2 Land

By comparing the expansion of agricultural land we can see developing countries are likely to bring more land into agricultural production. The information gathered from the Food and Agriculture Organization and EconStats™ for the land factor is based on the year to year amount of recorded arable land in each of the studied countries. When plotted on the index, it is evident that land is, and its expansion is, more important in agriculture for developing countries. Land utilization in developing countries increased as much as 50% in some cases compared with a relatively constant usage for developed countries over the period. Figure 2 shows that among Sub Saharan and Central American countries, the cost-shares devoted to land are relatively large, at nearly a third of revenue. Land expansion in developing countries is consistent with arguments in the growth literature. It has been explained in terms of the availability of frontier land in developing countries, long term investment, and land entitlement (see Southgate 1990; Angelsen, 1999). For developing countries, land expansion serves as the most widely available factor in some circumstances, forcing agriculture further into the margins of the country and often devastating existing resources, most notably forests and wetlands.

From the analysis in Graph 2, which depicts the total measured arable land in hectares, it becomes apparent that bringing land into production is a critical part of agriculture in developing countries. However, we can observe that expansion in this regard is restricted among a subset of developing countries, which indicates that the opportunity to increase the amount of land under agricultural production may not be a viable option for all developing countries. Land expansion in developing countries is based on the availability of a frontier or hinterland. In the case of Burundi, Malawi, and Zambia, land expansion may face physical and territorial barriers (Graph 2). Among our developed countries, land under agricultural production remains relatively constant. The relative contribution to the land factor (Figure 2) in North America and Europe is less than 20%, where as among in our developing countries this factor accounts for nearly 30%. From the increase in land and the relatively large cost-share attributed to it among developing countries, we can see that adoption of hinterland into production accounts for a considerable degree of output growth (Graph 6.1) among some of our developing countries (Mauritania, Benin), while others may face restrictions and barriers with regard to this factor.

Regard for environmental degradation and loss of increasingly tangible forest resources has motivated researchers to look into the effects of expanding agricultural land in developing countries. Southgate (1990) contributes the expansion of agricultural land into frontiers to a number of colonization projects carried out by the public sector in developing countries.

Expansion in this manner is seen as beneficial for the state and the farmer because "agricultural colonists benefit from grace periods for development credit and other subsidies," while maintaining regimes that "promote deforestation" (p.93). Similarly, Angelsen (1999) approaches this problem from under a micro-economic lens, arguing "Decisions about agricultural expansion (deforestation) in many frontier areas should be modelled as an investment decision, because forest clearing commonly gives farmers rights to the forest. Deforestation, [as] a title establishment strategy ... is unproductive... because it gives a negative contribution to overall production... and is a kind of rent-seeking" (Angelsen, 1999, pp.186-200). In contrast, VICE Media (2015) and Mostafiz (2013) have reported agriculture production in Bangladesh is beginning to suffer due to rising sea levels, which substantially facilitates migration further into the margins. My data shows land to be an important factor for agriculture in developing countries, yet presents trade-off between expansion and deforestation.

3.3 Livestock

Livestock in developing and developed agriculture is shown in the data to be constant or increasing at similar rates across all the countries included in the study. The livestock index produced in this study is based on a livestock production index found in the Food and Agriculture Organization's website database. Applying the index to this information represents the relative growth in livestock relative to production over the period, which includes meat, all dairy sources, eggs, honey, raw silk, furs, and hides (EconStats™, 2015). The index shows that, with regard to growth over the period, livestock input continues to contribute to growth for a number of countries in both sets. However, their respective cost-share contributions to livestock indicate that a more substantial part of growth among developing countries in the regions of Eastern Europe and Africa are reliant on livestock. Despite recent research showing livestock production remaining largely dominated by developed countries, the growth in livestock exhibited by developing countries has been accounted for by its substitution for machinery and by its being viewed as a secure investment (see Walker et al., 2000; Upton, 2004; Barkley & Barkley, 2015; Pica et. al., 2008). Though it is hard to draw particular conclusions from the data shown here, livestock can be said to be consistently growing in importance among a majority of countries represented.

The index of livestock growth shown in Graph 3 shows an increasing or relatively consistent livestock factor. Figure 2 shows livestock as the largest factor share for Eastern European and African countries, accounting for over a third of input. In comparison, my set of developed countries exhibit similar rates of growth, though there are subsets of these countries, including Hungary and Australia, which show a slight decline over the period. Hungary is included among Eastern Europe and is shown to contribute the largest cost-share to livestock among all the regions represented in this study. A similar case among our developing countries is Burundi in the Sub Saharan region. A decline in this factor will be represented heavily in the

TFP index. There are no substantial declines represented in this factor, which indicates these areas continue to be important to the input for agricultural growth.

The importance of livestock in agriculture across both developing and developed countries motivates analysis into the macro- and micro-economic advantages contained in this factor. Barkley & Barkley (2015) show livestock production is increasing in developed countries as livestock production is shown to benefit greatly from the economies of scale (pp.85-87). However, in developing countries "investment in livestock raises farm production through (a) extension of the land area that can be utilised; (b) diversification of the productive activity on a crop farm, and; (c) intensification, i.e. by raising livestock value of output and hence total production per hectare of agricultural land increases" (Upton, 2004, p.1). Furthermore, "[livestock] provide[s] a secure haven for capital, particularly during inflationary episodes" (Walker et. al., 2000, p.687). As this evidence explains, even in the face of waning corporate interest developing agriculture continues to rely on livestock as an increasingly productive input as well as a sound investment decision.

3.4 Machinery

The use of machinery in agriculture has been accredited with the persistent growth in agriculture among developed countries. Information for this factor was gathered from the World Development Index, the Food and Agriculture Organization, and EconStats™ on the number of tractors in a given country and excludes garden tractors. The index represents the change in tractor use per hectares of arable land. From this information we can view the relative growth in mechanization in each country over the study period. What I found is that machinery utilization is fairly consistent among the entire sample countries included, with three notable exceptions: Burkina Faso, Nepal, and South Korea. With respect to these countries, we can see that machinery claims a relatively small cost-share among Sub Saharan Africa, Developed Asia, and Central Asian, accounting for approximately 5% of input, compared to 14% and 17% in North America and West Europe, respectively. With regard to the high cost of mechanization, countries with heady levels of growth in this area are expected to have higher cost-shares devoted to this factor, though it is difficult to show under this model. Evidence of relatively high levels of mechanization in the West emerged on the basis of North American's and European's relative lack of available labour, which promoted labour saving equipment in these regions (see Fredrico, 2005; Barkley & Barkley, 2015). The consistency in the data presented here suggests this factor is fairly unchanged- being more heavily used by some countries than others- but not significantly accounting for growth.

The data shown in Graph 4 suggest that mechanization remains relatively constant over the study period with the exception of Burkina Faso, Nepal, and South Korea. Among these countries, tractor usage is shown to increase before reaching some level of stability. The machinery cost-share of these regions (Sub Saharan Africa, Developed Asia) is shown to be quite low compared to that of North America and Europe (Figure 2). The high rate of growth in this factor is indicative of its increasing importance in a select few countries and, in some circumstances, results in a greater share of input over the period. The growth of mechanization in these countries encourages further research into modeling how the cost-shares are changing over time with respect to factor inputs (see Li & Stewart, 2014). Because the factor shares given by the literature cannot account for possible changes over time, the growth of machinery in these countries may lead to growth in this sector not being properly accounted for in output.

