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Impact of Productivity Growth in Crops and Livestock on World Food Trade Patterns

Carlos Ludena[1]

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[1] Ph.D. Candidate, Center of Global Trade Analysis, Department of Agricultural Economics, Purdue University, West Lafayette, IN 47907-2056, Voice (765) 494-4210, Fax (765) 494-9176, email ludenac@purdue.edu

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Abstract

World food trade patterns have changed in the last 40 years with the share of world trade comprised of bulk commodities falling, and the share of world food trade comprised of processed commodities rising. These changes have been driven by a combination of supply and demand forces. On the demand side, world demand for livestock products and more highly processed food products has been rising more rapidly than that for bulk products. This increasing demand can either be met from domestic production or from foreign production – in the latter case resulting in increased international trade. The extent to which the increased demand can be met from domestic production depends importantly on the rate of productivity growth in the various components of the farm and food sector. This is why the relative rates of productivity growth in crops and livestock is also believed to be an important factor in determining the changing composition of trade. This study seeks to understand to what extent productivity growth in crops and livestock has affected world food trade patterns. We do so by first estimating total factor productivity growth in crops and livestock over the past four decades. The results show that productivity growth in crops has been larger in developed countries. However, non-ruminant productivity growth in developing countries has been larger. By incorporating these estimates into a back-casting exercise with the GTAP general equilibrium model, we hope to understand how these differential productivity growth rates have influenced the composition of world food trade.

Keywords: Productivity growth, trade patterns, livestock, ruminants, non-ruminants

Introduction

In the last 40 years, there have been some important changes in world food markets and in the pattern of agricultural trade. These changes are revealed by the change in shares of the major commodity groups in agricultural trade. The major change is that there has been a shift from bulk commodities (e.g. rice and cereal grains) to processed products (Figure 1). In 1962, bulk commodities represented almost 40 percent of world agricultural exports, and processed products only 20 percent. Now those shares are reverted and processed products now make out 40 percent of world agricultural exports.

The principal reasons why change in world food trade has happened are higher income (due to economic growth), differential factor accumulation and changes in technology, changes in transportation and costs, and policy interventions in food markets (Coyle et al, 1998). Coyle et al. determined that the demand and supply forces had most of the impact on these changes in world food trade. On the demand side, as per capita income increases, people tend to eat a more diverse diet, which includes meat, fruits and ready-to-eat foods, and tends to eat less of food staples such as cereals and legumes. The extent to which the increased demand can be met from domestic production depends importantly on the rate of productivity growth in the various components of the farm and food sector. This is why the relative rates of productivity growth in crops and livestock is also believed to be an important factor in determining the changing composition of trade.

There have been attempts to measure the impact of technological change in crops and livestock in food trade. Rae and Hertel (2000) and Nin et al. (2003a, 2003c) use partial factor productivity (PFP) to project changes in food trade. However, PFP is an imperfect measure of productivity, because it does not take account of the level of other inputs used in the individual activities.

A more accurate measure of productivity is total factor productivity (TFP) which is a measure that accounts for all relevant factors and gives a more comprehensive assessment of productivity. However, TFP measurement has the problem of input allocation to specific activities. For the agriculture sector in most countries, it is not possible to allocate inputs to individual activities within the sector. This makes it impossible to determine TFP. Given the importance of this problem, the literature on different methodologies for estimating input allocations is extensive, but in the end, all methods are frustrated by data gaps. To overcome this problem, Nin et al. (2003b) proposed a directional Malmquist index that gets around the need for complete allocation of inputs across agricultural sectors. They use this methodology to generate multi-factor productivity at the sub-sector level, specifically for livestock and crops.

In the first part of this paper we use the methodology developed by Nin et al. (2003b) to disaggregate productivity measures of livestock and crops in order to explain the changes in world food trade. Rae and Hertel (2000), Nin et al. (2003c) and Delgado et al. (1999) show that productivity growth in livestock is different for each specie, such as cattle, goats, pigs, and poultry. Rae and Hertel show that in Asia the rate of productivity growth for non-ruminants (pigs and poultry) is higher that the rate of productivity growth in ruminants (cattle, sheep and goats). For this reason it is important to have a disaggregate measure of TFP growth of livestock, since productivity growth for livestock species is different from each other.

In the second part of this paper, we use these disaggregate productivity measures to test the hypothesis that technological change in crops and livestock have an effect on world food trade patterns. Section I of this paper presents a brief review of changes in world food trade and its alternatives explanations. Section II discusses productivity measurement in agriculture and the problem of input/output allocation. Section III discusses the data and methodology for productivity measurement. Section IV presents the results of productivity measurement and the possible implications of these results. Section V discusses future directions in modeling these productivity changes.

Determinants of World Food Trade

What have caused this change in agricultural trade? There are various factors that have affected the shift in world food trade. According to Coyle et al. (1998) the first factor is economic growth and consequently, an increase in income. As per capita income grows, there is a shift in the products consumed, with an increased consumption of ready processed products. There is a tendency to have a more diverse diet, consuming more meats, beverages, and fruit, and reduce the consumption of food staples such as cereals and legumes (Cranfield, et al, 1998).

A second factor driving this change is food supply. As nations shift from an agricultural based economy to a manufacturing based economy, there is a shift in the use of resources. Given these changes, countries modify the composition of their outputs to factors that accumulate faster. For example, in South East Asia with the accumulation of human and physical capital there was a shift from agriculture to manufacturing. A third factor is change in transportation technology and costs. As new technologies are adopted (such as containerized shipping), costs and transit times have been reduced. Another factor is policy, in the form of government intervention that reduce/increase trade.

However, an important factor that affects food supply, and that was left out by Coyle et al. is the change in agricultural productivity. Sector-specific productivity can be one of the possible explanations for the large, unexplained residual in Coyle's predicted shift from bulk to high value food trade. Therefore, the impact of crops and livestock productivity growth is an important factor in the change in world food trade.

