# *Productivity growth and "catching-up": Implications fo China's trade in livestock products*

by

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## I. INTRODUCTION

In the past decade there has been a marked shift in the composition of grains/livestock in favor of processed livestock products. The value of coarse grains trade peaked in 1981 a about $20 billion. By contrast, global trade in cattle and other meat products amounted to $ and $11.7 billion, respectively in 1981, but, by 1995 their value had risen to $22.6 and $29 billion, respectively, substantially surpassing trade in coarse grains (GTAP version 4 datab There are a number of factors driving this changing profile of world trade. The first is on th demand side. As per capita income grows, people tend to prefer a more diverse diet, and expenditures on some food items such as meats, beverages, and fruit tend to grow faster tha food staples such as cereals and legumes. Delgado et. al. (1999) observe that the less than o quarter of the world's population living in the developed countries presently consume an average of three times the meat and five times the milk per capita as people in developing countries. Yet it is in developing countries where massive annual increases in the aggregate consumption of animal products are occurring. From the beginning of the 1970s to the mid 1990s, consumption of meat in developing countries increased by 70 million metric tons, a volume more than twice as large as the increase in developed countries, and two-thirds as l as the increase in consumption of cereals in developing countries.

A second factor driving the changing composition of world trade derives from the supp side. Coyle *et al.* (1998) note that another force driving the observed structural change in w food markets derives from the supply side, particularly in East Asia, where competition for scarce labor and capital with rapidly growing manufacturing activity, as well as environme constraints, have limited expansion of livestock production. Thirdly, innovations in interna transportation of livestock products via refrigerated containers and refrigerated bulk vessels also contributed to the growth. Finally, in some cases, such as beef imports into Japan, poli reforms have stimulated additional trade. Coyle, *et al.* (1998) ascertained that, of these four forces, the basic demand and supply-side forces were most important in fueling the changin composition of world food trade over the 1980-95 period.

But can we expect this relatively rapid growth in livestock trade to continue? Recent w by Cranfield *et al.* (1998) suggests that demand side forces are indeed in place to fuel such growth. Figure 1 reports fitted budget shares (at mean prices) for food products, from an AIDADS demand system estimated using 1985 data from the International Comparisons P The vertical bars show real income levels for six focus countries in 1985 in the following o (left to right): Ethiopia, Pakistan, Senegal, Korea, France and the United States. While grai budget share is declining over the full range of the sample, the budget shares for livestock, horticulture and vegetable and other food products increase at lower levels of per capita expenditure (section I), reach a maximum, and then decline as per capita expenditure grow Note that the importance of grains relative to livestock products changes dramatically as pe capita expenditure increases (section II). The latter has the largest budget share of the food products when per capita expenditure exceeds an average level of per capita expenditure ro equal to that of Pakistan in 1985. At lower income levels, the increasing budget share for

livestock products derives from an income elasticity of demand in excess of one. This mear
livestock demand can be expected to grow as fast, or faster than the economy at large, there
potentially fueling strong import demand. In fact, Cranfield *et al.* (1998) project annual gro
in per capita livestock product demand in Ethiopia (the poorest country in the sample) over
period 1995 to 2020 to be double that in the richer countries (3.4% vs. 1.8% in France). W
population growth is factored in, the annual growth in livestock demand is three times high
Ethiopia (Cranfield *et al.*, 1998b, Table 3).

Using a global food model ( International Model for Policy Analysis of Agricultural Commodities and Trade-IMPACT), Delgado et. al. (1999) project that aggregate meat consumption in the developing countries will grow by nearly 100 million metric tons (MM
between the early 1990s and 2020, whereas the corresponding figures for developed count
16 MMT. Similarly, additional milk consumption in the developed countries of 13 MMT o
Liquid Milk Equivalents (LME) will be dwarfed by the additional consumption in the deve
countries of 227 MMT. They also indicate that the experience will vary widely among the
different parts of the developing world, with China leading the way on meat with a doublin
the total quantity consumed. India and other South Asian countries will drive a large increa
total milk consumption.

These demand side forces could explain the rapid growth in livestock product trade in
last two decades. But what about the supply side? Why not just import grains and raise the
livestock locally? Clearly this depends on a whole host of factors, including local environn
constraints, transport costs and relative levels of productivity in livestock production. One
guess that eventually LDCs will catch up with, or at least approach, productivity levels in J
the US and Europe. Wouldn't it then make sense to ship the lower cost grains and grow the
labor-intensive livestock products locally? Sector-specific productivity considerations were
absent from the Coyle *et al.* (1998) historical analysis referenced above, and those authors
this as one of the possible explanations for the large, unexplained residual in their predicte
from bulk to high value food trade.

In a subsequent paper by Rae and Hertel (1998), the authors formally test
convergence in livestock productivity among the Asia-Pacific economies. They found ev
of recent convergence in productivity levels for pig and poultry production, but generally
ruminant production. At the country level, significant "catch-up" to North American leve
demonstrated for China (poultry and pigs), Australia (pigs, beef and milk), Korea (pigs and
and Southeast Asia (pigs). For non-ruminant production, the speed with which the techn
gap had been closing was greatest for China. The authors then attempt to draw out implic
for trade in livestock and grains. However, their projections are simple extrapolations o
'catch-up' trends. Clearly there is a limit to the amount of "catching-up" that can occur, a
needs to be taken into account when making projections. In this paper we seek to improve
Rae/Hertel effort by decomposing productivity growth into two parts. The first is an unde
trend in the technical frontier – while the second represents individual countries' mov
towards that frontier. This calls for a different approach to productivity measurement, whi
be developed in the next section.

This paper places particular emphasis on China. While considerable past research e
has been directed at quantifying China's possible future role in international grains trade (I

and Agcaoili-Sombilla 1997), a similar question arises with respect to trade in livestock products. China is a net exporter of pigmeat, but in 1991 switched from a net exporter to a importer of poultry meat. By 1995, China's pigmeat exports were 230,000 tonnes and net imports of poultry meat had reached 235,000 tonnes, making China the third largest poultr importer in the world. On a value basis in 1995, China had a positive trade balance for live products in aggregate. Delgado *et al* (1999) project net exports for 2020 of 300,000 tonnes each of pig and poultry meat. Wang *et al* (1998) make projections to 2005 under the assum of elimination of China's meat import tariffs. When the pork tariff is eliminated, 2005 net imports are 491,000 tonnes (compared with a baseline of 91,000 net exports in 2005). For poultry, elimination of the tariff gives net imports in 2005 of 989,000 tonnes (compared w 2005 baseline net imports of 709,000 tonnes). Recent unpublished research at OECD proj declining pigmeat net exports and a rapid increase in China's poultry meat imports to the y 2004. Thus there seems to be general agreement therefore that China will remain a net exp of pigmeat in the absence of tariff reductions, but that the volume of such exports will dimi However, the above findings are not unanimous when in comes to China's future trade stat with respect to poultry meat.

## II. BACKGROUND AND REVIEW OF THE LITERATURE

### Scope for Improvements in Livestock Technology

Modern science has developed, and continues to develop a large number of technologi enhancing the productivity of livestock production, processing and marketing activities. Th of exotic breeds has enabled genetic improvement within herds and flocks to be speeded u genetic improvement has been enhanced even further with the aid of biotechnology. The la involves the use of living organisms to produce improvements within animals, such as the various genetic engineering (DNA) techniques to manipulate genetic material and to transf genes from one organism to another. In such ways, animal quality may be rapidly upgraded through improvements in genetic make-up and in the rate of reproduction. Biotechnology h also aided improvements in feed efficiency, milk production, and in the development of vaccines. Numerous compounds have been developed to promote faster growth and impro feed efficiency, such as the use of anabolic steroids in cattle as a growth promotant. Also becoming well known is the elevation of natural levels of somatotropins (naturally-occurri protein hormones) in cattle, pigs, poultry and sheep. Growth rates, feed efficiency and milk yields may all be increased.