The notable productivity gains in North America and Europe due to mechanization of agriculture readily suggests the same model could be practiced in developing Africa and other regions. With respect to our developing countries, "Vast amounts of available land in the US, Canada, Australia, and Argentina led to the rapid adoption of... mechanized agriculture" (Barkley & Barkley, 2015, p.21). Furthermore "The first half of the twentieth century featured a boom in the consumption of fertilizer in Europe, and a boom of mechanization in the United States" (Fredrico, 2005, p.114). Fredrico (2005) notes the difficulty in measuring capital in this regard and mentions that milking machines, which are not represented in the data, were a significant part of livestock production increases. Fredrico also uses machinery tractors as a relative measure of mechanization (p.48). The significant conclusion we can draw from this analysis is that mechanization depends on a number of external factors- not the least of which are time, investment, and infrastructure. Furthermore, the methods of measuring mechanization could stand to be greatly improved. With regard to our panel, the problem is exacerbated when countries show significant increases in this area which cannot be properly measured.

3.5 Fertilizer

Similar to mechanization, the difference in fertilizer usage across developing and developed countries serves as a point of interest for economists. Information on fertilizer, provided in metric tonnes of consumption, was collected from the Food and Agriculture Organization's database. The statistics collected include nitrogenous potash and phosphate fertilizers, and do not include estimations of traditional fertilizers, such as animal and plant matter. The index shows large variations in fertilizer usage among developing countries compared to relatively constant usage in developed countries. Fertilizer accounts for less than 10% of input in Eastern Europe, Central America, and Sub Saharan Africa (Figure 2). In North America and Developed Asia (applied to South Korea) fertilizer claims approximately 20% of input revenue. Sporadic usage of fertilizer has been noted as having an effect on the high variability in crop yields and the farmers' decisions based on the availability and price of chemical fertilizer in developing countries (see Morris et. al., 2007). Furthermore, access to fertilizer in developing countries suffers from profiteering on the side of producers and public support programs due to its relatively high value and return (see World Economic Forum, 2013). These issues seem to be exhibited in the data indicating that fertilizer usage in developing countries shows more variation than any of the other factors.

The index on fertilizer shown in Graph 5 demonstrates a very interesting variation among developing countries compared to the relative consistency amongst developed countries. Developing countries reach levels as much as three times the level of usage in 1980 before plummeting to nearly zero by the end of the period. Variation in fertilizer use doesn't substantially influence growth in developing countries due to its minor cost-share portion (5%). Contrarily, fertilizer, as with machinery and land, represent another balanced input among the majority of our developed countries and accounts for approximately 20% input. Chile represents an interesting case, as fertilizer usage shows a substantial increase over the period yet, in South America, only accounts for 7 % of input. This presents another interesting case which could benefit from knowing how variations in this factor are effecting its cost-share over time.

With regard to developing countries, fertilizer, in conjunction with better seed, represents a more fluid method of attaining productivity gains than largely infrastructure backed mechanization. Fluctuations in fertilizer usage have been explained by the Morris, Kelly, Kopicki and Byerlee (2007) as problems with both supply and demand:

> "Demand for fertilizer is often weak... because incentives to use fertilizer are undermined by the low level and high variability of crop yields on the one hand and the high level of fertilizer prices relative to crop prices on the other... Unfavorable price incentives are aggravated by many other factors, including the general lack of market information about the availability and cost of fertilizer, the inability of many farmers... to purchase fertilizer, and the lack of knowledge on the part of many farmers about how to use fertilizer efficiently." (p. 5).

Added to this market failure is a degree of instability from government, noted by Akinwumi Ayodeji Adesina, Minister of Agriculture and Rural Development of Nigeria, during the 2013 World Economic Forum. "When I became minister in Nigeria, I inherited a system of fertilizer supply... [where] the government bought and sold [poor quality chemical fertilizer]... and crowded out the private sector" (World Economic Forum, 6:00). Fertilizer usage in Nigeria has since been privatized and increasingly relies on information and technology to reduce market failure. Nigeria offers a model for bringing chemical fertilizer usage into the fold of developing agriculture by pursuing productivity opportunities offered by emerging technologies.

4.1 Results

As the final part of the study, the data accumulated was combined with the output data in Graph 6 to estimate the change in the TFP from year to year over the period. Output data is based on value-added per worker data retrieved from the World Bank National and the Food and Agriculture Organization, and compiled by EconStats™. Value Added "agriculture measures the output of the agricultural sector (ISIC divisions 1-5) less the value of intermediate inputs. Agriculture comprises value added from forestry, hunting and fishing as well as cultivation of crops and livestock production" (EconStats™, 2015, WB, WDI). Indexing output for my panel of countries exhibits a strong contrast between the relatively constant developing countries and the consistently increasing developed countries. The large degree of separation between the panel countries, in addition to the analysis presented here, offers a conjecture as to why this productivity gap exists. Furthermore, the growth in the factors present here are assumed to explain much larger productivity gains among developing countries, which makes maximizing cost-share combinations a convenient argument.

The results provided in Graph 7 are not surprising considering the consistent levels of output exhibited over the period by developing countries. The rates of change in the TFP represented by the index shows very impressive growth among our developing countries, however, among the panel of developing countries the results are far more dismal and show slightly declining levels of TFP over the study period, meaning productivity and efficiency levels fell from the relative level in 1980. This was to be expected as constant levels of output in combination with growth of inputs, like livestock and land, which also retain a large cost-share, increasing with population, could possibly be driving these results. Regardless, the results in Graph 7 display an alarming trend, indicating that developing agriculture is less 'developing' than declining. The more profound effects of this decline advocate a deeper alienation of developing agriculture and the need for innovation and improvement in this area.

The results shown in this study are assumed to overestimate TFP for the developed panel due to the data on mechanization of agriculture not accounting for the growth in mechanization outside changes in tractor use. With regard to my developing panel, a substantial degree of output is centralized in three primary factors: labour, land, and livestock; and can account for much of the productivity growth in these countries. Evidence found in the literature also demonstrates how barriers outside of agriculture prevent the development of mechanization and fertilizer usage in developing countries (see also "development traps" Collier, 2007). Prescriptions for improvements in these areas have largely been based on improving access to information and markets through expanding use of information technology, which has proved to be inexpensive and accessible. With regard to the results in the data, productivity gains in developed countries are show to come from some degree of unmeasured growth, but also a higher relative productivity of inputs.

4.2 Conclusion

From this analysis we can draw three important conclusions. Drawing on this data and support from the literature, it is apparent that decreasing marginal returns produced by a burgeoning agricultural labour sector suggests demographic growth is not a sustainable method of driving agricultural growth. Labour intense agriculture drives land expansion projects. In some circumstances investment decisions are made on the basis of entitlement, which can lead to unproductive expansion. Under the physical restrictions of land input and constant labour inputs, with respect to the overall increase of the economy, may result in decreasing returns to scale and decline. Increasing farms at the frontier or hinterland margins is not a viable factor of growth in the face of rising population demands. Secondly, mechanization, because it cannot be properly measured, is assume to account for some portion of TFP thereby leading to its over estimation. Mechanization, however has been shown to be an integral part of western agricultural development, but requires a large degree of infrastructure outside of agriculture (Fredrico, 2007; Ploeg, 2008; Barkley & Barkley, 2015). Fertilizer, then, has offered a more immediate solution to productivity loss in developing countries, but it too suffers from market failure and government interference. Finally, agriculture in developing countries primary relies on labour, land, and livestock- out of the factors presented here. Because these factors are well recorded, productivity growth in developing countries can largely be accounted for by our measurements. Contrarily, the expansive factors used in developed agriculture makes it difficult to measuring these inputs resulting in substantial and unwanted bias in TFP growth calculations. Under these circumstances the relative TFP shows characteristics of a strong economy compared to that of a developing economy relative to the included factors. In this sense we can see TFP as the unmeasured factor productivity comparison rather than over estimated quantities.