There have been attempts to measure the impact of productivity growth in crops and livestock in food trade (Rae and Hertel (2000), Nin et al. 2003c). These authors use partial factor productivity (PFP) and estimates of rates convergence in technology to project changes in food trade. However, PFP is an imperfect measure of productivity, because it does not allocate inputs to individual activities. In the next section, we are going to review the approaches to measure productivity growth, and what has been done to overcome the problems from PFP.

Productivity Measurement

Total factor productivity measurement growth has developed in the last decades due to some key methodological contributions. One of the approaches that has been widely used in the last years is the Malmquist Index approach. Färe et al. (1994) implemented a distance function approach to productivity measurement using non-parametric methods. They decompose the differences in efficiency into changes in efficiency (catching-up), and changes in the frontier (technical change). A world frontier is built based on the data from all of the countries in the sample, enabling the comparison of each country to that frontier. How much closer a country gets to the world frontier is called ‘catching-up’; how much the world frontier shifts at each country’s observed input mix is called ‘technical change’ or ‘innovation’.” Countries cannot continue to “catch-up” indefinitely and at some point in time, they will reach the frontier, at which time further growth will be determined only by the rate of innovation, or movement of the frontier itself.

The popularity of the Malmquist index approach has been growing in the last years, with multiple applications in various areas. Coelli and Rao (2003) present a review of the application to multi-country agriculture productivity comparison, with the majority of the research in productivity been focused on sector-wide (or national) level productivity. However, the availability of research in sub-sector productivity is limited, because of data availability on input allocation to individual activities. For example, the amount of labor and fertilizer may be known, but not how much has been allocated to each activity. Without this information, “imperfect” partial factor productivity (PFP) measures such as “output per head of livestock” and “output per hectare of land” are used to measure sub-sector productivity (Rae and Hertel, 2000; Nin et al., 2003c).

Partial Factor Productivity (PFP) measures productivity in terms of a specific input. Some of the most common measures of PFP are yield and labor productivity. PFP is a simple, intuitive, and frequently used measure, but with some problems. For example, is high labor productivity always desirable? What are the appropriate measures of output and labor? According to Zepeda (2001), PFP may be misleading, and with no clear indication on how it changes. For example, land and labor productivity may increase by use of tractors, fertilizer or output mix. Total Factor Productivity (TFP) is a measure that accounts for all relevant factors, and hence offers a more comprehensive picture.

As mentioned by Nin et al (2003b), the most obvious way of finessing the differences between sector-wide TFP and commodity-specific PFP measures involves the estimation of input allocations to specific commodities. The research on this problem is extensive, and is reviewed in Nin et al. (2003b). Given the limitations of these methods, Nin et al. propose an alternative approach to the measurement of commodity-specific efficiency and productivity. They calculate crops and livestock productivity growth using directional distance functions, adapting a directional efficiency measure to focus on a single commodity at a time, not requiring the allocation of all inputs to specific outputs. Distance functions are used to estimate a Malmquist index to measure productivity growth in an output-specific direction (e.g. crops or livestock). In this paper we extend Nin et al.'s work estimating productivity growth for ruminants and non-ruminants, since the productivity for these livestock sub-sectors are expected to be different from each other (Rae and Hertel, 2000; Delgado et al. 1999).

Directional Malmquist Index

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. The Shephard's output distance function is defined as the reciprocal of the maximum proportional expansion of output vector y given input x, seeking to increase all outputs simultaneously. Figure 2 shows the output possibility set for period t and $t + 1$. The production possibility frontier given outputs y_1 and y_2 represents efficient combinations of these outputs. There are efficient and inefficient production units in this output possibility set. Points A and C represent an efficient and an inefficient production unit, respectively along the same ray through the origin at time *t*. The maximum proportional expansion of ***y*** with respect to the frontier for production unit C is denoted by the ratio OA/OC. How far the production unit in C is from the frontier is denoted by the distance from the production point to the frontier denoted by $D_0(\boldsymbol{x},\boldsymbol{y})$ = OC/OA.

Färe et al. show that the Shephard's distance function can be computed as the solution to a linear programming problem:

$$\left[D_0\left(\mathbf{x}^{k*},\mathbf{y}^{k*}\right)\right]^{-1}=\max_{z^k,\theta^{k*}}\theta^{k*} \tag{1}$$

Subject to

$$\sum_{k=1}^{N} z^k y_j^k \le y_j^{k*}\theta^{k*} \qquad j=1,\ldots,J$$

$$\sum_{k=1}^{N} z^k x_h^k \le x_h^{k*} \qquad h=1,\ldots,H$$

$$z^k \ge 0 \qquad k=1,\ldots,N$$

where *k* is the set of countries (k^* is a particular country), *j* is the set of outputs, *h* is the set of inputs, z^k is the weight of the *k*th country data and θ is the efficiency index, which is equal to one if country k^* is efficient in producing the output vector. The model exhibits constant returns to scale.

In contrast to the Shephard's output distance function, the directional distance function allows the expansion of output in a specified direction (Chambers, Chung and

Färe, 1996 and 1998; Chung, Färe and Grosskopf, 1997; Färe and Grosskopf, 1996). Stated as a linear programming problem, the directional distance measure is:

$$\vec{D}(\mathbf{x}, \mathbf{y}; \mathbf{g}_x, \mathbf{g}_y) = \max_{z^k, \beta} \beta \qquad (2)$$

subject to

$$\sum_{k=1}^{N} z^k y_j^k \geq y_j^{k*} + \beta g_{yj} \qquad j = 1, \ldots, J$$

$$\sum_{k=1}^{N} z^k x_h^k \geq x_h^{k*} - \beta g_{xh} \qquad h = 1, \ldots, H$$

$$z^k \geq 0 \qquad k = 1, \ldots, N$$

where $\boldsymbol{g}_y$ and $\boldsymbol{g}_x$ determine the direction in which D is defined and g_{yj}, and g_{xh} denote the jth and hth components of $\boldsymbol{g}_y$ and $\boldsymbol{g}_x$, respectively. The distance function is defined simultaneously as the contraction of inputs and the expansion of output ($-\boldsymbol{g}_x\ \boldsymbol{g}_y$), which in the case of an output oriented measure, we have that $\boldsymbol{g}_x = 0$.