In the area of animal health, biotechnology offers promise for the improved diagnosis treatment of animal disease. Livestock health research will also benefit from the increasing resources available to human health research. For example, genomics is a new science appl to both humans and livestock that permits sequencing and mapping of the genome (a genet map of a living organism). Genomics takes advantage of the work of the genomes of diseas organisms and permits the development of new generations of vaccines, including those th recombinant antigens to pathological agents ( Fitzhugh, 1998; Delgado et. al. 1999). Farm the developing regions typically lack low-cost, easy-to-use diagnostics, vaccines, and cont strategies for disease organisms and vectors. Among the parasitic diseases, trypanosomiasi (sleeping sickness) transmitted by tsetse flies, poses an enormous constraint to cattle produ in most of the humid and sub-humid zones of Africa. Other important parasitic diseases gr include helminthiasis and tick-borne diseases. Although helminths are rarely fatal, they bec limiting factor in the intensification stage. Ticks have the capacity to transmit diseases nota theleiriosis (or East Coast Fever) in Eastern and Southern Africa effective vaccine for this disease may soon be available with a potentially large impact in ruminant productivity in th countries (Delgado et. al. 1999).

To improve Feed quantity and quality, research to reduce costs and improve efficiency have to be highly targeted. The identification of suitable traits and their molecular markers improve the quality of tropical feeds derived from crops breeders use the markers to develo dual purpose crops with improved grain and protein content for humans and non-ruminant higher quality crops residues for ruminants. Plant genomics and phytochemistry will tackl nutritional factors, some of which can be poisonous to ruminants. Microbial techniques ex that can help enrich ruminant ecosystems with microbes that can better detoxify anti-nutrit factors.

Artificial insemination (AI) is a well-known reproductive technology, but recent developments in embryo transfer raise the possibility that it might replace AI. A range of associated techniques have been developed. The transfer of embryos from donor to recipier animals allows the build-up of genetically-superior animals using lower-grade and inexpen recipients. Thus herd improvement can be achieved at faster rates than with natural mating artificial insemination. But this form of reproduction will not become widespread in the developing countries within the next 20 years (Cunningham, 1997). Other techniques inclu splitting of embryos to produce multiple copies of genetically identical animals, embryo cl *in vitro* fertilization and sex determination. Recent advances in cloning of embryos could potentially have a large impact on livestock production, particularly of dairy cattle in the developed world. But this is still an area where a number of complex ethical issues have ye resolved (Cunningham, 1997).

Numerous mechanical technologies have been developed for application on farms, anc within processing and marketing systems. Some examples include electronic monitoring of individual animal performance and the use of computers to control feed rations and the ani environment. Advances in herd health management through adjusted weaning age, animal and housing design have cut expenses on medications while increasing growth rates and fe efficiency. Robotic techniques are increasingly used in processing operations, and other techniques allow product shelf-life to be extended and product quality to be enhanced.

Such developments are likely to continue apace into the future. Simpson *et al.* refer to 1992 report (U.S. Congress, OTA), that lists 42 potentially available animal technologies a 1992, of which 22 were expected to be available by 1995 and all but nine by the year 2000 course, the success with which these can be brought into commercial use in the country of (in many cases the USA) to recipient countries in Asia, and the rate and success with whicl may be adopted, will be influenced by many factors. Empirical research by economists typi focuses on estimating, and possibly extrapolating, the overall rate of adoption as evidenced aggregate productivity indexes. This is the approach adopted here.

**Measuring aggregate productivity**

The basic concept in productivity measurement is total factor productivity (TFP), the r an index of aggregate output to an index of aggregate input. Changes in TFP can be decom into components measuring changes in technical efficiency, scale, and the state of technolo (Capalbo, 1988). The literature on TFP measurement has historically been divided into two strands (Capalbo, 1988a,b; Capalbo *et al*., 1991): the growth accounting (index number) approach and the econometric approach.

The index number approach involves the use of detailed accounts of inputs and output aggregating them into input and output indexes, then in turn using these indexes to calcula indexes. The literature seems to prefer the Divisia index, because it is defined in continuou and is exact for the case of homogenous translog functions (Capalbo and Antle, 1988) The many ways to get a discrete approximation to the Divisia index. The Tornqvist approximat the most commonly used because of the popularity of second-order approximations to cost production functions. More specifically, if the logarithm of the cost function is quadratic in logarithm of prices and output, then the Tornqvist index is the "true" index. This is known Diewert's quadratic lemma (Diewert, 19976). The translog function does not require inputs perfect substitutes, but rather permits all marginal productivities to adjust proportionally to changing prices. Hence the prices from different periods being compared enter the Divisia to represent different marginal productivities.

The econometric approach to productivity measurement is based on statistical estimati the production technology. It allows the researcher to relax some of the assumptions implic the index number approach, including: neutrality of technical change, industry equilibrium (generally) constant returns to scale. Most studies use a flexible functional form to represen technology (production or cost function) and econometrically estimate this function, its derivatives, or both. Technical change is generally specified using time-trend variables (Ca 1988a,b). However, this comes at the cost of new assumptions. For sufficient degrees of freedom, and to mitigate multicollinearity problems, it is generally necessary to aggregate i data into a relatively small number of categories thereby implying input separability. Anoth strong assumption is that, with a few exceptions (Dorfman and Foster, 1991; Rudstrom and Foster, 1993; Kalirajan *et al.*, 1996), technological change is represented as a function of ti Additional assumptions of competitive pricing and efficient input utilization must be made estimating cost or profit functions. Finally, assumptions about the statistical properties of t data must be made.

Index numbers have been extensively used in the analysis of agricultural production. T U.S. Department of Agriculture uses this methodology and the Department's Economic Re Service routinely publishes total factor productivity measures from production accounts (B 1984 and 1985; Ball *et al*., 1997). Jorgenson and Nishimizu (1978) have extended this methodology to cover inter-country comparisons of TFP. This has led to a literature on mu lateral, total factor productivity indexes including applications to agriculture by Capalbo, B and Denny (1990), and Capalbo, Denny, Hoque and Overton (1991). Ehui and Spencer (19 have used the Divisia approach to TFP to measure the sustainability and economic viability

alternative farming systems in Africa. Developments in international comparisons of TFP c
found in Ball (1997).

Recently, a different approach to the use of index numbers has been developed, based
pioneering article of Caves, Christensen and Diewert (1982). They proposed a framework f
input, output, and productivity measurement that does not proceed from a continuous time
representation. As stated in Färe *et al*. (1996): "They revolutionized the index number appr
to productivity measurement by abandoning the idea that these indexes were at best a discr
(and therefore inaccurate) approximation to the continuous time derivatives used in econor
approaches. Instead, they showed that index numbers could be based directly on very gene
representations of technology, namely distance functions." They named these indexes after
Malmquist who first applied this methodology, in the context of consumption behavior, in

Färe *et al*.(1994) implement the Caves, Christensen and Diewert distance function app
to productivity measurement using non-parametric methods. Färe's approach does not requ
specific functional form (Caves *et al*. assume a translog structure), it does not require price
it can be implemented in a multiple-output setting with many inputs (no separability assum
are required). Furthermore, since they adopt a frontier function approach based on linear
programming, inefficiencies are permitted, thereby relaxing the requirement for long run
industry equilibrium. The resulting measures of efficiency are unit-free, so there is no prob
extending the methodology to international comparisons.

For our purposes, the most important part of the Färe *et al*. (1994) work is that if offer
convenient decomposition of productivity changes due to changes in efficiency (catching-u
and changes in the frontier, "technical change". This decomposition, in turn, enables us to
formally estimate the frontier, compared with the earlier assumption of Rae and Hertel (19
that North American productivity levels defined that frontier.