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Graphs and Figures:

List of Study Countries

Developed	Developing
North America/Australia	**Western Africa**
Australia	Benin
Canada	**Eastern Africa**
US	Burundi
Northwest Europe	Rwanda
Denmark	Malawi
France	Zambia
Germany	**Sahel Africa**
Norway	Burkina Faso
South Europe	Chad
Italy	Mali
Spain	Mauritania
South & Central America	Niger
Chile	**South Asia**
Mexico	Bangledesh
Eastern Europe	Nepal
Hungary	
Developed Asia	
S. Korea	

Figure 1: List of countries for which a full set of important year- to- year data is available and was included in this study.

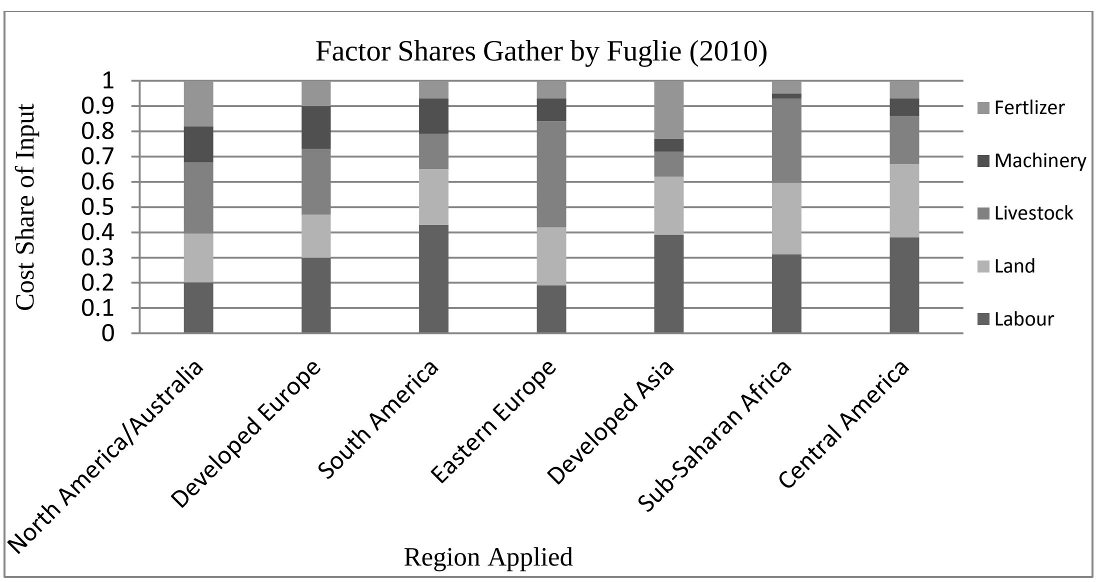
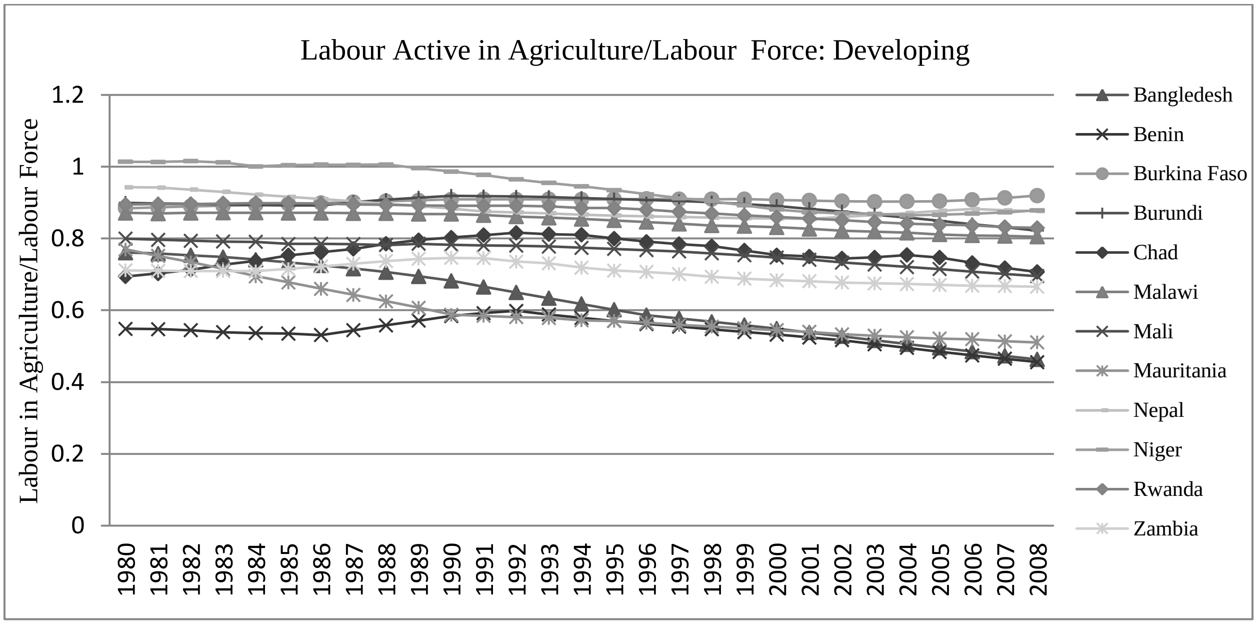
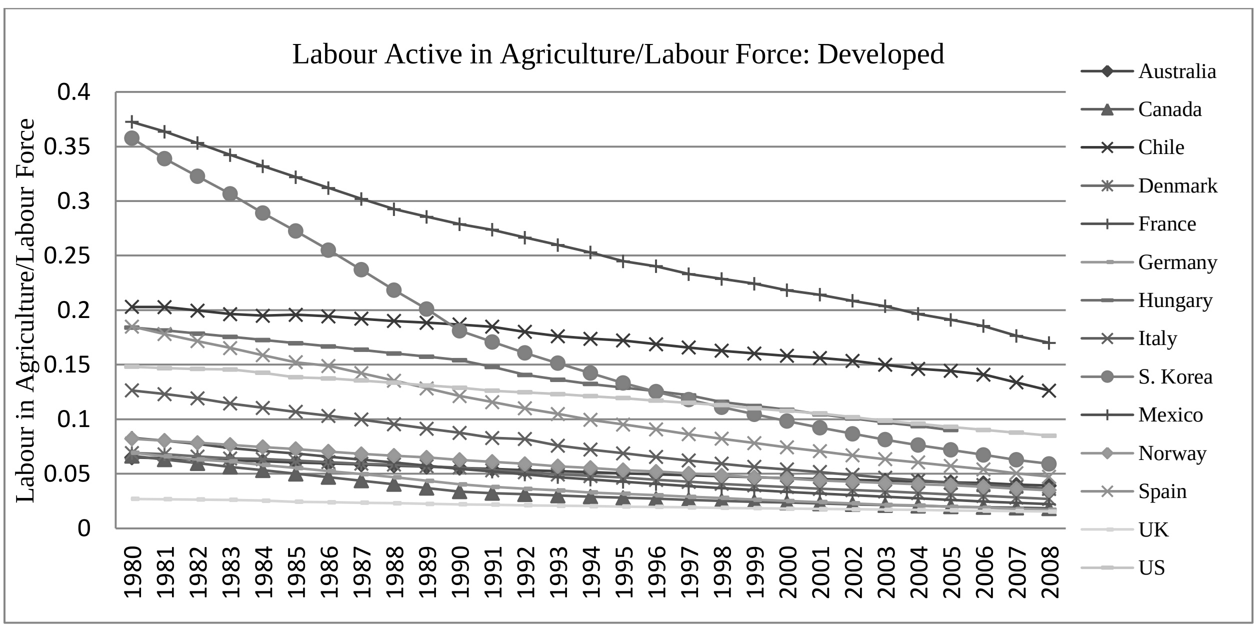