Figure 2 compares the directional output distance function (on product 2) and Shephard's output distance function. Using Shephard's distance function, if both goods are expanded by a factor of OA/OC, the production unit would lie on the frontier at point A, and would be defined as efficient. In contrast, the directional distance function starts at point C and moves in the direction of output 2, reaching the efficient frontier at point B. The distance estimated here is the maximum feasible expansion on output 2 direction's given the amount of inputs and output 1.

However, as shown by Nin et al (2003b), the distance to the frontier might change depending on the direction in which is measured. For example, in Figure 3 point C is closer to the frontier than point D when measured using Shephard's distance, but point B is closer to the frontier if measured output's 1 direction. As shown by Färe and Grosskopf, the Shephard's distance function is a special case of the directional distance function.

Nin et al. (2003b) take advantage of information on input allocation by introducing specific input constraints for allocated inputs, modifying the directional distance function measure in (2). The modified problem is:

$$D_0\left(\mathbf{x}, y_i, \mathbf{y}_{-i}; g=\left(y_i, \mathbf{0}\right)\right)=\max_{z^k, \beta_i^{k*}} \beta_i^{k*} \tag{3}$$

subject to

$$\sum_{k=1}^{N} z^k y_{-i}^k \geq y_{-i}^{k*} \qquad -i \in j \text{ and } j=1,2,\ldots,J$$

$$\sum_{k=1}^{N} z^k y_{-i}^k \geq y_i^{k*}\left(1+\beta_i^{k*}\right) \qquad i \in j \text{ and } i \notin -i$$

$$\sum_{k=1}^{N} z^k x_{hj}^k \leq x_{hj}^{k*} \qquad h \in A$$

$$\sum_{k=1}^{N} z^k y_h^k \leq y_h^k \qquad h \notin A$$

$$z^k \geq 0 \qquad k=1,\ldots,N$$

where A is the set of allocatable inputs, x_{hj}^k is the level of the allocatable input *h* used to produce output *j* of firm *k* and y_i^{k*} is the particular output for which efficiency is being measured.

Nin et al. argue that there are two features that distinguish their measure from the general directional distance measure. The first is that the direction of expansion of outputs and contraction of inputs increases only the *i*th output while holding all other outputs and all inputs constant. The second is that physical inputs that can be allocated to other outputs are treated as different inputs. That is, allocatable inputs are constrained individually by output, and inputs that are not allocable are constrained in aggregate. For example, land in pasture is a livestock input and cropland is a crops input.

Using the modified distance function, the product-specific directional Malmquist index is defined as:

$$DM(t,t+1) = \left[\frac{\left(1+\vec{D}_0^t\left(x^t, y_i^t, y_{-i}^t; y_i^t, \mathbf{0}\right)\right)}{\left(1+\vec{D}_0^t\left(x^{t+1}, y_i^{t+1}, y_{-i}^{t+1}; y_i^{t+1}, \mathbf{0}\right)\right)} \cdot \frac{\left(1+\vec{D}_0^{t+1}\left(x^t, y_i^t, y_{-i}^t; y_i^t, \mathbf{0}\right)\right)}{\left(1+\vec{D}_0^t\left(x^{t+1}, y_i^{t+1}, y_{-i}^{t+1}; y_i^{t+1}, \mathbf{0}\right)\right)} \right]^{0.5} \qquad (4)$$

The directional Malmquist index indicates increase in productivity if its value is greater than one. The index in (4) can be decomposed into and efficiency component and a technical change component.

$$DEFF(t,t+1) = \frac{\left(1+\vec{D}_0^t\left(x^t, y_i^t, y_{-i}^t; y_i^t, \mathbf{0}\right)\right)}{\left(1+\vec{D}_0^t\left(x^{t+1}, y_i^{t+1}, y_{-i}^{t+1}; y_i^{t+1}, \mathbf{0}\right)\right)} \qquad (5)$$

and

$$DTECH(t,t+1) = \left[\frac{\left(1+\vec{D}_0^{t+1}\left(x^t, y_i^t, y_{-i}^t; y_i^t, \mathbf{0}\right)\right)}{\left(1+\vec{D}_0^t\left(x^t, y_i^t, y_{-i}^t; y_i^t, \mathbf{0}\right)\right)} \cdot \frac{\left(1+\vec{D}_0^{t+1}\left(x^{t+1}, y_i^{t+1}, y_{-i}^{t+1}; y_i^{t+1}, \mathbf{0}\right)\right)}{\left(1+\vec{D}_0^t\left(x^{t+1}, y_i^{t+1}, y_{-i}^{t+1}; y_i^{t+1}, \mathbf{0}\right)\right)} \right]^{0.5} \qquad (6)$$

However, there are two limitations of the directional Malmquist Index. The first is that it is not always defined, where in some cases the distance function takes values of -1, in which case the Malmquist index is not well defined. This is illustrated in Figure 4, where the LP problem in y_2 direction is not feasible because technical progress has occurred allowing production of more y_1 and y_2 than was possible in period t. The extent of this problem in our data is illustrated in table 3. The second is that there might be a reallocation factor bias in the measure, that is, movement of unallocated inputs from one activity to the other rather than technical growth.

Data

Data for inputs and outputs was collected principally from FAOSTAT 2004 (unless noted) and covered a period of 40 years from 1961 to 2001. The data are from 130 countries and 31 regions considering three outputs (crops, ruminants and non-ruminants), and nine inputs (feed, animal stock, pasture, land under crops, fertilizer, tractors, milking machines, harvesters and threshers, and labor). Nin et al. notes that there are two limitations with these data. First, it has limited information on prices, and second, it does not allocate input usage to activities in agriculture. As mentioned by Zepeda (2001), this is of particular importance when allocation is skewed to a small group of producers or crops such that reallocation could greatly improve agricultural output. Because of this reason, the data from FAO can take full advantage of the product-specific distance measure developed by Nin et al. (2003b). This allows the estimation of productivity growth by sector given the inputs used and the output of all other sectors given these data limitations.

