



Examining Trends and Drivers of Production and Import Demand for Selected Agricultural Commodities

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Executive Summary

Agricultural economists have spent a great amount of effort examining production, consumption, and trade patterns of agricultural commodities in various parts of the world. The bulk of previous work in this area has focused on wheat, coarse grains, oilseeds, rice, cotton, sugar, and key animal products; in each case a detailed set of production and trade projections have been calculated annually by various organizations. These commodities represent a significant share of total agricultural production and trade worldwide, as well as much of the changes in agricultural production and trade that have occurred globally over the past three decades.

The purpose of this paper is to review research examining production and trade patterns in global agriculture and extend that line of work to consider commodities that are understudied, yet important in many regions. We begin by reviewing production and trade trends for sixteen agricultural products; this group of products was selected to represent a range of commodities and a cross-section of countries from different regions of the world. The sixteen products included four animal products, four grain and oilseed products, four Mediterranean products, and four tropical products. From the sixteen selected commodities we identified four to be studied more closely; chicken was the representative animal product, corn was the representative grain product, tomatoes were the representative Mediterranean product, and coffee was the representative tropical product.

Data were collected to characterize factors that are expected to have had an impact on changes in production and import demand of the four commodities between 1991 and 2006. We consider the impact that output prices, input prices, and input quantities have had on production levels for the major producers of chicken, corn, tomatoes, and coffee. In addition, we assess the relationships that exist between per capita import demand quantities and prices, incomes, diet (measured by caloric consumption rates), and trade openness. Import demand models are also developed for chicken, corn, tomatoes, and coffee. A detailed set of production and trade projections for the sixteen commodities are not calculated here, but we do outline some of the major drivers that should be considered when calculating production and trade projections. We also begin to develop a framework to assess production and trade projections for horticultural products.

Regression results found a positive and statistically significant relationship between changes in coffee prices and coffee production. Conversely, a negative relationship exists between prices and production levels of tomatoes and chicken. Fuel prices were found to inversely affect the production levels of tomatoes and coffee, yet were positively related to production levels of chicken and corn. Estimated coefficients were positive for wage rates for all commodities; this suggests that higher wage rates may have induced greater levels of productivity. Water availability was positively related to chicken and coffee production whereas land availability was positively related to chicken and corn production. Also, results from all four production models show a positive relationship between technology and output levels.

We see some support that output prices are more important in determining import demand relative to determining production levels. The import demand models estimated an inverse relationship between import prices and import demand for

chicken, corn, and tomatoes. In addition, the estimated coefficient for per capita income was positive and statistically significant for chicken, corn, and tomatoes. The level of trade openness was positively related to import demand for all four commodities; the largest effects were for tomatoes and corn. Furthermore, we found a negative and statistically significant relationship between per capita import demand and domestic production for corn and tomatoes.

Our results support claims that between 1991 and 2006 i) corn production was positively related to fuel prices, ii) water shortages did divert resources from tree crops and animal products to field crops, iii) additional land has been used for animal and grain production, iv) technology was a driving force for advances in agricultural production, v) income and trade openness were key determinants for import demand, and vi) caloric intake was not an important influence for import demand patterns among the commodities studied.

Production of the selected agricultural commodities has been driven predominantly by changes in market conditions for agricultural inputs. Import demand for the same group of agricultural commodities has been, and continues to be shaped by income and trade openness. Overall, our results show that production and import demand of various agricultural commodities have responded to different factors, and that it is important to consider the driving forces for individual commodities. Models that are used to predict production and import demand for grains, oilseeds, and animal products should be extended to include horticultural products, but they also need to consider the idiosyncrasies associated with global horticultural markets.

Introduction

Over the last four decades there have been significant increases in global production, consumption, and trade of agricultural products. Growth in production of agricultural products is often linked to improvements in technology and greater trade flows are associated with trade liberalization. Here we examine trends in global agricultural markets and develop a framework to assess the determinants of production and trade for selected agricultural products between 1991 and 2006. Understanding the underlying drivers of production and trade in recent history, coupled with expectations about the direction and magnitude of change among the determinants, will allow us to shed some light on production and trade patterns over the next decade.