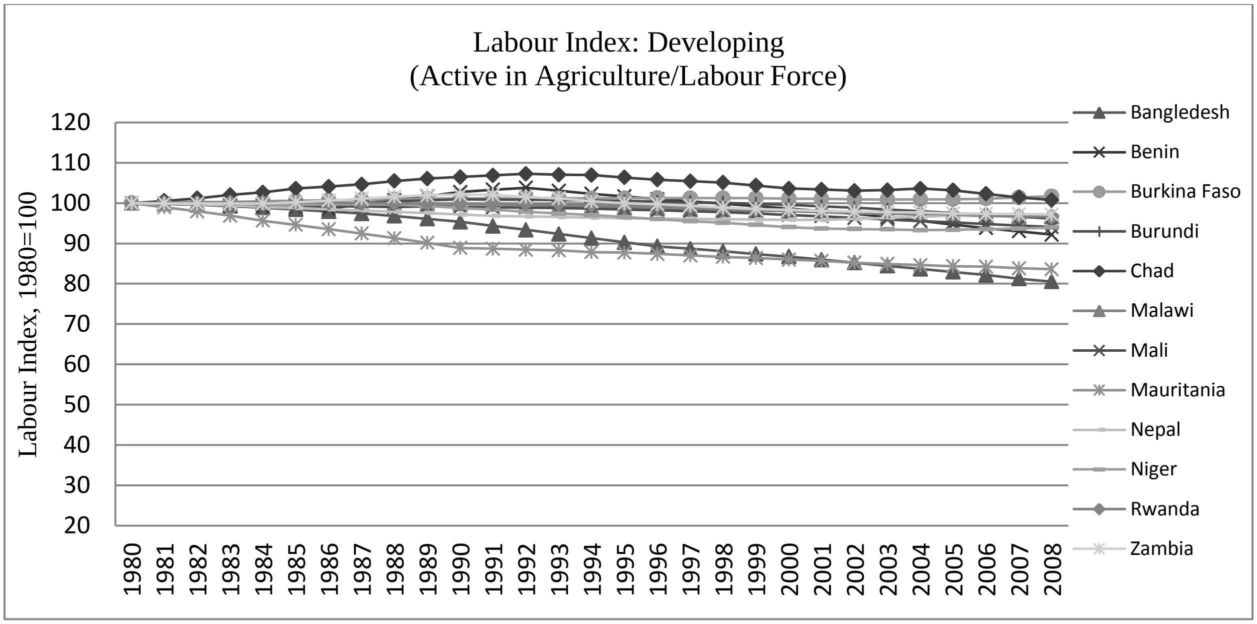
Figure 2: Factor Shares gathered according to a number of independent regional studies and categorized according Fuglie (2010).



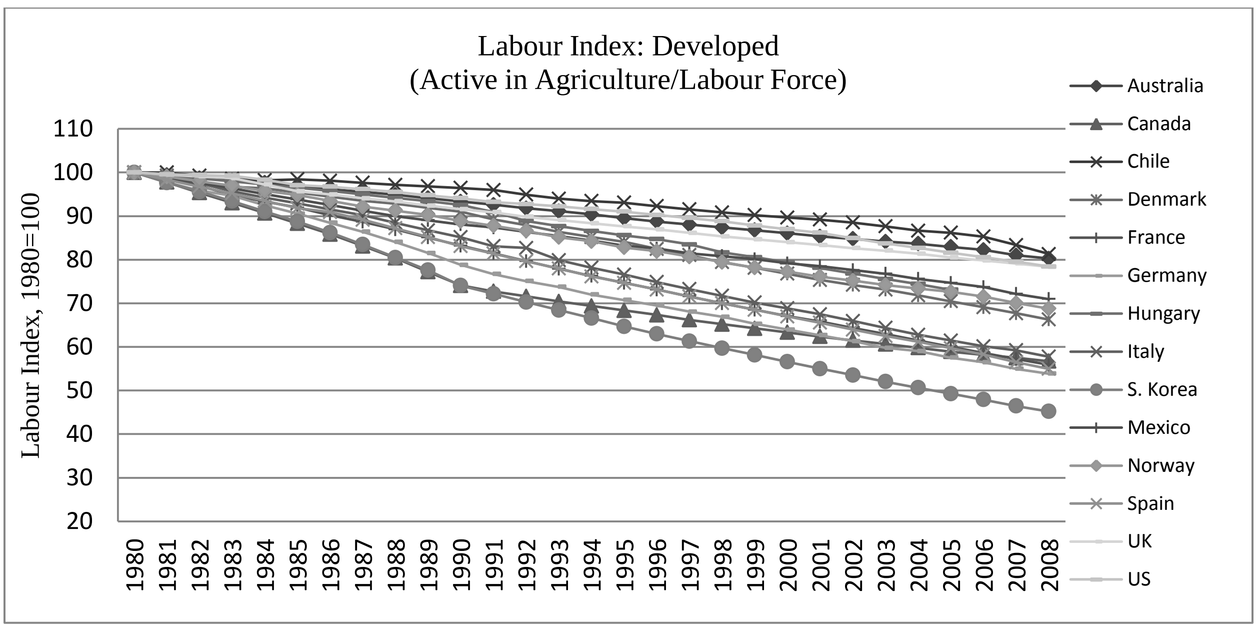
Graph 1.1: Labour active in agriculture as a fraction of the entire labour force for developing countries.



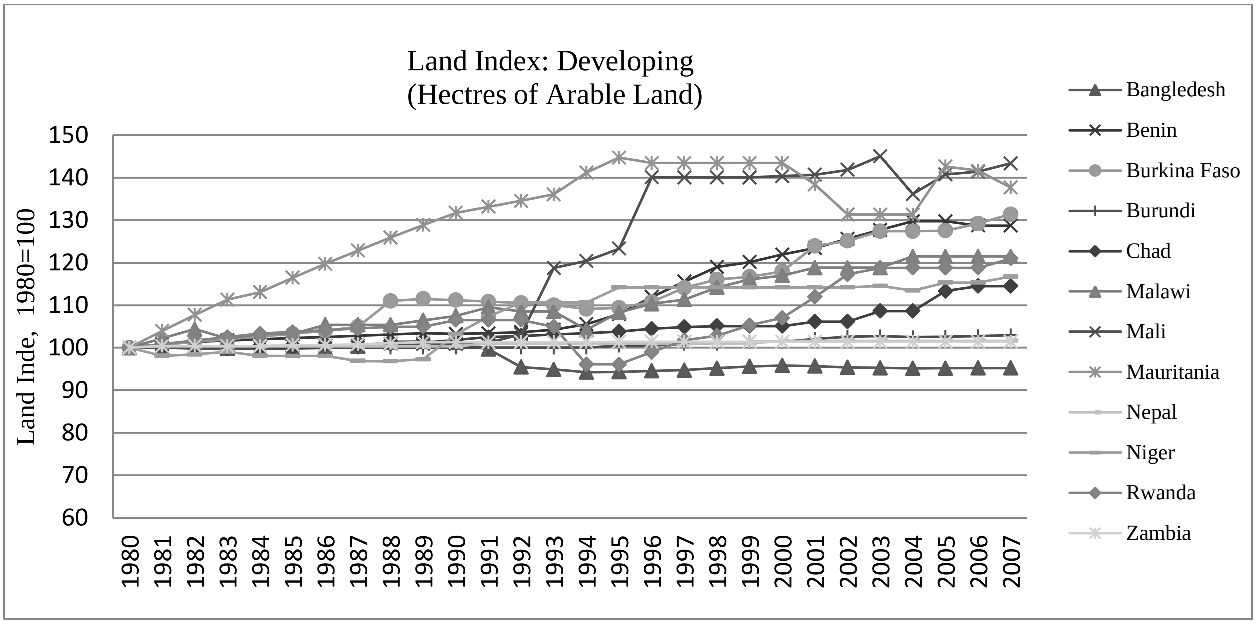
Graph 1.2: Labour active in agriculture as a fraction of the entire labour force for developed countries.