Nin at al. (2003b) used the FAO dataset and assumed that three of the inputs were allocatable. Feed, animal stock and pasture are assigned to livestock production, and land under crops is assigned to crops. Inputs that are not allocated are labor, fertilizer and tractors. In this paper we assume five allocatable inputs: land under crops to crops, ruminant stock and milking machines to ruminants, non-ruminant stock to non-ruminants. Feed is allocated to livestock but cannot be allocated between ruminants and non-ruminants. All other inputs remain unallocatable among outputs. Description of inputs and outputs used are:

Outputs:

The quantity of crop production is in millions of 1990 international dollars. FAO's crop production index estimated for each country is scaled using the value of crop output for 1990. The quantity of livestock production is in millions of 1990 international dollars. Output aggregates for ruminants and non-ruminants are built using international prices from Rao (1993, table 5.3). The 1990 output series were extended to cover the 1961-2001 period using the FAO production index. Ruminant and non-ruminant production is in millions of 1990 international dollars. Production indices for ruminants and non-ruminants were estimated using the same methodology as FAO, and using data from Rao (1993).

Inputs:

Fertilizer: Quantity of Fertilizer ((N, P, K) in metric tons of plant nutrient consumed in agriculture by a country.

Labor: The total economically active population in agriculture (in thousands), engaged in or seeking work in agriculture, hunting, fishing, or forestry, whether as employers, own-account workers, salaried employees or unpaid workers assisting in the operation of a family farm or business.

Land, expressed in 1,000 Hectares, and includes: Land under crops is the land under temporary crops (doubled-cropped areas are counted only once), temporary meadows for mowing or pasture, land under market and kitchen gardens, land temporarily fallow (less than five years), land cultivated with permanent crops such as flowering shrubs (coffee), fruit trees, nut trees, and vines but excludes land under trees grown for wood or timber. Pasture land includes land used permanently (five years or more) for herbaceous forage crops, either cultivated or growing wild (wild prairie or grazing land).

Machinery: There are three types of machinery used as inputs: Tractors, harvesters and threshers and milking machines, expressed as the total number in use. Tractors refer to total number of wheel and crawler tractors (excluding garden tractors) used in agriculture. We do not make any allowance to the horsepower of the tractors. Harvesters and threshers refer to the number of self-propelled machines that reap and thresh in one operation. Milking machines refer to the total number of installations consisting of several units, each composed of a pail, a pulsator and four-teat cups and liners.

Animal Stock: Is the number of cattle, sheep, goat, pigs, chicken, turkeys, ducks and geese expressed in livestock unit (LU) equivalent. Given the variability of body sizes of the main animal species across geographical regions, animal units are standardized for comparisons across the world. Carcass weight statistics from 2000 are used to generate conversion factors for several regions around the globe, and used to convert stock quantities into livestock units using OECD cattle as the unit measure.

Feed: The amount of feed is expressed in metric tons of total protein supplied to livestock per year. Amounts of edible commodities (cereals, bran, oilseeds, oilcakes, fruits, vegetables, roots and tubers, pulses, molasses, animal fat, fish, meat meal, whey, milk, and other animal products from FAOSTAT food balance sheets) fed to livestock during the reference period, are transformed into protein quantities using information of feed protein content for each commodity.

Results

The results of the estimation of the nonparametric Malmquist index for agriculture and the indices measured in the product-specific direction are presented in table 1. Results show that world agriculture productivity grew at a rate of 0.75 per year, where non-ruminant productivity grew at a higher rate (1.81) compared to crops (1.11) and ruminant (-0.07) productivity. As we compare developed and developing countries, the first set of countries grew at a higher rate in agriculture, crops and ruminant productivity, but developing countries grew at a higher rate in non-ruminant (pork and poultry) productivity.

Productivity growth in ruminants was higher than 1 percent in developed regions such as EU15 and Eastern Europe, and lower than 1 percent (or negative) in less developed regions. However, pork and poultry productivity growth is higher than 3 percent in developing regions such as South America and Transition markets. Looking at some specific cases in non-ruminant productivity, Brazil, Guatemala, China and Spain stand out with productivity growth rates higher than 3 percent annually. The largest productivity growth in crops corresponds to the two European countries Austria and Spain. The largest decrease in productivity corresponds to Cuba.

As discussed before PFP measures are inaccurate in cases where there has been factor substitution. The TFP measures improve the PFP measures by fully using all available information on input allocation while maintaining sector-wide constraints for inputs where activity specific allocations are not available. We focus on our disaggregate livestock measures to show the improvement in productivity measurement. The PFP measures are output per hectare of arable land and output per livestock unit of animal stock.

At the regional level, we have that for developed countries TFP is greater than PFP in all agricultural sub-sectors. However, for developing countries the contrary is true, where TFP is less than PFP in all sub-sectors. This suggests that on average, farmers in developing countries have tended to substitute other inputs for land and livestock, causing that the measure of PFP overstates productivity growth. Regions where TFP is greater than PFP in all sub-sectors are Developed countries, industrialized countries, Western Europe, EU 15, and North and Central America. Regions where TFP is less than PFP are Developing countries, Asia, Asia Developing, East and South East Asia, Latin America and the Caribbean, South America and the Caribbean. These results are consistent with the findings of Nin et al. (2003b) where TFP was less than PFP in all regions except for Western Europe.

Table 2 shows the average total factor productivity growth rates between 1990 and 2001 for all regions and countries in our sample. As we look at the results, developed countries show a higher average productivity growth for crops and non-ruminants as compared to developing countries. However, developing countries show a higher productivity growth in ruminant productivity. As we look at specific regions we have South American shows comparable productivity growth rates in crops as the western European countries. This may be caused by the emergence of Brazil (average productivity growth of 3.97%) and/or Argentina as important players in the world market of soybeans and other grains.