**The Distance Function Approach**

Following Fare et al, for each time period t=1,….,T, the production technology $S^t$ m
the transformation of inputs $x^t$ into outputs $y^t$. The output distance function is defined at t a

(1) $D_0^t(x^t, y^t) = \inf\{q : (x^t, y^t / q) \in S^t\}$

To define the Malmquist index it is necessary to define distance functions with respect to t
different time periods:

(2)……. $D_0^t(x^{t+1}, y^{t+1}) = \inf\{q : (x^{t+1}, y^{t+1} / q) \in S^t\}$

which measures the maximal proportional change in outputs required to make $(x^{t+1}, y^{t+1})$ fe
in relation to the technology at t. Also a distance function that measures the maximal
proportional change in output required to make $(x^t, y^t)$ feasible in relation to the technology
t+1:

(3) $D_0^{t+1}(x^t, y^t) = \inf\{q : (x^t, y^t / q) \in S^{t+1}\}$

The Malmquist productivity index with technology in period t as the reference, is then defi
as:

(4) $$M^t = \frac{D_o^t(x^{t+1}, y^{t+1})}{D_0^t(x^t, y^t)}$$

The index can be defined also with the technology in t+1 as the reference technology. Fare
defined the Malmquist productivity change index as the geometric mean of the two indexe:

(5) $$M_0(x^{t+1}, y^{t+1}, x^t, y^t) = \left[\left(\frac{D_0^t(x^{t+1}, y^{t+1})}{D_0^t(x^t, y^t)}\right)\left(\frac{D_0^{t+1}(x^{t+1}, y^{t+1})}{D_0^{t+1}(x^t, y^t)}\right)\right]^{\frac{1}{2}}$$

The index can be decomposed into to parts:

(6) $$M_0(x^{t+1}, y^{t+1}, x^t, y^t) = \frac{D_0^{t+1}(x^{t+1}, y^{t+1})}{D_0^t(x^t, y^t)}\left[\left(\frac{D_0^t(x^{t+1}, y^{t+1})}{D_0^{t+1}(x^{t+1}, y^{t+1})}\right)\left(\frac{D_0^t(x^t, y^t)}{D_0^{t+1}(x^t, y^t)}\right)\right]^{\frac{1}{2}}$$

where the ratio outside the brackets measures the change in relative efficiency between yea
and t+1 (a measure of “catching-up”). The geometric mean inside the brackets captures the
in technology between the two periods evaluated at t and t+1 (technical change). (In this st
we assume neutrality of technical change and so the geometric mean used by Fare et al in t
technical change component of the index is not necessary.)

## III. RESULTS FOR 1961-97

Our data on the global livestock sector are drawn from FAOSTAT 1998, the statisti
database of the Food and Agriculture Organization of the United Nations (FAO). In particu
data on livestock production and animal stocks covering the period 1961-1997 for ten
countries/regions were used to estimate the Malmquist Index and the two components of
productivity change identified above. Note that since we do not have a complete inventory
inputs used in livestock production, our measurement of "output per head of livestock" is c
partial, not total, factor productivity indicator. (It is very difficult to obtain input allocation
the production of agricultural commodities, since most farms produce multiple products.) F
this point on, we will refer to our measure of partial factor productivity simply as "producti
However, it should be borne in mind that this measure is fundamentally limited and will be
inaccurate in the face of substantial factor substitution.

Table 1 reports the average annual rate of productivity growth over the sample peri
each country/sector pair in the sample, reported as a ratio of productivity in the year t+1 an
We can see, for example, that the average rate of productivity growth in Australian pig

production over the 1961-97 period was 1.62%/year. In the case of pig production, China exhibits the highest rate of productivity growth over this period (4.19%/year). Beef produc Sub-Saharan Africa actually experienced technological regress over the 1961-97 sample pe Comparing mean productivity growth rates, the poultry sector was the most dynamic durin period, with a mean annual growth rate of 2.7%.

However, perusal of Table 1 raises more questions than it answers: Can we expect t high rate of productivity growth in China's pig production to continue? How much of this growth was due to "catching-up" which is eventually doomed to diminish in significance? 2 presents the Fare *et al.* decomposition of productivity growth into country-specific catch growth rates (main body of the table) and world-wide frontier (technical change) growth ra (bottom row of the table). Given the importance of more recent developments in formulatin projections into the future, we report separately the changes for the full sample period and decade of the nineties (1991-97).

Based on Table 2, we can see that China's rapid rate of productivity growth since 1 largely due to "catching-up", which proceeded at an average annual rate of 3.4%. Moveme the pig frontier was relatively low (0.7%/year) and appears to be slowing down (0.5%/year 1990's). Furthermore, China's rate of productivity growth due to catching up has diminish considerably in the 1990's. This has important implications for forecasts of likely growth c the next decade. Simple trend-based extrapolation of past growth rates – such as the 4.2% g rate in Table 1 – are likely to be too optimistic for China's pig production.

Poultry and milk productivity offer a very different picture from developments in th sector. Here, it is movement in the frontier that has been dominating the industry over the three decades. Indeed, despite reasonably rapid productivity growth, many of the regions h been falling further behind, as indicated by a value for catching-up index that is less than o These are clearly the most dynamic sectors, and the ones where there is the greatest future potential for growth due to catching-up. Of course, there are some notable exceptions. Pou production in China has been catching-up at a remarkable pace (more than 7%/year) in the 1990's. Korean catch-up in beef production over the same period has been even more dram (8.1%/year).

It is quite instructive to also examine the time path of cumulative Malmquist indexe calculated as the sequential multiplicative products of the annual indexes. Figures 2 and 3 display these charts for poultry and pig production in China. In poultry production, it is cle from Figure 2 that technical change has been driving growth in productivity until the 1990s Note, however, the sharp upturn in catching-up at the end of the sample. This is why we pi the high growth rate for the 1990's in Table 2. Because China was falling behind the fronti during most of the sample period, the technical change (frontier) index is above the total Malmquist index until very recently. China's pig production, shown in Figure 3, offers a st contrast to the case of poultry. Here, there is very little growth in the frontier, with virtually the growth fueled by catching up. This evidence suggests that modernisation of the pig sec China may have commenced around a decade earlier than was the case for poultry.

## IV. PRODUCTIVITY FORECASTS

In this section we seek to develop projections of technological change in livestock productivity to the year 2005 with an emphasis on the non-ruminant livestock sector in Ch We do so by making separate projections of the catching-up and technical change portions productivity.

*Catching-up and the logistic function:* In the case of catching-up, we assume that th observable growth in productivity can be modeled as a diffusion process of new technolog Previous studies have shown (see Jarvis, 1981) that the cumulative adoption path often foll logistic curve. Initially, productivity changes slowly because new innovations take some tin be adopted -- usually there is the need of adapting the new technologies to different condit those of the country that generated the innovation. After this, a period of rapid growth is expected (e.g., as the risk of applying the new technology is reduced). This is illustrated by case of China's pork production in the past decade. Finally, productivity growth slows whe nearly all producers who will find the technology profitable have adopted, and the process reaches a stable ceiling.

We specify the following logistic function to represent the catching up process for e of the regions in the sample:

(7) $$Z_t = \frac{K}{1 + e^{-a-bt}}$$

In this equation, the parameters alpha and beta determine the shape of the logistic relations each region. The parameter K determines the ceiling, or maximum productivity level, to wh the region in question is expected to converge. In estimating this relationship, we use actua observed values for K. These are equal to the maximum productivity value for each sector among all countries in each year.