The purpose of this paper is to examine patterns of, and attempt to understand the underlying drivers of changes in, production and trade for key agricultural products. The paper is organized into four sections and each section addresses a separate but related objective. First, we provide an overview of previous work that has examined trends, prospects, and forecasts for production and trade in agricultural markets. Second, we document patterns in production and trade between 1961 and 2006 for agricultural commodities that are economically important in many regions of the world. Third, data are collected to understand the factors that are expected to have influenced production and trade flows of agricultural commodities. Fourth, we develop an economic model and employ regression analysis to quantify the drivers of changes in production and trade quantities for selected agricultural products. The results from the regression analyses will provide statistical relationships between the influencing factors and production and trade patterns. Historical relationships can then be used to predict future patterns of production and trade for the selected agricultural commodities.

Myriad studies highlight historical patterns and forecasts for production and trade of specific agricultural products, notably coarse grains and animal products. The research presented here builds upon previous work in two ways. First, we provide a more thorough investigation of trends and patterns of production and trade for horticultural products. Second, our research estimates the quantitative relationships that exist between contributing factors and changes in global agricultural production and trade patterns between 1991 and 2006. Our analysis considers production and trade of sixteen agricultural products that are widely produced and consumed in various countries. The sixteen products were chosen based on their relative value of production and trade, and to reflect a range of countries from different regions in the world. We included four animal products (beef, chicken, dairy, and pork), four grain/oilseed products (corn, rice, soybeans, and wheat), four commodities that we aggregate into a group called Mediterranean products (cotton, oranges, sugar, and tomatoes), and four commodities that we aggregate into a group called tropical products (bananas, cocoa, coffee, and palm oil).

A Review of Published Situation and Outlook Reports

Much work has been completed that organizes data describing historical production and trade patterns for agricultural commodities (*e.g.*, Koo and Taylor 2007; FAO, 2008; USDA-FAS, 2008). There also exists a substantial amount of work that

provides outlook reports, or forecasts, for production and traded quantities of various agricultural products (e.g., Rosegrant et al. 2001; USDA-ERS, 2008). Outlook reports incorporate information about expected changes in economic conditions in the United States and elsewhere to project future patterns of production and trade.

Brookins (2007) examined the major forces that are shaping global agricultural markets and found that changes in agricultural policy, consumer tastes, emerging markets, supply chains, and risk management strategies are the key drivers. Mattson and Koo (2006) also examine the forces influencing world agricultural markets with an eye on grain products. The authors explain how trade liberalization, research and development, ethanol and bio-diesel production, and supply and demand conditions in emerging countries will dictate future changes in production, prices, and traded quantities of agricultural products. USDA-ERS (2001) examines global food consumption and trade patterns through a series of papers; each paper examines a specific factor contributing to consumption changes between 1970 and 2000. The effects of changes in urbanization, transportation, diet, food safety, animal welfare, and organic markets are examined in detail. The USDA-ERS (2001) paper focuses mostly on U.S. markets; however, it was one of the few publications that examined consumption and trade patterns trends for a wide range of agricultural products, including fruits and vegetables.

The USDA-ERS (2008) report reviews global production patterns, trade flows, and year-end stocks for major field crops and animal products. The most recent report also shows production and trade projections between 2007-08 and 2017-18. Projections show that the traded quantity of corn will increase by approximately 15 percent between 2007 and 2018; the increase will be fueled by import demand for corn in North Africa, the Middle East, and Mexico. Global imported quantities of wheat are expected to increase by 23 percent and much of the increase is expected by importers in Africa, the Middle East, and East Asia. Soybean trade is expected to increase nearly 50 percent over this time period; most of the additional soybean exports are expected to come from Brazil, and the additional import demand for soybeans is expected in China. Over this time period, production of U.S. soybeans is expected to decrease by about 10 percent, and the exported quantity of U.S. soybeans is expected to fall by 25 percent. Rice trade is expected to increase by 28 percent; Thailand and Vietnam will lead the increase in rice exports, and the Middle East and Africa will lead the increase in rice imports.

Cotton trade is expected to increase by 50 percent between 2007 and 2018. Greater quantities of cotton are expected to be exported from the United States, selected Africa countries, and Brazil; China is expected to increase cotton imports nearly threefold between 2007 and 2018. Less cotton is expected to be planted in the United States between 2008 and 2011, but after 2011 it is expected to increase to 2008 levels. Other research suggests that the WTO ruling against U.S. support for cotton may decrease U.S. production. If cotton subsidies are reduced in the next Farm Bill, U.S. cotton production may decrease by as much as 30 percent (Sumner 2007a; Sumner 2007b). Meat trade is also predicted to increase; the traded quantities of beef, pork, and poultry are each expected to increase by approximately 40 percent between 2007 and 2018. The United States will export a greater share of beef and pork to Russia, and Brazil will export a greater share of chicken to East Asia, the Middle East, and North Africa.