Looking at ruminant productivity growth, South America and especially Asia show large productivity growth rates when compared to other regions. As we look at individual countries in these two regions we have that Brazil (5.24%) and China (6.31%) show large productivity gains. Non-ruminants show also large average productivity growth rates for South America and Asia. The gap in productivity growth between these two regions and Western Europe is even larger than the gap in ruminant productivity. Looking again at Brazil and China, these two countries show average productivity gains of 5.24 and 6.31 percent, respectively.

These differences in productivity growth between regions may have some important implications on food trade, depending on how these changes interact with the other drivers in world food trade, such as the increased income. It is clear from the results that South America and Asia are the two developing regions with large productivity growth rates during the last decade. This may denote that these two regions are becoming an important

Future Directions: Making the Link between Productivity and Trade

In order to address this link between productivity and trade we plan to introduce these estimates into a General Equilibrium Model and explore the role of differential productivity growth in determining change in world food trade patterns between 1990 and 2001. We will use a modified version of the GTAP General Equilibrium Model (Hertel, 1997) to project the backward changes in country and regional production, consumption and trade flows between 2001 and 1990. GTAP is a standard multi-region-model built from a complete set of national accounts and detailed inter-industry linkages. We use version 6.0 GTAP database, aggregating for commodities and regions.

Several modifications to the standard GTAP model will be undertaken in order to better fit the productivity estimates that have been generated. Agriculture is treated as a single-input multi-product sector. That is, an agricultural sector that produces crops and livestock. We specify a CET functional form and modify the database to reflect the multi-product agricultural sector. The elasticity of transformation used for the CET is calculated through the estimation of a region-specific production possibility frontier (PPF) for agriculture in two periods using FAO data and directional measures specified before. The productivity parameters in GTAP are calibrated to reproduce the productivity measures for agriculture (crops and livestock).

The demand system will be based on the econometrically estimated AIDADS functional form (Cranfield et al., 1998 and 2000), in combination with information distribution, which seems to improve the quality of the estimates of the Engel relationships as they relate to livestock products. The AIDADS functional form will be incorporated into the GTAP database, as it seems that explains a good part of the structural change in world food trade (Coyle et al. 1998; Yu et al., 2000, 2002).

With these modifications we first define a simple backcasting simulation where we shock population, endowments, etc. backwards from 2001 to 1990 to see how they affect trade patterns. First we use the common TFP growth (decay) for all agriculture, then we introduce the differential growth rate between crops and the two livestock types, to later compare the resulting trade changes to those that actually occurred. We would expect to find that given the productivity growth rates found in this study and increased income growth in developing regions that these may provide an explanation on how food trade patterns have changed in the last 10 years.

Conclusions

This paper has tried to extend previous work of sub-sector productivity growth and shed some light of the effects of productivity changes crops and livestock in world food trade patterns. We have also outlined a way to introduce these productivity changes into a general equilibrium model to be able to model the effect of productivity growth in food trade patterns. In this way we would be able to estimate how food trade patterns are affected by technical change in crops and livestock.

The results show how developing regions in the last 40 years have shown higher productivity growth rates in non-ruminants, but much lower productivity growth rates in crops and ruminants when compared with developed countries. However, as we look on the last decade, developing regions, especially South America and Asia show larger productivity growth rates in ruminants and non-ruminants as compared to developed regions such as Western Europe.

These results may have some important effects on world food trade patterns. However these effects may depend on how the other forces, such as changes in income, may interact. For example, some regions may have had large productivity gains that boost their supply, but that may not affect food trade patterns if income growth changes their consumption and nets the supply effect.

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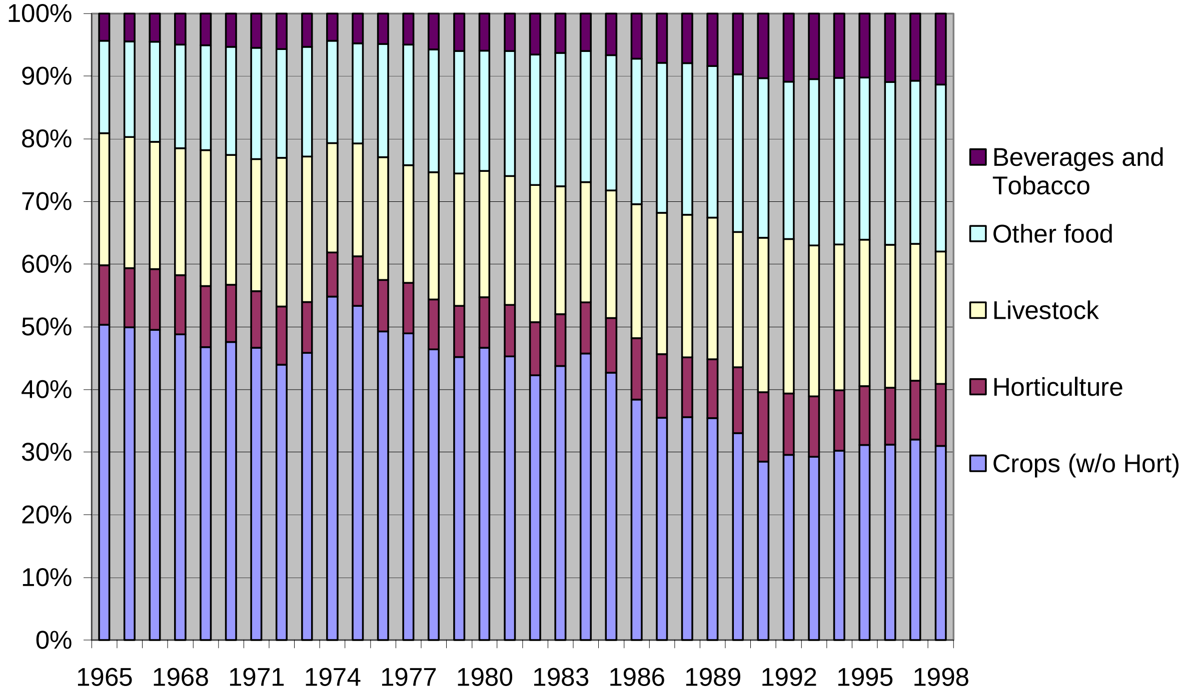
Figure 1. Share of World Food Trade