The parameters of the logistic function are estimated by the following transformatio

(8) $$Y_t = \log\left(\frac{Z_t}{\mathrm{K}_t - Z_t}\right) = a + bt$$

using an iterative Cochrane-Orcutt (C-O) procedure to correct for autocorrelation. We use from the full period: 1961-97 for estimating pig productivity. However, there appears to be sharp break in the poultry productivity data following the economic reforms of the mid-80' we only use this later period: 1985-97 in the poultry estimation. Results from estimation of different models are provided in Table 3. The beta coefficients in the logistic model for bot and poultry are highly significant and have positive sign meaning that there is convergence toward the frontier. Also poultry production is in an earlier stage of the diffusion process g that the speed of diffusion reflected in the beta parameter is higher than that in pigs.

*Technical change -- estimation of the frontier:* While we are able to use actual

observations of the frontier in estimating the logistic function, when it comes to forecasting
need some way of predicting the evolution of this productivity ceiling. We choose to make
simple function of time, as follows:

$$\text{(9)} \qquad K_t = e^{m+gt}$$

The bottom portion of table 3 shows the results of the estimation procedure of the productivity frontier for pigs and poultry. These results confirm the difference in the speed technical change between both sectors given by the coefficient gamma, the rate of growth i frontier.

*Forecasting:* For purposes of forecasting it is useful to have some idea of the possi distribution of outcomes, not just a single point-estimate. A distribution of the forecasts fo sector was approximated using the Efron bootstrapping method[1]. The methodology procee the following steps:

i) The residuals from the regression of $Y_t$ on t (equation 8) are scaled by a factor of (T/(T-l and assigned mass 1/T.

ii) $e_t^*$ is chosen by random draw with replacement from i) and added to the right hand side to generate a new vector of quantities $Y_t^*$.

iii) New parameter estimates $(a^*, b^*, r^*)$ are generated from regressing $Y_t^*$ on t and then u generate a forecast.

iv) Steps ii) and iii) are repeated a large number of times by redrawing from i) and used to a distribution for the forecasts.

v) To consider the effect of the frontier's forecast in China's productivity forecast, steps i) are used to generate a distribution of the frontier's forecast. Values of K are chosen by random draw simultaneously with $e_t^*$ in step ii) and used in iii) to generate the forecast

Figures 4 and 5 show the histograms of the productivity values obtained using the bootstrapping methodology for pigs and poultry, respectively. Table 4 summarizes the mea standard deviation and implied growth rates for productivity in these two sectors. Producti poultry is expected to grow three times as fast as for pigs (7.6% vs. 2.3% per year) over the forecast period. Compare this with the forecasted developing world total production annua growth rate of 3.0% and 2.8% for poultry and pork respectively for the priod:1993-2020 by Delgado et. al.(1999). Table 5 decomposes these growth rates into the portion attributable catching-up and that attributable to movement in the frontier. Poultry is higher on both cou about three times. That is, the frontier in poultry productivity is projected to grow three tim fast as for pigs over this period -- and China is expected to continue rapid catch-up in poul productivity as well. In the case of pigs, slower growth in the frontier, coupled with curren levels of productivity which are closer to that frontier (66% in 2005), translate into slower overall productivity growth.

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[1] Dorfman, J.H., C.L.Kling and R.J.Sexton "Confidence Intervals for Elasticities and Flexibilities: Reevaluati Ratios of Normals Case" *AJAE 72(4), November 1990, 1006-17.*

## V. IMPLICATIONS FOR TRADE: PROJECTIONS TO 2005

*Trade model and database:* Following the lead of Rae and Hertel (1998) we incor the previous projections of productivity growth into a slightly modified version of the applied general equilibrium model (Hertel 1997) to project national and regional produ consumption and trade flows between 1995 and 2005. This is a relatively standard, multi- model built on a complete set of economic accounts and detailed inter-industry linkages fo of the economies represented. The GTAP production system distinguishes sectors by intensities in five primary production factors: land (agricultural sectors only), natural res (extractive sectors only), capital, and skilled and unskilled labour. In trade, produc differentiated by country of origin, allowing bilateral trade to be modeled, and bi international transport margins are incorporated and supplied by a global transport secto model is solved using GEMPACK (Harrison and Pearson 1996).

The 50 commodities in the version 4 GTAP database have been aggregated up commodity groups, of which 6 commodities (rice, wheat, other grains, oil crops, other cro processed food) compete for use in the feedstuffs composite. (We modify the mo incorporate feedstuff substitution into the livestock production functions.) Livestock farm represented by three aggregates: beef cattle (i.e. ruminant livestock), other livestock (i.e ruminants)[1] and raw milk production. These farming sectors provide inputs to the processing (ruminant meat), other meat (non-ruminant meat) and dairy products indust each region. All remaining production sectors are aggregated into manufactures and servi other natural resource based commodities. Regions are aggregated to match the regions re in tables 1 – 3.

*Macroeconomic projections:* The productivity catch-up which we have projected only part of the story of what will be happening in the world economy in the coming years sectors will also be experiencing technological change. Income growth will tend to bo demand for livestock products relative to grains, and in some regions there will be a stron away from food products altogether. On the supply side, the accumulation of skilled lab capital in China -- can be expected to continue to promote the shift of activity away agriculture, in favor of manufacturing and services.

As has become standard with the GTAP model, following the work of Gehlhar projections are made through exogenous shocks to each region's endowments of physical c skilled and unskilled labor, population, and technology.[2] Table 4 reports the sho population, endowments and productivity that we assume in this paper. Forecasts for popu investment (capital stock), and labor force are based on the latest forecasts from the World as of spring, 1999. Projected changes in skilled labor are based on expected increases in the of tertiary educated labor and are taken from Ahuja and Filmer for developing cou Projections for the OECD countries are based on inputs developed for the World Bank's

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[2] We also follow Gehlhar's suggestion that increasing the standard trade elasticities is appropriate in longer run simulations. For this eleven year period, we double the standard GTAP values for the elasticities of substitution between imports and domestic goods and among imports from different sources.

Economic Prospects (1997). The stock of farmland in each region is simply held constant.

Forecasting productivity growth is notably difficult. Therefore, we adopt a rather approach which is transparent and which can be easily modified. First of all, based on th of Bernard and Jones (1996), we observe that productivity growth tends to be more ra agriculture than in manufacturing, which in turn has a higher productivity growth rat services. (They find virtually no evidence of productivity growth in mining where qua reserves confound the usually difficult measurement problems.) Based on their averages OECD as a whole (Bernard and Jones, 1996, Table 1), we obtain the following multiples manufacturing productivity growth rate for the other sectors: (non-livestock) agriculture = manufactures, services = 0.5 * manufactures, and mining = 0 * manufactures. In this way, able to link productivity growth in each sector of the economy to a common metric -- nam rate of manufacture's productivity growth.

We then divide economies into four groups according to their overall rate of produ growth: low, medium, high and very high. The assumed annual growth rates producti manufacturing value-added for these groups are as follows: 0.25%, 0.75%, 1.25 1.75%/year. As can be seen from the entries in Table 6, the low growth group includes Southeast Asia, and New Zealand. The medium group includes the US, Sub-Saharan Afri ROW. Higher productivity growth rates are foreseen for Australia, the EU, and South Ar Finally, Korea and China's productivity growth rates are expected to remain quite l although somewhat lower than implied by the period prior to the Asian crisis. As a check plausibility of these assumptions, we compare our baseline cumulative GDP growth (sec last column) to that forecast by the World Bank, in the last column of Table 6. Apart from and Korea, all of these GDP projections are reasonably close. In order to hit the World targets for these regions, we would have to raise the very high growth category still furt light of the current macro-economic uncertainty in that region, we opt for our more conse projections.

In deference to the fact that these productivity projections are *ad hoc* in nature, order to capture the potential impact of macroeconomic uncertainty in China on that co trade in livestock products, we specify a distribution of possible outcomes for non-liv productivity. In particular, we assume a symmetric, uniform distribution with mean equal estimates in Table 6, and minimum equal to one-half that value. By implication, the ma productivity outcome in this distribution would be 1.5 * the mean value.