Rosegrant et al. (2001) applied a partial equilibrium displacement model to assess the production, consumption, and trade patterns for nineteen agricultural products across thirty-two countries. Here baseline projections for production and trade levels were calculated in 2020 and then alternative projections were made using a different set of assumptions about future levels of research and development and using different policy frameworks. Rosegrant et al. (2001) found in the baseline projections that global import demand will fall for rice and rise for wheat by 2020. Meat demand in developed countries will remain relatively constant but will increase in developing countries over the same time period. China will become a larger importer of food by 2020; however, the baseline projections report that the value of Chinese agricultural imports will only reach 6 percent of the value of China's agricultural production. Trade liberalization is a key parameter in the projections for 2020; removing agricultural policies adds \$36 billion to the world food economy and approximately 60 percent of the gains would go to stakeholders in developing countries.

Each year the Food and Agricultural Policy Research Institute (FAPRI) employs a computable general equilibrium model to provide a comprehensive analysis of the forces affecting global production and trade patterns. The FAPRI model incorporates macroeconomic conditions with agricultural policy variables to project global production and trade patterns for coarse grains, oilseeds, cotton, sugar, and animal products for a ten-year period. The most recent FAPRI projections (FAPRI, 2008) dedicate a significant amount of attention to the impact that energy policies applied in the United States, the EU, Argentina, Canada, and Brazil will have on global agricultural markets. FAPRI (2008) projects higher nominal prices and production levels for all agricultural commodities; however, the price increases beyond 2009 are modest for most of the commodities due to increases in stocks, planted area, and yields.

World soybean prices are projected to remain above 2007 levels until 2018, and this is mostly driven by increased global demand for vegetable oil and oilseed meal used in animal production, notably in China. Brazil is projected to become the largest producer of soybeans by 2016 (FAPRI, 2008). Although global rice consumption is expected to grow over the ten-year period, diet changes in Asian countries will dampen total demand for rice relative to the other commodities and rice trade will remain relatively low. Sugar prices are expected to increase through 2017 due to increased levels of ethanol produced using sugar cane in Brazil and changes in European policies applied to sugar. Ethanol and bio-diesel prices are expected to fall until 2012, and then increase through 2017 due to U.S. and EU energy policies that mandate the use of alternative energy sources. Global demand for animal products, notably poultry products, is expected to increase between 2008 and 2017 due to increases in population and income in developing countries. Overall, net imports of the commodities studied are expected to increase by up to 20 percent in Asia and up to 10 percent in African and Middle Eastern countries.

Less work has been done that studies production and trade patterns for Mediterranean and tropical products. Rickard and Sumner (2006) provide a global overview of production and trade patterns in the processing tomato industry between 1980 and 2005, and highlight some likely changes in production and trade over the next ten years. Over the past decade, production of processing tomatoes has been relatively constant in North America and Europe and rising in western regions of China. Price

supports applied to Mediterranean crops (including processing tomatoes and citrus products) in Europe are scheduled to be eliminated by 2011, and this is expected to decrease EU production levels. Global production for Mediterranean and tropical products is expected to increase due to changing diet patterns (see USDA-ERS, 2001; de Haen et al., 2003), and much of the additional import demand for these products is expected to occur in China and Latin America. USDA-FAS (2008) provides a summary of production and trade patterns for selected horticultural products in key global markets, but does not project production levels or traded quantities. Better information about the drivers of production and trade of Mediterranean and tropical products will facilitate the development of situation and outlook reports for these important agricultural sectors.

Underlying all of the models that are used to predict production and trade patterns for agricultural commodities are a set of assumptions that characterize key parameters. Projected production quantities are based on a set of assumptions about technological advances and yield improvements, relative prices for commodities and inputs, agricultural policy parameters, input quantities, and production expectations in other parts of the world. Predictive models for trade flows include assumptions about macroeconomic conditions, policy parameters, population and income growth, domestic production levels, and diet patterns. There is a growing literature on the relationship between trade and the changing composition of diets in the United States (*e.g.*, USDA-ERS, 2001), other OECD countries (*e.g.*, Srinivasan, Irz, and Shankar, 2006), and developing countries (*e.g.*, Huang, Rozelle, and Rosegrant, 1999; Coyle, Gilmour, and Armbruster, 2004; Pingali 2004). Our analysis will examine changes in several of these key parameters to assess the drivers of agricultural production and trade in recent history.