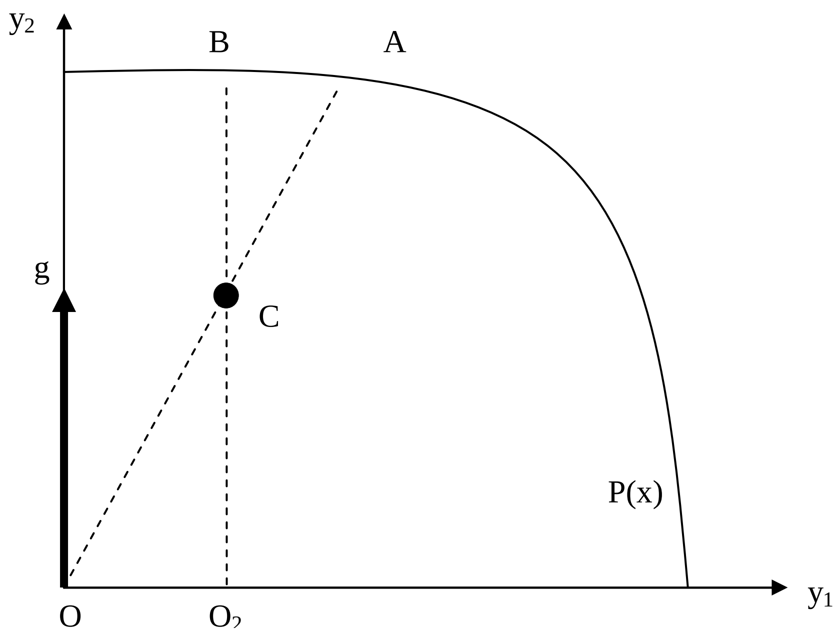


Figure 2. Output possibility set and distance functions

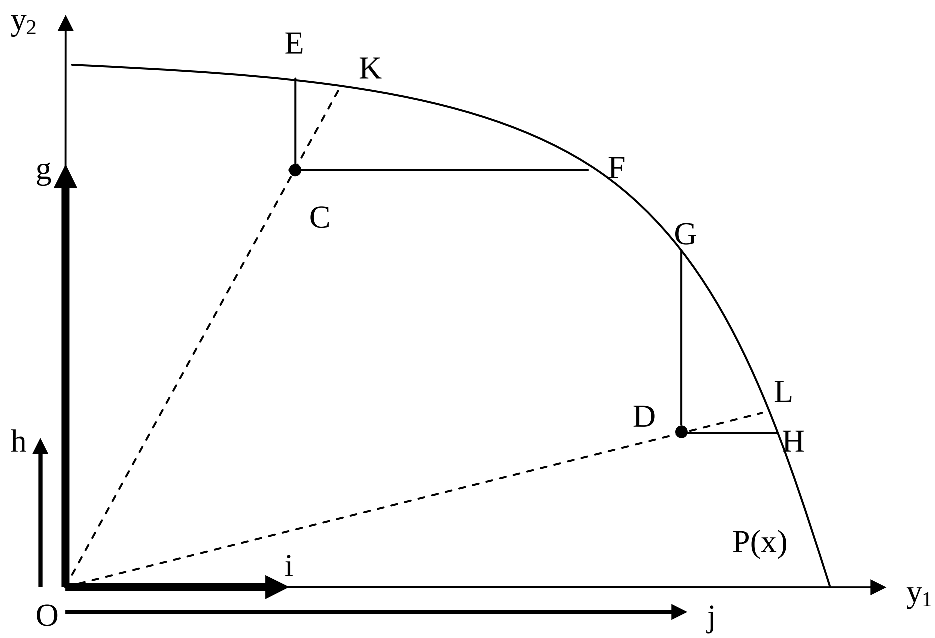


Figure 3. Distance to the frontier measured in different directions

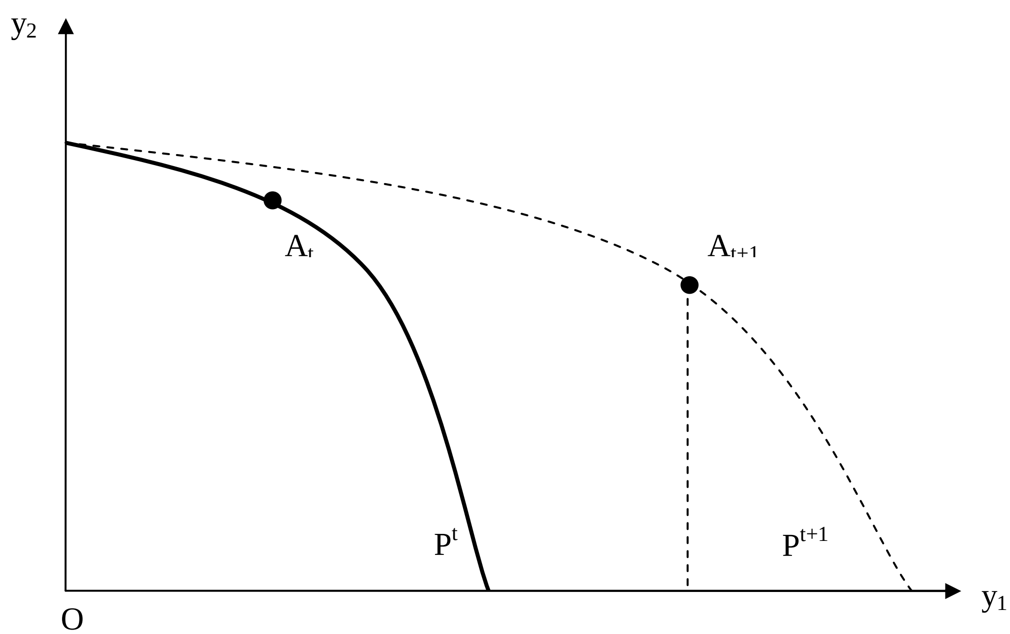


Figure 4. Efficiency in y_1's direction of a production point in t + 1 with technology in t as reference (not explained in text).