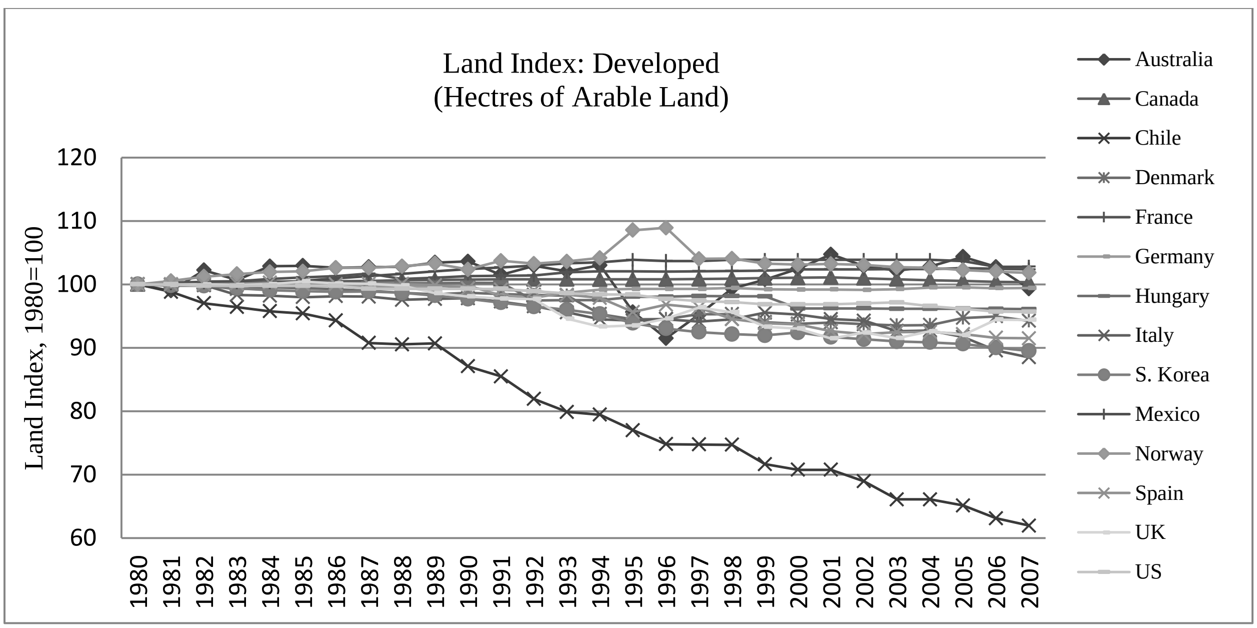
Graph 1.3: Portion of the labour force devoted to agriculture for developing countries.



Graph 1.4: Portion of the labour force devoted to agriculture for developed countries.



Graph 2.1: Land being brought into and out of agricultural production in developing countries.



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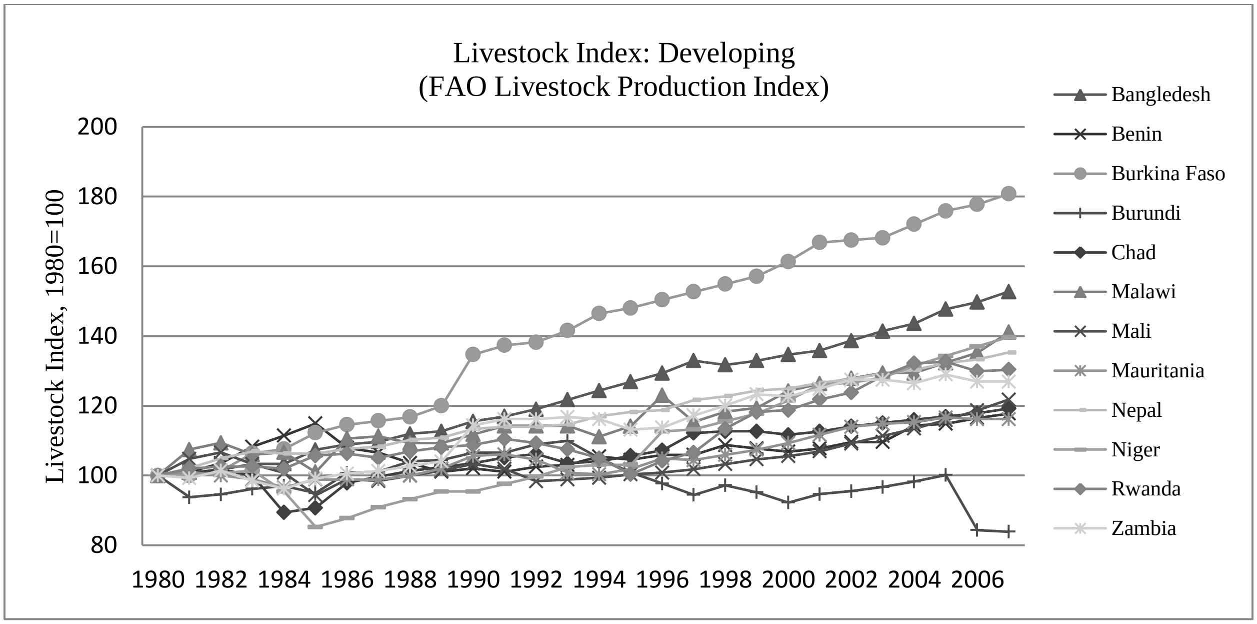
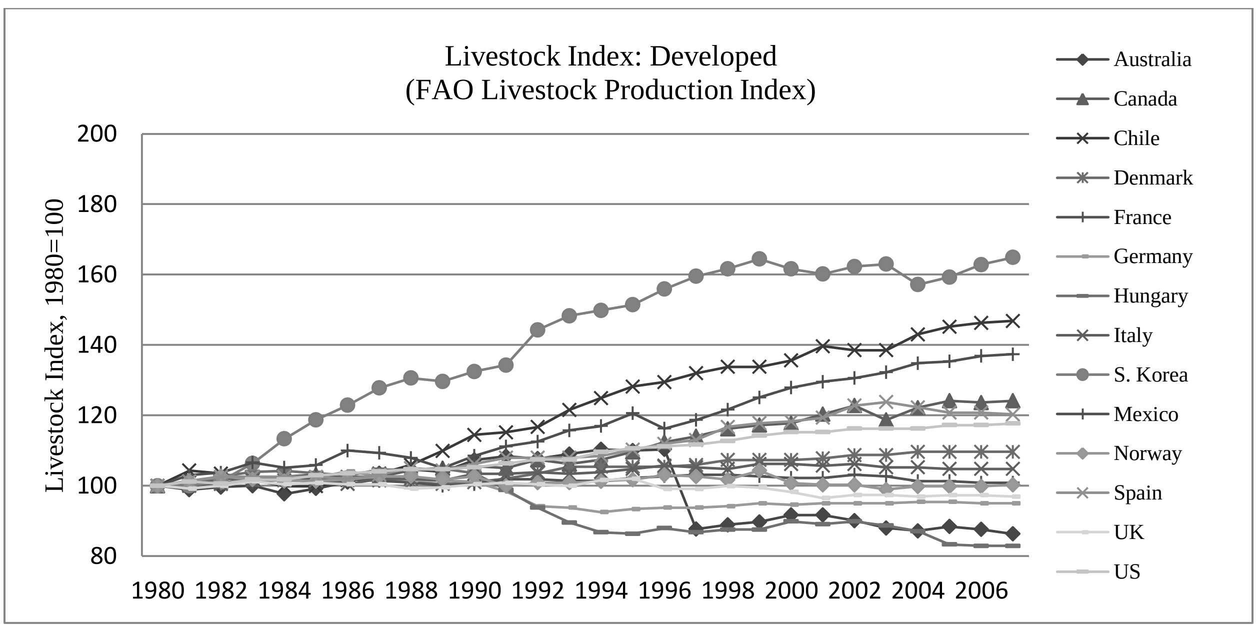
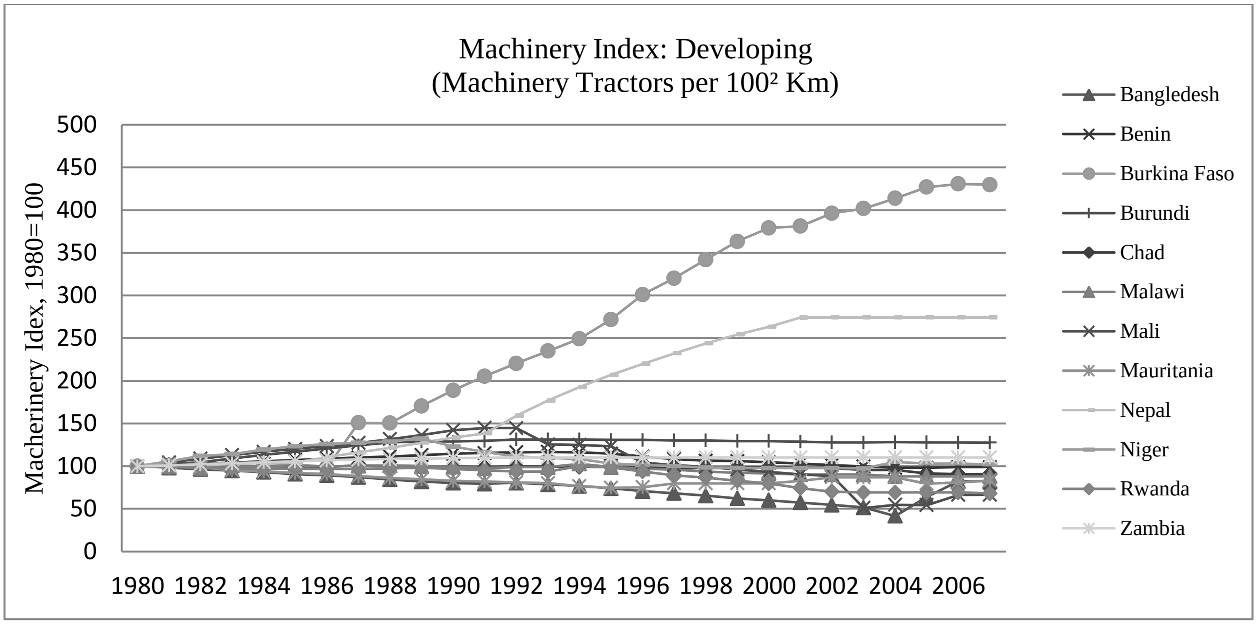