Examining Trends in Global Agricultural Production

We collected country-level data between 1961 and 2006 that describes production quantities for the sixteen selected agricultural products. For each selected agricultural product in each country, we have forty-six time series observations. Many of products are produced in at least seventy countries and therefore we have more than 3,100 observations describing production quantities per product. We use country-level data in the regression analysis; however, given the amount of production data collected, we aggregate country-level data into regional data in the figures shown below. The figures aggregate data into the following five regions for purposes of illustration. The region denoted Africa includes 54 countries; Asia includes the 50 countries east of the Mediterranean Sea plus the 26 countries in Oceania; Europe includes 52 countries; the North American region includes 14 countries (and includes the 9 countries in Central America); South America includes the 14 countries south of Panama and the 25 countries in the Caribbean.

Figure 1 shows the composition of global production for three meat products in 1976 and again in 2006. Dairy products were not included in Figure 1 as the units of production could not be shown on the same scale; global dairy production increased from 395 million metric tons in 1976 to 550 million metric tons in 2006 and production increased by at least 50 percent in each region. Between 1976 and 2006, global production of beef increased 50 percent, pork production increased 250 percent, and chicken production increased approximately 400 percent. Across the

meat sectors, the most significant production gains occurred in Asia, and the production gains for chicken and pork in Asia were substantial. Figure 2 shows a similar story for grain and oilseed production between 1976 and 2006; here production of corn, rice, soybeans, and wheat increased by at least 50 percent, and in the case of soybeans, it increased 200 percent. Asia accounted for the greatest share of growth in production of corn and rice; Europe had substantial increases in wheat production, and South America had the greatest percentage increase in soybean production.

Overall, production of Mediterranean and tropical products occurred in a different set of countries from those that were the largest producers of animal, grain, and oilseed products. Figure 3 illustrates that production of cotton, oranges, and tomatoes increased by at least 100 percent; production of sugar increased by 60 percent (from approximately 1 billion metric tons in 1976 to 1.6 billion metric tons in 2006). Cotton and orange production increased the most in Asia. Tomato production increased the most in Asia but also increased substantially in North Africa, and sugar production increased the most in South America. Production of the selected tropical products increased by at least 100 percent, and in the case of palm oil it increased twelve fold between 1976 and 2006. Most of the growth in production of tropical products occurred in Asia. Figure 4 shows that the greatest increases in cocoa production between 1976 and 2006 occurred in Africa and the greatest increases in coffee production occurred in South America. During this time period there were also significant increases in the production of bananas and palm oil in Asian countries; between 1976 and 2006 Asian banana production increased from 11 to 38 million metric tons and Asian palm oil production increased from 2 to 33 million metric tons.

The drivers of production for selected agricultural products

Economic models that estimate production consider the impact of output prices, input prices, input quantities, and other factors that are relevant. Rickard and Fox (1999) estimated yield functions for various grain crops in Ontario, Canada, and considered the impacts from the own price of the commodity, a price of fertilizer, precipitation during the growing season, and technological improvements. Results showed that there was a positive and statistically significant relationship between annual rainfall and yields and crop prices and yields for all of the grain crops studied.

Here we develop an economic model to estimate production of selected agricultural products using data between 1991 and 2006. We estimate production functions for chicken, corn, tomatoes, and coffee; these products were selected to represent the four agricultural commodity areas that we outlined above (*i.e.*, animal products, grains/oilseed products, Mediterranean products, and tropical products). In each case, we examine the impact that seven variables have had on production levels of the selected agricultural products across the top producing countries.¹ For each agricultural product, we collected panel data for 16 years (from 1991 to 2006) across five countries, yielding 81 observations. In some instances, data were not available for certain years in certain countries and the total number of observations fell to as few as 60. More specifically, we collected data that characterizes seven variables that are commonly considered important in explaining production levels; variables include the price of the commodity, the price of another commodity that is a substitute in production, the price of fuel, the price of labor, the quantity of water available

(measured as the annual rainfall), the quantity of arable land available, and the quantity of technology available to producers.