The last piece of the productivity puzzle to be resolved before creating a fore productivity growth in the livestock sectors. This is the central issue at hand. As noted abo focus our efforts on projecting pig and poultry productivity in China by bootstrapping the l function to obtain a distribution of forecasts for this critical sector. Livestock produ projections in other sectors/regions are simply taken from the paper by Rae and Hertel (1 Following those authors, we apply these productivity shocks to both value-added and to th composite, in order to maintain a constant ratio of feed use per animal. Provided these sho positive, feed consumption per unit of output (the feed conversion ratio) will decrease. If the case, then the implications for feed demand, and hence for trade in grains and oilse

[3] Sub-Saharan Africa was omitted and the historical trends are used.

well as livestock products could be substantial. There is considerable evidence to suppo
assumption. A recent survey conducted by Wailes *et al* (1998) gathered data on feed use a
range of enterprise and livestock types in seven provinces of China where the trend is to
development of specialised livestock production units and larger, more intensive manag
systems. They concluded that such structural changes will contribute to a declining dema
feedgrains per kg of meat production. Another set of livestock and feeds projections for
are those of Simpson *et al* (1994, Tables 7.6, 7.7 and 8.1), covering the period 1989-91 to
Their projections imply little increase in feed inputs per animal so feed per unit output (th
conversion ratio) shows negative growth, indicating increases in feed efficiency especia
poultry. This is consistent with the projections of Wang et al (1998) who assume improve
in feed efficiency for all animal types and technologies. Finally, Tweeten (1998) r
projected annual USA growth rates in output per feed of 0.2% (beef and pigs), 0.6% (mil
2.0% (poultry). If the US is the source of much of the new livestock production technolog
is transferred to China, then such improvements will eventually be felt in China.

*Results:* Given our interest in livestock products trade, and the space constraints fac
in this paper, we focus here on the impact of alternative livestock productivity scenarios
changes regional trade balances -- particularly those for China. Table 7 reports the *cha*
sectoral trade balances for each region in our global simulation of the period 1995-2005
for China these figures predict that the increase in wheat imports will exceed the cha
exports by $2,879 million by 2005. Outside of ROW, which is a composite of many di
countries (the Asian NICs, South Asia, the Middle East and North Africa, Central and E
Europe, Russia), China emerges as the major *incremental* importer of livestock products
than beef and dairy products), and these are supplied by Australia, New Zealand, North A
and the EU. China's projected incremental grain imports are also substantial. Most o
incremental demand for net imports of grain is satisfied by Australia, North America and th
It should be noted that our analysis abstracts from the implementation of the Uruguay Rou
well as from the possible accession of China to the WTO. Both of these developments
substantially change this pattern of net trade changes.

Table 8 puts the changes in China's sectoral trade balances in perspective. Th
column reports the 1995 trade balance, by sector, based on the version 4 GTAP databas
next column of Table 8 reports the change in trade balance shown in Table 7. Adding this
first column gives the projected trade balance in 2005. From this last column we see th
trend toward increasing imports relative to exports in most of the agriculture-related secto
positive trade balance in manufacturing and services is expected to continue. This is partic
striking in the case of grains and other crops. It conforms with the findings of Delgado
(1999) who estimate that China will be a 46MMT net importer of cereals by 2020.
livestock sector the results show that China will become a net importer of non-ruminant pr
in the year 2005.

There are many uncertainties implicit in the forecasts in Table 8. Table 9 focuses
uncertainty associated with China's productivity growth. The analysis revolves arou
uncertainty associated with the change in China's sectoral trade balance -- reported once
for convenience in the first column of Table 9. The second grouping of columns in thi
relate to the uncertainty derived from our pig and poultry livestock productivity forecasts,

the last two groupings are derived respectively from the uncertainty in non-livestock secto uncertainty in both livestock and non-livestock. The distribution of productivity shocks aggregate sector (pork and poultry combined) is shown in Figure 6. This is conve summarized with a triangular distribution with a range of 40% productivity change (me 20%). We use the Gaussian Quadrature approach to Systematic Sensitivity Analysis proposed by DeVuyst and Preckel (1997) and automated by Arndt (1996) and Arndt and P (1998) in order to draw a weighted sample from this distribution and generate st deviations for our simulation results. These are reported in Table 9 for the change ir balance. Not surprisingly, the main impact of uncertainty in non-ruminant livestock produc to generate uncertainty in the non-ruminant trade balances. For example, the projected cha the trade balance for "other meats", consisting primarily of processed pig and poultry prod $-1220 million, while the standard deviation is about one-fourth of that -- or $332 m Applying Chebyshev's inequality, we can then obtain a 95% confidence interval on the pro trade balance in 2005 (+/- 4.5 standard deviations). For total non-ruminants, this range $+2,483 to $-6,686. Thus it does not appear that we can definitely say China will be importer of non-ruminant products in the year 2005. Furthermore, this only refle uncertainty generated by our forecast of productivity in this sector. What about uncertainty productivity of other sectors?

As noted above, we have specified a uniform distribution for the non-liv productivity growth in China, ranging from one-half the mean to 1.5 * mean productivity Once again we employ the Gaussian Quadrature approach to SSA and generate st deviations for the change in trade balance, based on this new source of uncertainty. findings are reported in the second group of columns in Table 9. The most striking thing these findings is that it is the non-ruminant livestock trade balance that is most sensitive uncertainty in non-livestock productivity! Even the non-livestock sectors' trade balances a volatile (relative to the mean outcome). Indeed, the standard deviation resulting fro uncertainty is nearly as large as that reported in Table 9 ($576 million vs. $687 million). non-livestock productivity growth is equally as important as livestock productivity gro determining the future livestock import requirements of China. When non-livestock produ is high, income growth and demand rise more quickly. Furthermore, with more competitiv livestock sectors, resources tend to be drawn away from livestock production, thereby sl growth in livestock supplies. Both of these factors contribute to a negative change in C livestock trade balance. The combined effect of uncertainty in livestock and non-livestock in a wider gap between the extreme values of the confident interval.

## SUMMARY AND CONCLUSIONS

This paper represents work in progress aimed at better understanding the growth an diffusion of productivity in the livestock sectors, worldwide. The particular goal of the rese presented here is to decompose the historical -- and projected -- changes in technology into components: shifts in the global technology frontier, and movement towards that frontier b individual regions.

Our historical analysis shows that the situation can be very different across product the same country. For example, in China, most of the productivity growth in pig productio the past three decades has been due to "catching-up" to a relatively stable frontier. In contr poultry production, China's has only recently begun catching up. Most of its productivity g over recent decades has been due to movement in the frontier.

In order to assess the likely consequences of future changes in livestock productivi international trade in livestock and related products, we used a modified version of the GT model of global trade to make projections to the year 2005. Uncertainty in China's future productivity growth rates was also taken into account. Our findings are that China will exh larger increase in net imports of both feedstuffs and non-ruminant products than any other in our model. China will be the largest incremental net importer of wheat, other grains and oilseeds (and also of processed foods, which includes processed animal feeds). The project increased trade in these products will flow primarily from North America, the EU and to a extent Australia. For non-ruminant livestock and meat, the same three exporting regions wi the predominant beneficiaries. The projections also point to increasing net imports of feeds and livestock products into Japan, Korea and Southeast Asia, where livestock productivity growth was generally lower than in other regions. Thus for China we project increased net exports of ruminant meats, but a switch from net exporter to net importer status for non-ru products despite China's productivity gains in this sector.