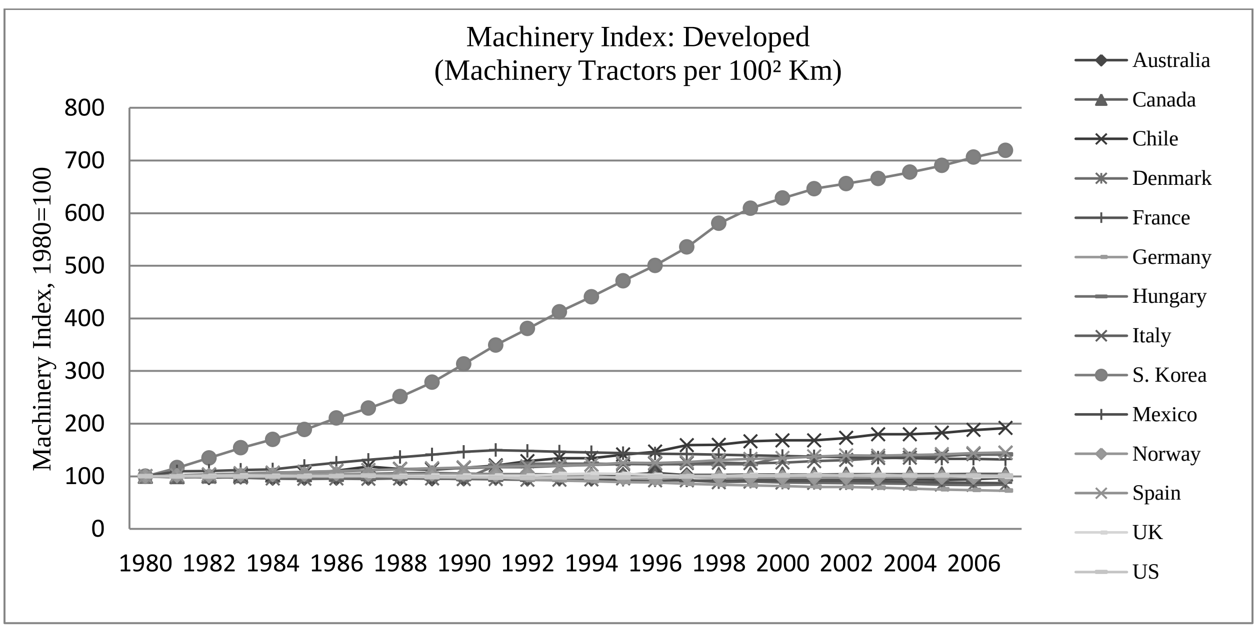
Graph 3.1: Change in livestock related production in developing countries. Based on information from the Food and Agriculture Organisation electronic files and EconStats™.