The production models can be described using the following notation, where Q denotes production. In the specification shown in Equation (1a), superscripts i and h denote agricultural products where product h is a substitute to product i in production, superscript k denotes a country, and subscript t denotes time.

$$(1a) \quad Q_t^{ik} = f^*(P_t^{ik}, P_t^{hk}, F_t^k, S_t^k, W_t^k, L_t^k, T_t^k)$$

The price of the agricultural product i in country k in time period t is denoted as P_t^{ik} , and the price of a substitute product h in country k in time period t is denoted as P_t^{hk} . Based on the production data, we selected agricultural commodities that are reasonably close substitutes in production across the countries studied. Pork was selected as the substitute for chicken production, soybeans are the substitute for corn production, cotton is the substitute for tomato production, and bananas are the substitute commodity for coffee producers. We also consider the prices for two key inputs—fuel and labor—used to produce the agricultural commodities. The price of fuel is denoted F_t^k and the price of labor is denoted as S_t^k . We collected data on the real price of diesel measured in U.S. cents per liter to characterize the price of fuel (FMECD, 2007); the monthly per capita gross domestic product in country k is used as a proxy for the price of labor. Three input quantities are also included in the model to examine the relationship between factor inputs and production levels. We collect data to describe the quantity of water, denoted as W_t^k , the quantity of land, denoted as L_t^k , and the quantity of technology, denoted as T_t^k . The quantity of water is the total annual level of precipitation in millimeters in country k (National Climate Data Center, 2008), and the quantity of land is the number of available acres in country k (FAO, 2008); available acres includes arable acres plus land under permanent crops. We use a time trend as a proxy for the level of technology available in country k to capture the effect that technology has had on the production levels of selected agricultural commodities. All financial data is deflated into real 2000 U.S. dollars using the Consumer Price Index (USDOL-BLS, 2008).

Examining Trade Flows for Selected Agricultural Products

Our examination of historical trade flows follows the format we used to examine production patterns. We collected country-level data between 1961 and 2005 for imported quantities of the 16 selected agricultural products. Given the amount of import data collected, we aggregate country-level data into regional data to highlight general trends in Figures 5, 6, 7, 8, and 9. Data that describes imported quantities of the 16 agricultural commodities is aggregated into the same five regions that were used for the production data.

Figure 5 shows the regional-level import patterns for beef, chicken, pork, and dairy. Global trade of beef products fell between 1976 and 2005. Global beef trade increased from 1976 to the mid-1990s and then returned to pre-1980 levels by the year 2000; global beef trade peaked in 1992 at which point it was nearly 100 percent higher than it was in 1976. Trade levels for the other animal products were significantly higher in 2005 compared to 1976; trade levels increased by approximately 300 percent for dairy products, 500 percent for pork products, and 700

percent for chicken products. Increased trade for dairy products occurred mostly in North America and Europe, and European imports of pork products increased significantly over this time period. Chicken imports increased across all regions. Trade patterns for grains and oilseeds also increased significantly between 1976 and 2005. Figure 6 shows that trade of corn, soybeans, and wheat increased by approximately 90, 300, and 100 percent respectively. The bulk of the increase in grain and oilseed imports went to Asian and African countries. Compared to corn, soybeans, and wheat, relatively little rice is traded internationally, and growth in rice trade has been modest.

During this time there were also large increases in traded quantities of Mediterranean products. Figure 7 shows that imported quantities of the selected Mediterranean products were higher in 2005 compared to 1976. Cotton imports nearly doubled and tomato imports tripled. The increase in global tomato imports appears to have been driven by European imports; however, Rickard and Sumner (2006) found that increased levels of processed tomato imports into the EU have coincided with increased levels of EU exports of processed tomato products. This finding, coupled with anecdotal evidence from industry sources, suggests that the processed tomato industry in Europe is blending EU product with a lower-cost imported product and then marketing the blended product in export markets. Recent evidence has indicated that this activity might also be prevalent for other Mediterranean products, including olive oil (Mueller, 2007). Although sugar trade is not shown in Figure 7, global sugar imports increased from approximately 6 million metric tons in 1976 to almost 20 million metric tons in 2005. The growth in sugar trade occurred in all regions outside of North America; in each region outside of North America, sugar imports increased by at least 300 percent. Imports of sugar into the United States are managed through a complex set of import quotas and U.S. trade policies for sugar products are considered to be the primary reason why imports of sugar into the North American region are lagging behind other regions (Sumner, 2007a).