By recognizing uncertainty in the estimates of China's non-ruminant livestock productivity growth, we obtained confidence intervals for the trade balances that did not pr the possibility that China may continue to be a net exporter of livestock products. And whe conducted simulations over a range of productivity growth rates in all sectors but livestock reached a similar conclusion. In this case, productivity gains in China's cropping and lives processing sectors would improve her international competitiveness in livestock products, such general productivity growth would result in more rapid increases in incomes and henc livestock product demands. Therefore we conclude that productivity growth in other secto the Chinese economy is just as important as livestock productivity growth in determining China's future imports of livestock products. Further analyses should include further examination of these issues. Finally, our analyses do not examine trade policy reforms. Giv China's relatively high tariffs on meat imports, that could be reduced should China gain en the WTO, such reforms could also have an important impact on China's future role in international livestock products trade.

| Table 1: Average annual productivity growth (in percentage) | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Pigs | | Beef | | Poultry | | |
| | 1991-97 | 1961-97 | 1991-97 | 1961-97 | 1991-97 | 1961-97 | 1991-9 |
| Australia | 0.80 | 1.62 | 0.26 | 1.00 | 1.00 | 3.03 | 2.19 |
| China | 2.71 | 4.19 | 0.40 | 1.51 | 10.62 | 3.00 | 0.06 |
| Japan | -0.08 | 1.59 | -0.05 | 2.27 | -0.43 | 2.20 | 1.59 |
| Korea | 0.22 | 2.53 | 8.09 | 1.87 | 2.81 | 3.05 | 0.91 |
| New Zealand | 1.01 | 1.86 | -0.70 | 1.37 | 2.06 | 4.97 | 2.55 |
| South East Asia | 0.73 | 1.98 | -0.17 | 0.42 | 0.01 | 1.26 | 1.87 |
| North America | 0.92 | 0.99 | 0.59 | 1.03 | 2.99 | 2.36 | 1.95 |
| E.U. | 0.87 | 0.75 | 0.26 | 1.28 | 2.06 | 2.94 | 2.09 |
| South America | 2.49 | 1.19 | 0.70 | 0.14 | 1.91 | 3.20 | 1.41 |
| Sub-Saharan Africa | 0.66 | 0.20 | 0.03 | -0.08 | 0.20 | 0.94 | 0.30 |

| Table2: Average annual catching-up and technical change growth rates (in percentage) | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Catching-up | | | | | | |
| Region | Pigs | | Beef | | Poultry | | |
| | 1991-97 | 1961-97 | 1991-97 | 1961-97 | 1991-97 | 1961-97 | 1991-97 |
| Australia | -0.3 | 0.9 | 0.3 | -0.7 | -1.9 | 0.6 | 0.2 |
| China | 2.2 | 3.4 | 0.4 | -0.2 | 7.4 | 0.6 | -1.9 |
| Japan | -0.5 | 0.8 | 0 | 0.5 | -3.3 | -0.2 | -0.4 |
| Korea | -0.2 | 1.8 | 8.1 | 0.1 | -0.2 | 0.7 | -1 |
| New Zealand | 0.5 | 1.1 | -0.7 | -0.4 | -0.9 | 2.5 | 0.6 |
| S.E.Asia | 0.3 | 1.2 | -0.1 | -1.3 | -2.9 | -1.1 | -0.1 |
| North America | 0.5 | 0.2 | 0.6 | -0.7 | 0 | 0 | 0 |
| EU(15) | 0.4 | 0 | 0.3 | -0.4 | -0.9 | 0.6 | 0.1 |
| South America | 2 | 0.4 | 0.7 | -1.6 | -1 | 0.8 | -0.5 |
| Sub-Saharan Africa | 0.2 | -0.5 | 0.1 | -1.8 | -2.7 | -1.4 | -1.6 |
| ***Mean*** | ***0.5*** | ***0.9*** | ***1.0*** | ***-0.6*** | ***-0.7*** | ***0.3*** | ***-0.5*** |
| Technical Change | 0.5 | 0.7 | 0.0 | 1.7 | 3 | 2.4 | 2 |

| Table 3 Parameters and regression statistics of the logistic function and the exponential frontier | | | | |
|---|---|---|---|---|
| Logistic | | | | |
| | $\hat{a}$ | $\hat{b}$ | $\hat{r}$ | R2 |
| Pigs | -1.5908 | 0.04997 | 0.93 | 0.939 |
| S.Error | 0.38 | 0.01 | 0.06151 | |
| Poultry | -3.553 | 0.074 | 0.52 | 0.892 |
| S.Error | 0.43 | 0.01 | 0.24 | |
| Exponential frontier | | | | |
| | $\hat{m}$ | $\hat{g}$ | $\hat{r}$ | R2 |
| Pigs | 4.689 | 0.007 | 0.90 | 0.895 |
| S.Error | 0.09 | 0.00 | 0.07 | |
| Poultry | 1.209 | 0.024 | 0.60 | 0.964 |
| S.Error | 0.04 | 0.00 | 0.13 | |

Table 4 China: productivity forecasts and growth

| | Productivity Forecasts | | | | Rates of growth using the mea | | | |
|---|---|---|---|---|---|---|---|---|
| | Mean | Standard Deviation | Minimum Value | Maximum Value | Productivity 1995 | Forecast* 2005 | Period 1995 Total Growth | Ar |
| Pigs | 98.5 | 4.58 | 82.8 | 115.7 | 78 | 98.5 | 25.9 | |
| Poultry | 4.48 | 0.233 | 3.45 | 5.36 | 2.15 | 4.48 | 108.8 | |

* Forecasts are based on estimates for the period 1961-97 for pigs and 1985-97 for poultry (post-reforms period where pou showing convergence in productivity). Units are kgs/head for pigs and kgs/chicken's stock for poultry

Table 5 China: Productivity growth decomposition (1995-2005)

| | Total | Catching-up | Technical Change | China's productivity / Fro 1995 | 2 |
|---|---|---|---|---|---|
| Pigs | 25.9% | 14.8% | 9.6% | 57% | 6 |
| Poultry | 108.8% | 55.5% | 34.2% | 29% | 4 |

Table 6: Annual growth rates of exogenous variables used in the projections and GDP growth

| | Population | Endowments | | | Non-agricultural Productivity | Forecast GDP |
|---|---|---|---|---|---|---|
| | | Unskilled labor | Skilled labor | Capital | | |
| Australia | 0.91 | 1.04 | 4.72 | 1.59 | 0.75 | 3.0 |
| China | 0.75 | 1.06 | 3.33 | 8.22 | 1.75 | 6.3 |
| Japan | 0.18 | -0.26 | 2.57 | 0.33 | 0.25 | 0.8 |
| Korea | 0.74 | 0.64 | 4.74 | 1.53 | 1.75 | 2.9 |
| New Zealand | 0.73 | 0.71 | 4.72 | 2.28 | 0.25 | 2.3 |
| South East Asia | 1.36 | 1.89 | 6.27 | 2.31 | 0.25 | 2.6 |
| North America | 0.78 | 0.89 | 3.02 | 3.04 | 0.75 | 2.7 |
| E.U. | 0.09 | 0.02 | 3.02 | 0.76 | 1.25 | 1.9 |
| South America | 1.37 | 1.94 | 5.50 | 0.96 | 1.25 | 2.7 |
| Sub-Saharan Africa | 2.55 | 2.84 | 5.97 | 1.05 | 0.75 | 3.0 |
| ROW | 1.38 | 1.86 | 5.45 | 2.47 | 0.75 | 3.2 |

Table 7: Change in trade balance (millions of U$S)