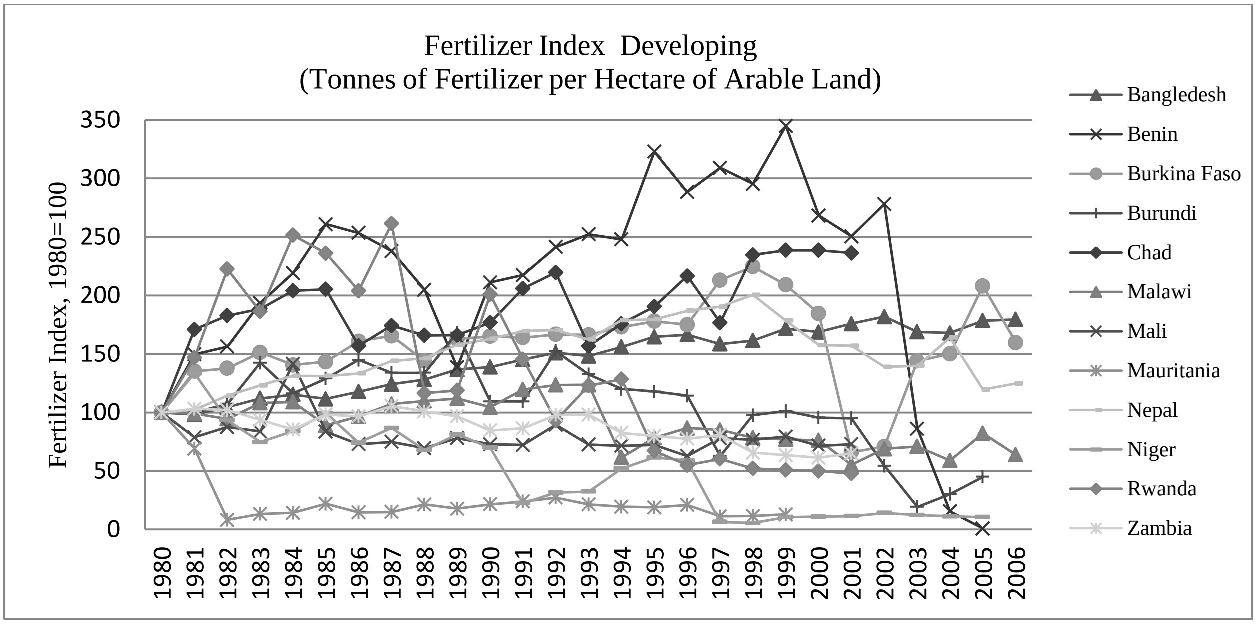
Graph 3.2: Change in livestock related production in developed countries. Based on information from the Food and Agriculture Organisation electronic files and EconStats™.



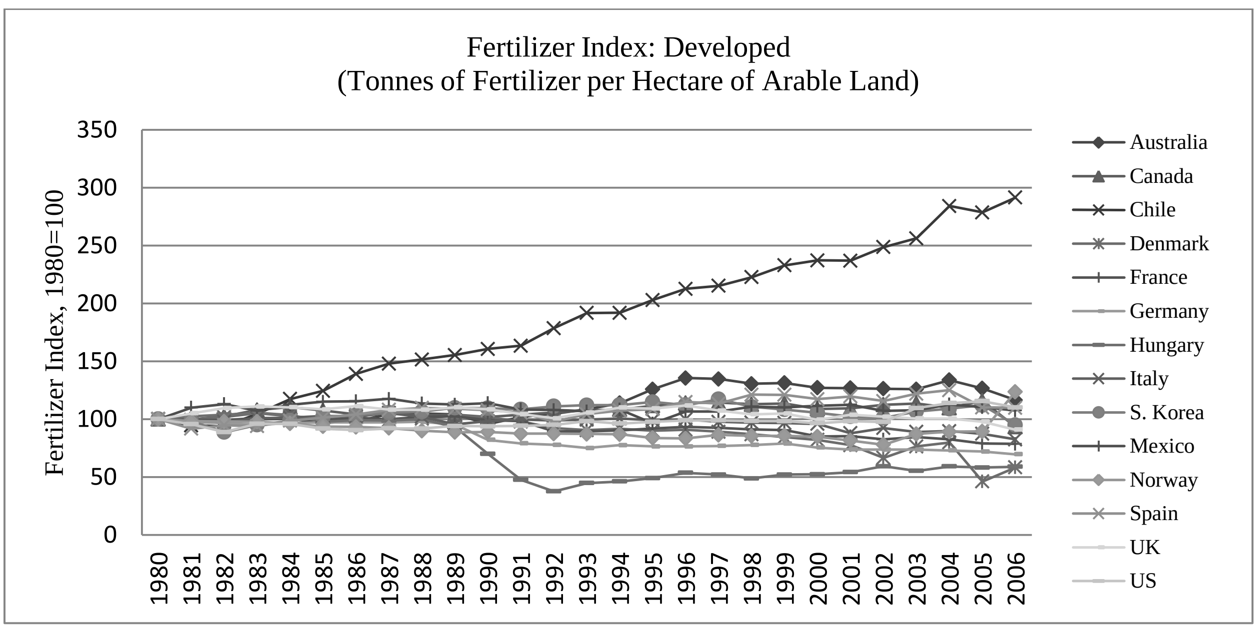
Graph 4.1: Machinery tractors utilization per 100² kilometres of arable land for developing countries.



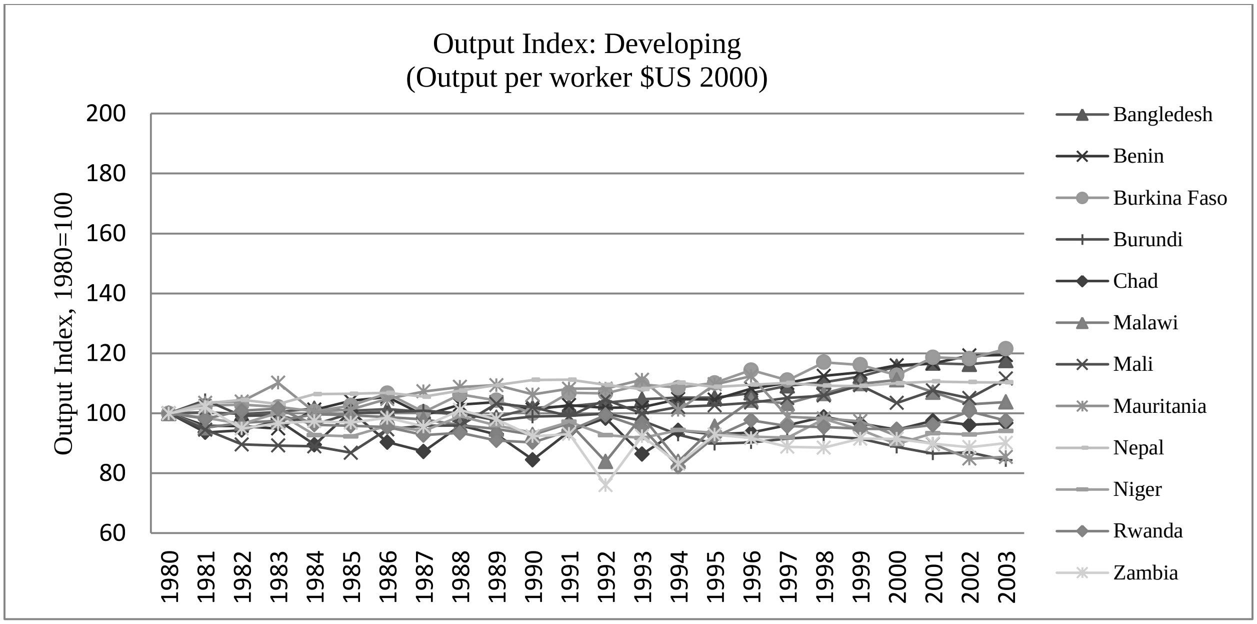
Graph 4.2: Machinery tractors utilization per 100² kilometres of arable land for developed countries.