Import demand growth for tropical agricultural commodities is similar to the increases observed in many of the other selected agricultural markets. Figure 8 shows that global imported quantities of cocoa and coffee have increased, and in the case of coffee, the increased level of trade has occurred across several regions. Figure 9 shows the substantial increases in the imported quantities of bananas and palm oil between 1976 and 2005. Global imports of bananas rose from approximately 6 million metric tons in 1976 to 15 million metric tons in 2005. The increase in global imports of palm oil were even greater over this time period; total imports of palm oil increased from 2 million metric tons in 1976 to over 24 million metric tons in 2005 with most of the increased level of imports occurring in Asia, followed by Europe.

The drivers of import demand for selected agricultural products

Various agricultural economists have developed models to estimate import demand of agricultural commodities. Rosson, Hammig, and Jones (1986) studied import demand determinants for apples, poultry, and tobacco; Halliburton and Henneberry (1995) examined import demand for almonds in Pacific Rim countries; Lanclos, Devadoss, and Guenther (1997) investigated import demand for U.S. frozen potatoes; and Le, Kaiser, and Tomek (1998) studied import demand for U.S. red meat products into four Pacific Rim countries. Previous work has typically found that there is a negative and

statistically significant relationship between import quantities and trade barriers. Furthermore, estimates of the elasticity of import demand for generic promotion efforts in foreign countries have been in the range of 1.0 to 6.0; these results indicate that export promotion programs for agricultural commodities yield higher levels of imports.

We assess factors that are believed to have influenced import patterns for four products—chicken, corn, tomatoes, and coffee. In each case, we estimate the impact that six explanatory variables have had on per capita import levels across the top five importing countries.² For nearly all of the selected agricultural commodities, the top five importing countries are different from the top five producing countries. Also, the determinants used to estimate import demand for agricultural commodities are different from the determinants used to estimate production patterns.

The variables included in the import demand models focus on factors that help to explain changing patterns of import quantities; variables include the price of the commodity, the price of another commodity that is a substitute in consumption, per capita income, the level of trade openness, per capita calorie consumption, and where applicable, the quantity of the commodity produced in the importing country. Rather than assess the impact that factors have had on total import quantities, we examine the per capita import quantities. Examining per capita import quantities allows the model to attach more weight to large importing nations with relatively low population levels. The per capita quantity of an agricultural commodity i imported into country k in time period t is denoted as M^k_t . In the import demand specification shown in equation (2a), superscripts i and j denote agricultural products where product j is a substitute to product i in consumption, superscript k denotes a country, and subscript t denotes time.

$$(2a) \quad M^k_t = f^*(P^{ik}_t, P^{jk}_t, I^k_t, C^k_t, O^k_t, D^{ik}_t)$$

The price of the imported product i into country k in year t is denoted as P^{ik}_t and the price of product j , which is a substitute in consumption, is denoted as P^{jk}_t . The consumption substitute used for chicken is beef; it is wheat for corn, bananas for tomatoes, and cocoa for coffee.³ All prices used in the import demand models are unit prices and are calculated by dividing the total value of imports by the total quantity of imports (FAO, 2008). In addition to price effects, we also consider the impact of per capita income, denoted as I^k_t , per capita calorie consumption, denoted as C^k_t , the level of trade openness, denoted as O^k_t , and the per capita level of domestic production, denoted as D^k_t , in year t for country k . The per capita gross domestic product (total gross domestic product divided by population) is used as a proxy for per capita income (IMF, 2008); the per capita calorie consumption is the average calories per person per day available in country k (FAO, 2008); the level of trade openness is characterized by the value of imports as a share of gross domestic product in country k (World Bank, 2008); domestic production is measured in metric tons per capita (FAO, 2008). All financial data is deflated into real 2000 U.S. dollars using the Consumer Price Index (USDOL-BLS, 2008).

Beef import prices were unavailable for the Russian Federation and Saudi Arabia in some years; chicken prices in Romania and Kuwait were used as proxy values for the missing data in Russia and Saudi Arabia respectively. Data for per capita calorie

consumption was only available from 1991 to 2003, so the 2003 data is also used as a proxy for 2004 and 2005 in all countries. In some import demand models certain explanatory variables are omitted if data do not exist. For example, there is no domestic production of coffee in the top coffee-importing countries and therefore the per capita quantity of domestic production is omitted in the model that estimates import demand for coffee.