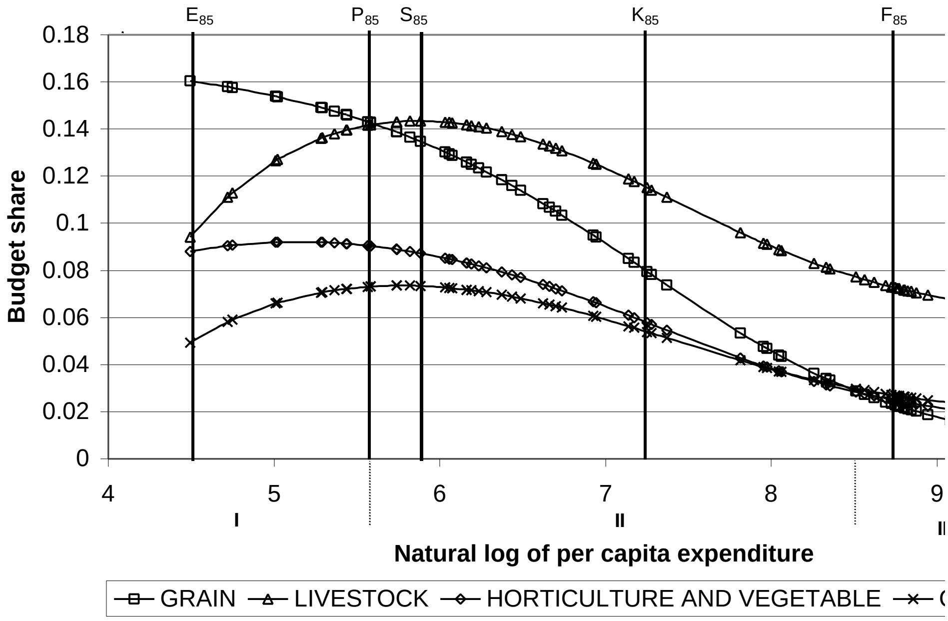
| | China | Japan | Korea | S.E.Asia | Australia | N.Zealand | N.America | EU | S.America | S.S.Africa | ROW |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Rice | -2 | 1 | 0 | -25 | 10 | 0 | 115 | 13 | -17 | -19 | -94 |
| Wheat | -2879 | -107 | -86 | -466 | 463 | -14 | 4058 | 2234 | -167 | -341 | -3033 |
| Other grains | -1972 | -311 | -178 | -401 | 37 | -9 | 3266 | 1151 | -119 | -92 | -1797 |
| Oils | -646 | -569 | -186 | -540 | 30 | -1 | 2943 | -510 | 815 | 75 | -1631 |
| Beef cattle | -30 | -10 | 2 | -230 | 339 | 47 | 287 | 1452 | -202 | 37 | -1764 |
| Other lvstk | -2501 | -165 | -181 | -330 | 94 | 271 | 2814 | 3537 | -354 | -184 | -3197 |
| Milk | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Beef | 224 | -421 | -241 | -154 | 448 | 433 | 975 | 1062 | -337 | -203 | -2122 |
| Other meat | -1220 | -650 | 29 | 355 | 34 | 3 | 1650 | 2597 | -157 | -241 | -2591 |
| Dairy prod. | -214 | -52 | -36 | -305 | 447 | -56 | 126 | 1908 | -232 | -222 | -1793 |
| Other natres | -47022 | 7094 | -8897 | 11489 | 2908 | 893 | -6269 | -6916 | 4146 | 7516 | 26101 |
| Procfood | -4609 | -1451 | 941 | -3932 | 1063 | 147 | 5184 | 6106 | 3269 | -748 | -7742 |
| Other crops | -9632 | -458 | 487 | -4221 | 1426 | -13 | 2362 | 11375 | 9595 | 1461 | -15208 |
| Manufactures | 63546 | -6788 | 14377 | -12826 | -7522 | -2694 | -39664 | 4368 | -17244 | -10921 | -43792 |
| Services | 6957 | 3887 | -6033 | 11586 | 223 | 992 | 22155 | -28377 | 1004 | 3883 | 58661 |
| Total | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

| Table 8 Projected change in China's trade balance (millions of U$S) | | | |
|---|---|---|---|
| | Initial trade balance 1995 | Projected Change 1995-2005 | Final trade Balance 2005 |
| Rice | 2 | -2 | 0 |
| Wheat | -1924 | -2879 | -4802 |
| Other grains | -989 | -1972 | -2961 |
| ***Total grains*** | **-2910** | **-4853** | **-7763** |
| Oils | 377 | -646 | -269 |
| Other crops | -583 | -9632 | -10215 |
| ***Total crops*** | **-3116** | **-15131** | **-18247** |
| Beef cattle | 31 | -30 | 1 |
| Beef | -6 | 224 | 218 |
| ***Total ruminants*** | **26** | **194** | **219** |
| Other livestock | 684 | -2501 | -1817 |
| Other meat | 935 | -1220 | -285 |
| ***Total non-ruminants*** | **1619** | **-3721** | **-2102** |
| Dairy products | -24 | -214 | -238 |
| ***Total livestock & products*** | **1621** | **-3741** | **-2120** |
| Procfood | 1115 | -4609 | -3494 |
| ***Total food*** | **-380** | **-23480** | **-23860** |
| Other natres | -2384 | -47022 | -49406 |
| Manufactures | 45580 | 63546 | 109125 |
| Services | 4403 | 6957 | 11360 |

Table 9 China: confidence interval for the trade balance

| | Initial trade balance | Uncertainty in Other-Livestock Productivity. Chebychev's 95% confidence interval | | | Uncertainty in non-livestock Productivity Chebychev's 95% confidence interval | | | Uncertainty in livestock and non-livestock productivity Chebychev's 95% conf. interval | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1995 | SD | Interval | | SD | Interval | | SD | Interval | |
| Rice | 2 | 0 | 1 | 0 | 1 | 3 | -2 | 1 | 3 | -2 |
| Wheat | -1924 | 33 | -4653 | -4952 | 183 | -3980 | -5625 | 185 | -3968 | -5636 |
| Other grains | -989 | 29 | -2830 | -3091 | 162 | -2231 | -3690 | 164 | -2221 | -3701 |
| ***Total grains*** | **-2910** | | **-7483** | **-8043** | | **-6208** | **-9317** | | -6187 | -9339 |
| Oils | 377 | 20 | -180 | -358 | 99 | 178 | -716 | 101 | 187 | -726 |
| Other crops | -583 | 198 | -9322 | -11108 | 585 | -7581 | -12849 | 617 | -7438 | -12991 |
| ***Total crops*** | **-3116** | | **-16985** | **-19509** | | **-13611** | **-22882** | | -13437 | -23056 |
| Beef cattle | 31 | 0 | 3 | -1 | 4 | 21 | -19 | 5 | 22 | -19 |
| Beef | -6 | 8 | 252 | 184 | 8 | 252 | 184 | 11 | 266 | 170 |
| ***Total ruminants*** | **26** | | **255** | **183** | | **273** | **166** | | 288 | 151 |
| Other livestock | 684 | 687 | 1274 | -4908 | 576 | 773 | -4407 | 910 | 2280 | -5914 |
| Other meat | 935 | 332 | 1209 | -1779 | 260 | 887 | -1457 | 424 | 1622 | -2192 |
| ***Total non-ruminants*** | **1619** | | **2483** | **-6686** | | **1660** | **-5864** | | 3902 | -8105 |
| Dairy products | -24 | 4 | -222 | -254 | 31 | -96 | -379 | 32 | -95 | -380 |
| ***Total lvstk & products*** | **1621** | | **2517** | **-6757** | | **1837** | **-6077** | | 4095 | -8334 |
| Procfood | 1115 | 107 | -3012 | -3975 | 305 | -2123 | -4864 | 322 | -2043 | -4945 |
| ***Total food*** | **-380** | | **-17479** | **-30241** | | **-13897** | **-33823** | | -11385 | -36335 |
| Other natres | -2384 | 469 | -47294 | -51517 | 7308 | -16520 | -82291 | 7317 | -16480 | -82332 |
| Manufactures | 45580 | 355 | 110724 | 107526 | 8202 | 146034 | 72216 | 8211 | 146074 | 72176 |
| Services | 4403 | 579 | 13963 | 8757 | 1365 | 17501 | 5219 | 1484 | 18038 | 4682 |
| ***Total*** | **47219** | | **59914** | **34524** | | **133118** | **-38679** | | 136247 | -41809 |