Table 1. Annual Productivity Growth Rate (%), 1961-2001

Country/Region	TFP				PFP		
	Agriculture	Crops	Ruminants	Non-Ruminants	Crops	Ruminants	Non-Ruminants
Angola	-1.34	-1.55	-0.16	0.07	0.75	0.28	-0.91
Austria	0.84	2.28	0.55	1.47	0.85	0.83	1.05
Brazil	0.81	0.79	1.20	4.33	0.93	0.88	4.55
Burkina	-0.56	1.12	-0.72	-1.49	2.58	0.48	-0.61
China	1.00	0.75	2.87	3.39	2.71	5.35	3.24
Cuba	-0.74	-4.66	-2.17	0.31	-2.40	0.04	1.89
Guatemala	1.10	1.31	0.56	3.43	2.87	-0.47	2.76
Guinea Bissau	-0.54	-0.82	-0.88	-1.64	0.08	0.15	0.10
Iran	0.64	1.17	0.60	2.02	4.21	1.69	0.80
Madagascar	-0.25	-0.44	0.00	0.62	0.42	0.80	-0.51
Morocco	0.78	0.66	0.79	1.76	2.22	2.18	-0.08
Mozambique	-0.23	-0.20	-0.72	0.47	-0.10	0.18	1.14
Sierra Leone	0.09	0.05	0.06	1.65	-0.10	-0.52	-0.41
Spain	1.67	2.59	1.77	3.14	2.25	1.08	1.99
Sudan	0.40	0.19	1.06	-0.07	0.91	-0.83	-1.13
Tanzania	0.81	0.66	1.97	2.11	0.90	0.58	0.99
Zambia	-0.02	-0.76	-0.71	0.99	1.48	-0.47	-0.04
Zimbabwe	0.34	0.48	-0.06	0.95	1.33	0.06	0.21
World	0.75	1.11	-0.07	1.81	1.99	0.58	1.31
Developed Countries	1.04	2.57	0.93	2.11	1.41	0.83	1.30
Developing Countries	0.57	0.51	0.38	2.38	2.28	1.55	2.47
Least Developed Countries	0.54	0.14	0.40	1.24	1.44	0.57	-0.07
Industrialized Countries	1.36	3.17	1.54	2.66	1.54	0.72	1.03
Low Income Countries	0.47	0.20	0.87	1.43	1.94	1.96	0.80
Low-Income Food Deficit	0.52	0.36	0.63	2.92	2.26	2.23	2.57
Transition Markets	0.81	3.06	0.76	3.24	0.92	1.14	1.44
Africa	0.65	0.70	0.20	1.54	1.74	0.39	0.25
Africa Developing	0.80	0.61	0.88	1.32	1.53	0.61	2.79
Africa South of Sahara	0.57	0.24	0.59	0.80	1.62	0.58	-0.56
Asia	0.44	-0.09	0.63	1.96	2.34	2.61	2.28
Asia Developing	0.96	0.25	0.50	2.71	2.56	2.53	2.72
East and South East Asia	0.44	0.03	-0.28	1.58	2.23	1.30	1.68
Asia-Pacific	0.80	0.41	0.85	2.60	2.40	2.14	2.26
Near East	0.42	-0.06	-0.05	1.54	2.58	0.61	0.69
Western Europe	0.93	3.33	0.96	2.47	1.59	0.66	0.87
EU 15	1.03	3.46	1.06	2.66	1.62	0.65	0.86
Eastern Europe	0.93	2.03	1.18	2.10	0.88	1.55	1.36
North & Central America	1.11	2.07	1.73	1.63	1.89	0.71	1.24
Latin America & Caribbean	0.71	0.98	0.10	2.59	1.67	0.60	2.93
Caribbean	-0.30	-2.03	-0.96	1.02	-1.27	0.37	2.64
South America	0.73	1.23	0.29	3.05	1.70	0.44	3.31

Only countries for which the LP problem is feasible for all years are shown

Table 2. Annual Total Factor Productivity Growth Rate (%), 1990-2001

Country/Region	Agriculture	Crops	Ruminants	Non-Ruminants
Angola	4.68	7.22	1.61	5.75
Austria	1.53	2.64	1.26	2.47
Brazil	3.57	3.97	5.24	11.81
Burkina	1.44	2.70	1.31	1.85
China	2.16	2.15	6.31	4.33
Cuba	-0.59	-1.95	-0.41	-0.47
Guatemala	1.00	0.96	0.66	3.80
Guinea Bissau	1.45	1.91	0.47	-0.26
Iran	1.52	3.45	2.13	2.22
Madagascar	0.11	0.00	1.70	2.63
Morocco	-1.13	-3.07	-1.05	-2.72
Mozambique	1.24	3.89	0.70	0.04
Sierra Leone	-1.58	-2.13	-1.16	0.53
Spain	2.66	4.00	1.28	2.90
Sudan	3.01	6.02	3.77	5.22
Tanzania	0.20	-0.20	1.33	0.43
Zambia	0.40	-1.31	1.56	0.64
Zimbabwe	-0.52	-0.09	-0.61	-0.09
World	0.79	1.84	0.26	2.49
Developed Countries	1.12	2.96	0.79	3.07
Developing Countries	1.23	1.39	1.28	2.68
Least Developed Countries	1.10	2.69	1.09	3.01
Industrialized Countries	0.64	0.47	1.31	-0.34
Low Income Countries	1.11	1.13	1.70	3.60
Low-Income Food Deficit	1.15	1.41	0.52	0.69
Transition Markets	1.59	7.34	1.26	7.82
Africa	0.73	1.14	0.30	0.35
Africa Developing	1.30	1.12	1.67	0.31
Africa South of Sahara	1.30	1.39	1.16	0.16
Asia	1.44	1.36	2.97	3.31
Asia Developing	1.31	1.53	2.06	3.33
East and South East Asia	-0.38	-0.61	0.07	0.67
Asia-Pacific	1.52	1.79	2.37	3.29
Near East	-0.67	-0.35	-0.96	-0.18
Western Europe	0.91	2.88	0.84	2.78
EU 15	0.91	2.94	0.90	3.19
Eastern Europe	0.15	0.18	0.39	3.12
North & Central America	0.53	1.35	0.71	1.61
Latin America & Caribbean	1.70	2.08	0.96	4.45
Caribbean	-1.29	-3.36	-0.99	0.11
South America	2.11	2.95	1.82	6.06