Development of the Regression Models

Eight single equation models were developed to estimate production and per capita import demand for each of the four selected agricultural commodities. We transformed the collected data into logarithmic equivalents yielding a double logarithmic functional form; this allows the resulting coefficients to be approximately interpreted as percentage changes (or elasticities). Each production model included up to 16 time periods (1991 to 2006) for 5 countries or 80 observations; each import demand model included up to 15 time periods (1991 to 2005) for 5 countries or 75 observations. All output prices in the production models were lagged by one time period; output price variables in time period $(t-1)$ were used to examine production patterns in time period t . We use lagged variables for output prices as planting decisions are based, in part, on prices observed in the previous year. All other variables used in the production and import demand models were taken from time period t , or the same time period that production and per capita import quantities were observed.

The specification used to estimate the four production models is shown in Equation (1b); the estimated coefficient for agricultural commodity i (α_i^i) and the associated p-value will be used to assess the statistical relationships that exists between an explanatory variable and the production quantity of agricultural commodity i . A p-value of 0.05 indicates that the estimated coefficient is statistically significant at the 5 percent level, indicating a strong likelihood that the variable affects the level of production.

$$(1b) \quad \ln Q_t^{ik} = \alpha_0^i + \alpha_1^i \ln P_{t-1}^{ik} + \alpha_2^i \ln P_{t-1}^{hk} + \alpha_3^i \ln F_t^k + \alpha_4^i \ln S_t^k + \alpha_5^i \ln W_t^k + \alpha_6^i \ln L_t^k + \alpha_7^i \ln T_t^k$$

It is expected that higher prices of product i in time period $(t-1)$ would lead to higher levels of production of i in time period t . Higher prices of product h (the substitute commodity in production) would most likely lead to lower levels of production of i ; this relationship is expected to hold more strongly in the corn and tomato models and less so in the chicken and coffee models. Switching production from corn to soybeans and tomatoes to cotton is less constrained than switching from chicken to pork and coffee to bananas in the short run. Higher prices for inputs, such as fuel and labor, are expected to have an inverse effect on production levels. However, it could be argued that higher input prices might be associated with higher output prices and there could be a positive relationship between input prices and production quantities. A model that is more complex than the one we present here, such as a two-stage least squares econometric model, would be able to assess these detailed relationships. Greater levels of input quantities, such as water, land, and technology would also be expected to have a positive relationship with production quantities holding all else constant.

The models used to estimate per capita import demand quantities of product i are specified in Equation (2b); here the estimated coefficients for agricultural commodity i (β_n^i) and the associated p-values will be used to assess the statistical relationships that exist between six explanatory variables and per capita quantities of imports.

$$(2b) \quad \ln M_t^{ik} = \beta_0^i + \beta_1^i \ln P_{t-1}^{jk} + \beta_2^i \ln P_{t-1}^{jk} + \beta_3^i \ln I_t^k + \beta_4^i \ln C_t^k + \beta_5^i \ln O_t^k + \beta_6^i \ln D_t^{ik}$$

On the import demand side, it is expected that higher import prices of product i would lead to lower levels of per capita imports of product i ; similarly, higher prices of import product j (the substitute commodity in consumption) would lead to more per capita imports of product i . Higher levels of income and calorie consumption are expected to have a positive relationship with per capita import quantities. Once again, depending on the agricultural commodity and the importing country, it might be the case that higher levels of caloric intake are linked to either lower or higher levels of per capita imports. For example, higher levels of calorie consumption in a developing country would be expected to have a positive relationship with import demand for meat products (de Haen et al., 2003) or wine, and it would be expected to have a negative relationship with import demand for skim milk powder or palm oil. Overall, the level of trade openness is expected to be positively related with import demand. The relationship between domestic production of i and import demand for i may be positive or negative depending on the importing country and the agricultural commodity.

Regression results for production models and implications

Table 1 shows the estimated coefficients and the associated p-values for the four production models. The Adjusted R^2 values for the four regressions range between 0.41 and 0.98, suggesting that the changes in explanatory variables provide a reasonably good explanation of the changes in production of the selected agricultural commodities. The first column of results in Table 1 provides the estimated coefficients for chicken production. The estimated coefficient for the price of chicken is -0.51 and statistically significant; this indicates that a 1 percent increase in the price of chicken is associated with a 0.51 percent decrease in chicken production. Overall, this result suggests that higher prices of chicken are not correlated with higher levels of chicken production. In fact, this result may be driven by the demand side whereby higher prices are correlated with lower levels of chicken consumption. The results for input prices indicate that chicken production uses energy and labor relatively efficiently.