**Figure 1: Fitted budget shares for food products (evaluated at mean prices). Source: Cranfield, et al., 1998**



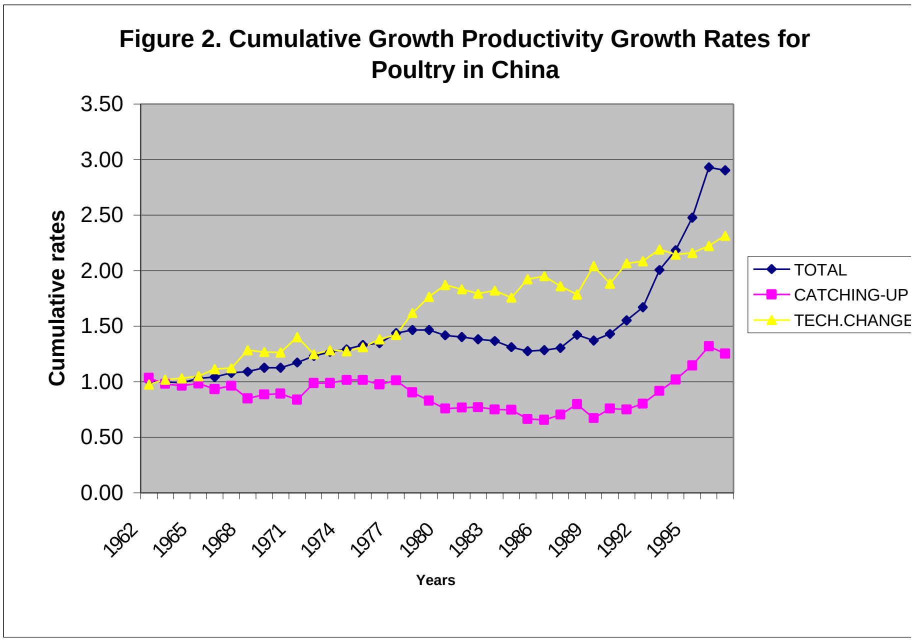


Figure 2. Cumulative Growth Productivity Growth Rates for Poultry in China
Cumulative rates
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
1962
1965
1968
1971
1974
1977
1980
1983
1986
1989
1992
1995
Years
TOTAL
CATCHING-UP
TECH.CHANGE

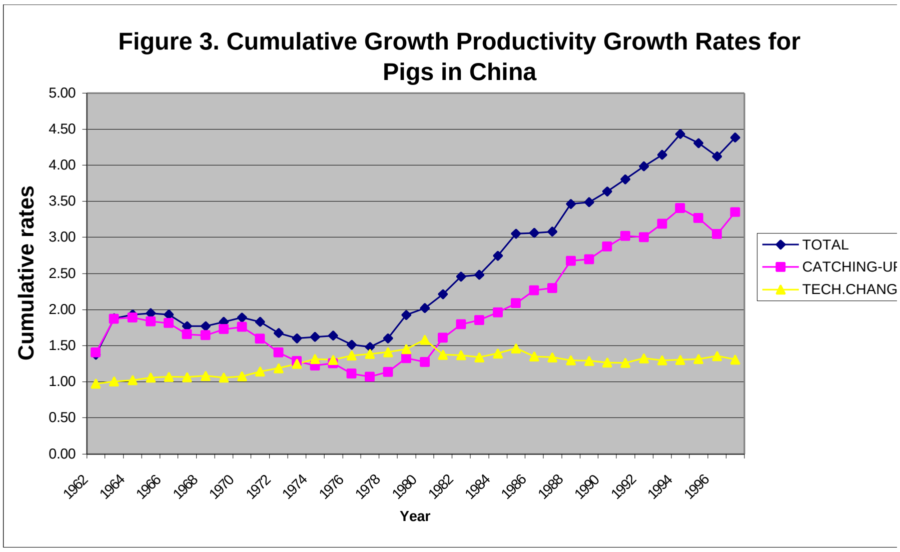



Figure 3. Cumulative Growth Productivity Growth Rates for Pigs in China
Cumulative rates
5.00
4.50
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
1962
1964
1966
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
Year
TOTAL
CATCHING-UP
TECH.CHANG

Figure 4. Bootstrapped Productivity Forecasts for Pigs in China

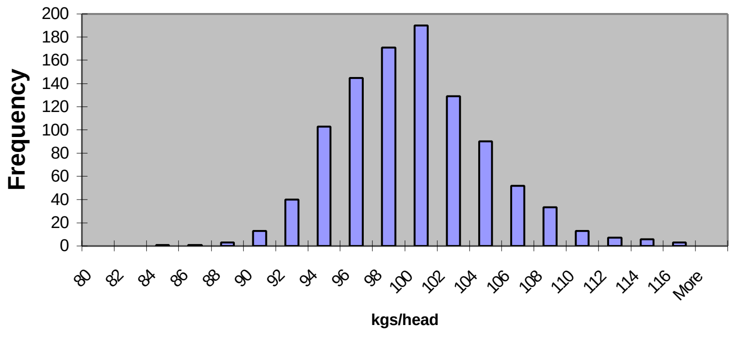
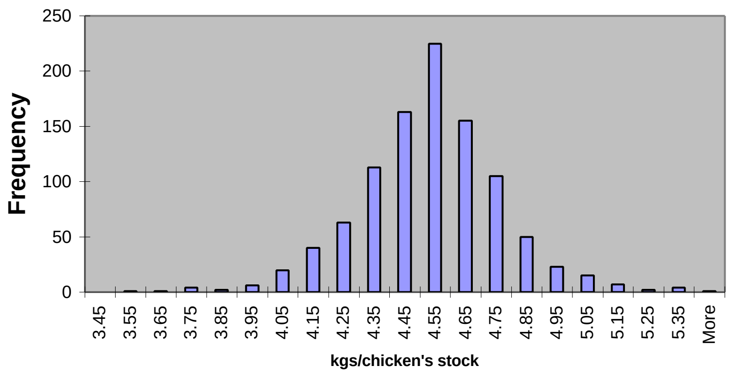



Figure 5. Bootstrapped Productivity Forecasts for Poultry in China



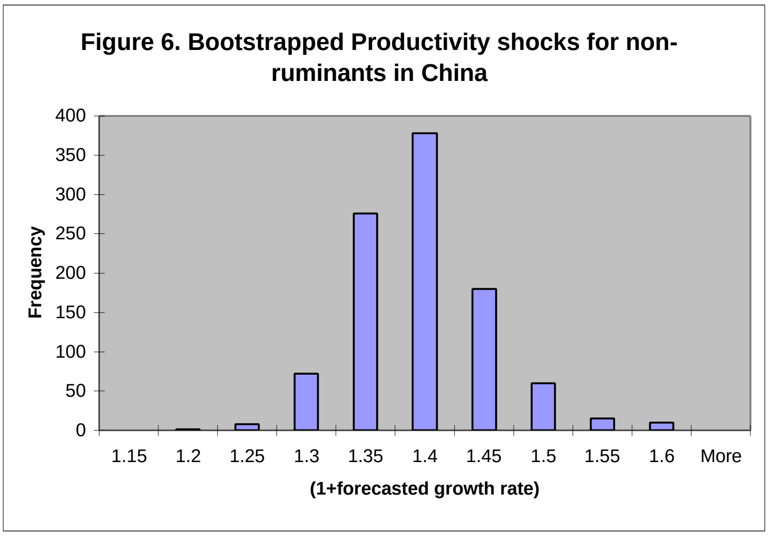


Figure 6. Bootstrapped Productivity shocks for non-ruminants in China
400
350
300
250
200
150
100
50
0
Frequency
1.15
1.2
1.25
1.3
1.35
1.4
1.45
1.5
1.55
1.6
More
(1+forecasted growth rate)

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