Only countries for which the LP problem is feasible for all years are shown

Table 3. Number of feasible LP Problems in Crops, Ruminants and Non-Ruminants Direction when the Observation being evaluated is from Period t and the Technology is from t + 1 (one LP Problem per year, 1961-2001; max=40)

Country/Region	Crops	Ruminants	Non-ruminants	Country/Region	Crops	Ruminants	Non-ruminants
World	40	40	40	Myanmar	36	21	23
Former USSR	37	40	35	Namibia	13	30	25
Albania	32	40	34	Nepal	14	40	20
Algeria	40	40	37	Netherlands	1	17	7
Angola	40	40	40	New Zealand	2	40	3
Argentina	30	12	8	Nicaragua	26	33	25
Australia	36	20	14	Niger	18	40	23
Austria	40	40	40	Nigeria	38	25	24
Bangladesh	5	15	5	Norway	6	40	14
Belux	2	7	3	Pakistan	0	31	8
Belize	40	22	22	Panama	39	40	39
Benin	20	23	12	Papua New Guinea	36	6	5
Bhutan	5	19	4	Paraguay	40	27	25
Bolivia	40	39	39	Peru	40	39	39
Botswana	32	39	40	Philippines	33	22	26
Brazil	40	40	40	Poland	37	40	30
Bulgaria	13	40	8	Portugal	40	40	39
Burkina	40	40	40	Puerto Rico	0	16	25
Burundi	29	31	27	Romania	34	40	33
Cambodia	40	29	32	Rwanda	9	5	6
Cameroon	32	28	28	Saudi Arabia	18	34	22
Canada	29	13	16	Senegal	40	38	35
Central Africa	24	40	24	Sierra Leone	40	40	40
Chad	37	40	34	Singapore	2	18	27
Chile	36	40	37	Somalia	3	17	13
China	40	40	40	South Africa	37	39	39
Colombia	37	38	21	Spain	40	40	40
Congo Dem	35	19	27	Sri Lanka	38	18	19
Congo Rep	31	15	20	Sudan	40	40	40
Costa Rica	35	33	19	Suriname	40	37	37
Cuba	40	40	40	Swaziland	23	10	8
Czechoslovakia	25	40	23	Sweden	1	22	11
Ivory Coast	39	14	12	Switzerland	7	40	23
Denmark	2	12	6	Syria	9	22	14
Dominican	15	23	10	Tanzania	40	40	40
Ecuador	34	37	28	Thailand	23	21	30
Egypt	2	6	6	Togo	40	33	33
El Salvador	40	40	33	Trinidad & Tobago	18	29	32
Ethiopia dr	27	33	29	Tunisia	40	40	39
Finland	18	40	23	Turkey	40	17	15
France	37	21	10	Uganda	38	31	28

Country/Region	Crops	Ruminants	Non-ruminants	Country/Region	Crops	Ruminants	Non-ruminants
Gabon	28	13	19	UK	36	40	17
Gambia	32	30	27	USA	1	14	5
Germany	39	40	26	Uruguay	1	5	40
Ghana	40	24	30	Venezuela	24	40	37
Greece	40	25	14	Vietnam	38	21	18
Guatemala	40	40	40	Yemen	36	40	39
Guinea	40	40	39	Yugoslavia	32	40	31
Guinea Bissau	40	40	40	Zambia	40	40	40
Guyana	32	11	13	Zimbabwe	40	40	40
Haiti	3	17	7	Asia (Former)	34	34	34
Honduras	38	40	32	Europe (Former)	34	34	34
Hungary	10	19	13	Low Income Countries	40	40	40
Iceland	11	36	27	Africa	40	40	40
India	16	40	13	Africa Developed	18	39	17
Indonesia	40	40	38	Africa Developing	40	40	40
Iran	40	40	40	Africa South of Sahara	40	40	40
Iraq	26	20	23	Asia Developed	13	24	32
Ireland	23	40	27	Asia Developing	40	40	40
Israel	1	12	2	Caribbean	40	40	40
Italy	40	39	35	Developed Countries	40	40	40
Jamaica	27	25	36	Developing Countries	40	40	40
Japan	12	23	22	East & South East Asia	40	40	40
Jordan	35	34	38	Eastern Europe	40	40	40
Kenya	31	40	34	EU 15	40	40	40
Korea Popular	18	12	9	Industrialized Countries	40	40	40
Korea	9	8	3	Latin America & Caribbean	40	40	40
Laos	23	27	26	Least Developed Countries	40	40	40
Lebanon	20	16	11	Low-Income Food Deficit	40	40	40
Lesotho	38	40	39	Near East	40	40	40
Liberia	28	6	15	North & Central America	40	40	40
Libya	19	28	32	North America	6	10	8
Madagascar	40	40	40	Oceania Developed	36	30	9
Malawi	38	40	36	Oceania Developing	40	40	40
Malaysia	23	3	6	Asia and Pacific	40	40	40
Mali	39	40	40	South America	40	40	40
Mauritania	32	40	35	South Asia	11	22	4
Mexico	27	37	40	Transition Markets	40	40	40
Mongolia	18	40	26	Western Europe	40	40	40
Morocco	40	40	40	Asia	40	40	40
Mozambique	40	40	40				
% Countries /Regions all feasible	37	48	28				