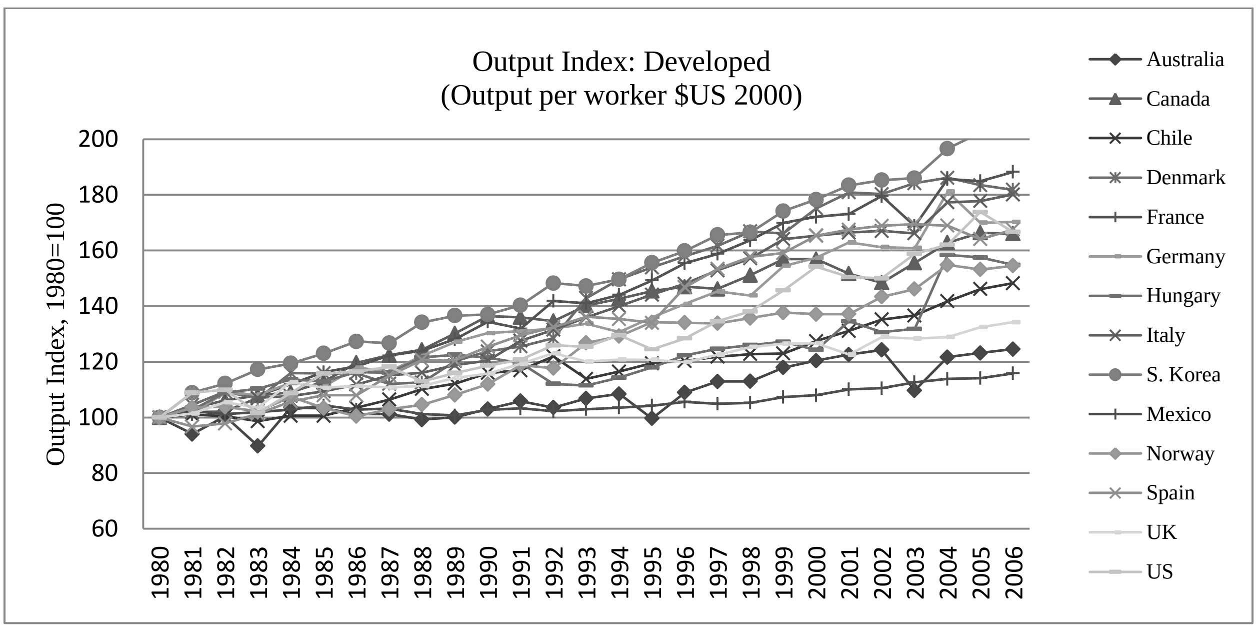
Graph 5.1: Change in Fertilizer utilization as tonnes of fertilizer per hectares of arable land in developing countries.



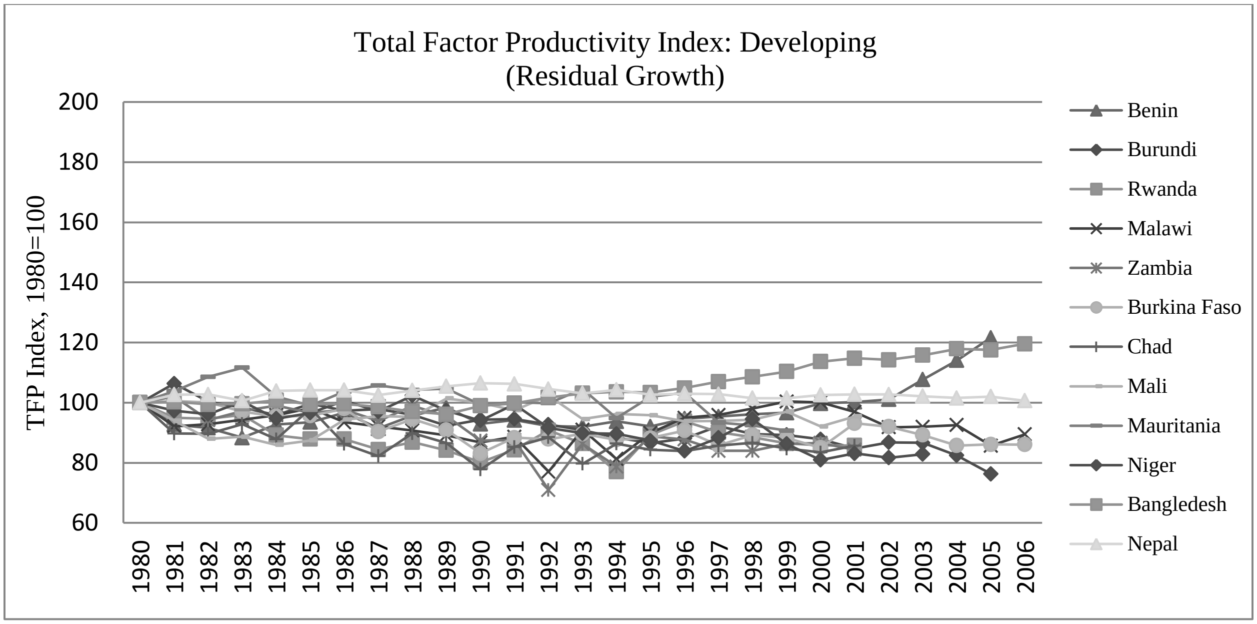
Graph 5.2: Change in Fertilizer utilization as tonnes of fertilizer per hectares of arable land in developed countries.



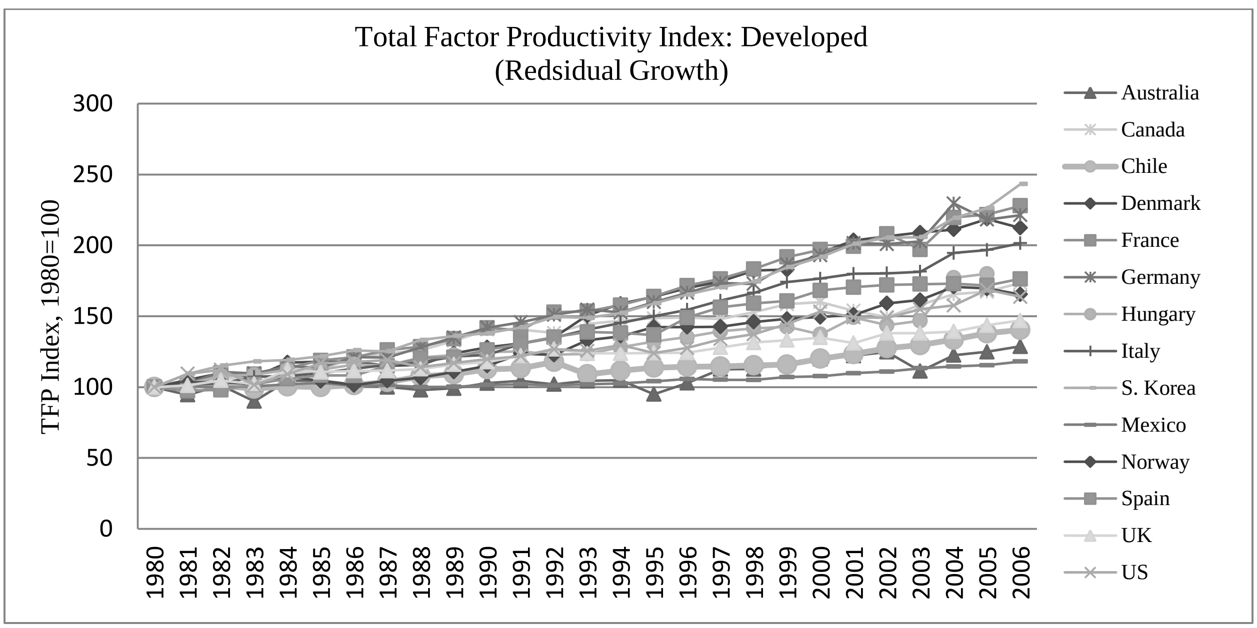
Graph 6.1: Change in output per work as a measure of sector output in $US 2000 in developing countries.



Graph 6.2: Change in output per worker as a measure of sector output in $US 2000 in developed countries.



Graph 7.1: Index based on year- to -year change in TFP, my information on year- to- year factor change and Fuglie's (2010) collection of regional cost-shares of input for developing countries.



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