In corn production, the estimated coefficient for the price of corn is positive, indicating that higher corn prices are linked with higher levels of production. Like the coefficients estimated in the chicken model, the input price coefficients are positive and statistically significant. Corn production is not considered a labor-intensive crop, and our results suggest that higher labor costs lead to more corn production. The positive coefficient for the price of fuel suggests that higher fuel prices are linked to greater quantities of corn production; the relationship between corn production and fuel prices is one that has generated much discussion in 2007 and 2008. The estimated coefficient for land is 1.39 suggesting that a 1 percent increase in arable land yields a 1.39 percent increase in corn production.

The third column of results in Table 1 shows the estimated coefficients for tomato production. Here data for fresh tomatoes is combined with data for processing tomatoes and this may be influencing the price coefficients. In the tomato model, the coefficients for the quantity of water and the quantity of land are negative; this suggests that tomatoes are a relatively efficient crop in terms of water and land use. Across the four commodities studied here, tomato production shows the strongest positive relationship with technology.

The final column of results in Table 1 outlines the impact that the selected variables have had on coffee production. The estimated coefficient for the price of coffee is 0.86 (and the p-value is 0.01) indicating that production of coffee is quite sensitive to changes in its price; a 1 percent increase (decrease) in the price of coffee leads to a 0.86 percent increase (decrease) in coffee production. As expected, the coefficient for the price of bananas is negative and statistically significant. The coefficient for the price of fuel is negative and is positive for the price of labor; this result suggests that alternative crops to coffee are more labor intensive. There exists a positive relationship between water availability and production as well as between technology and production. The relationship between land and production is negative indicating that as land becomes more scarce coffee production increases, perhaps due to yield increases.

Overall, the production model results suggest that water availability has a positive and statistically significant relationship with chicken and coffee production and a negative and statistically significant relationship with corn and tomato production. This finding indicates that in times of water shortages, production will shift towards field crops and away from chicken and coffee. The coefficients for fuel price and land availability indicate a positive relationship for chicken and corn and a negative relationship for tomatoes and coffee; as the fuel price or quantity of arable acres increases, production will shift from tomatoes and coffee (vegetables and permanent crops) to chicken and corn (animal products and grains). We use monthly income levels to characterize labor costs and based on this proxy, our results suggest that as labor costs increase, so does the production of all four agricultural products. This result is strongest for coffee, the only commodity analyzed that is produced exclusively in developing countries. This finding supports the idea that agricultural labor is becoming increasingly productive in developing countries relative to agricultural labor productivity levels in developed countries (World Bank, 2008). All four commodities have a positive relationship with technology, yet tomatoes and chicken production have been most responsive to technology over the time period studied. The top producing countries of chicken and tomatoes include many of the countries that have observed the highest share of research and development spending per capita (Rosegrant et al., 2001; World Bank, 2008).

Regression results for import demand models and implications

Table 2 shows the estimated coefficients and the p-values (in parenthesis) for the four import demand models. The first column of results outlines the estimated coefficients for per capita import demand of chicken. Per capita imports of chicken are negatively related to the price of imported chicken meat; the results indicate that a 1 percent increase in the price of imported chicken meat is linked to a 1.07 percent decrease in the per capita import demand for chicken meat. The results also indicate that per

capita income and trade openness are important drivers of per capita import demand for chicken.

The second column of results in Table 2 provides estimated coefficients for per capita import demand of corn. The estimated coefficient for the import price of corn and the price of the substitute, wheat, are not statistically significant. Import demand of corn does have a positive and statistically significant relationship with per capita income, calorie consumption, and trade openness. Also, the estimated coefficient for the final explanatory variable, domestic production, is negative indicating that increased production of corn domestically dampens import demand for corn; this result suggests that domestically produced corn is a reasonably close substitute for imported corn.

The third column of results in Table 2 highlights the relationships between the six explanatory variables and per capita import demand of tomatoes. The results here follow our expectations quite closely. The price of imported tomatoes is negatively related to per capita import demand whereas the price of the consumption substitute shows a positive relationship with per capita imports of tomatoes. Coefficients for per capita income, diet, and trade openness are all positive (yet the coefficient for calorie consumption is not statistically significant). The estimated coefficient for domestic production is -0.06 and statistically significant; this implies that a 1 percent change in domestic production leads to a 0.06 percent reduction in per capita import demand of tomatoes.

The results for per capita imports of coffee, shown in the final column in Table 2 show that the estimated coefficient for trade openness is the only variable that is statistically significant. Here an estimated coefficient is not included for domestic production as the top coffee importing countries do not have a domestic production source.

A review of the regression results for per capita import demand models shows that price is more important than it was in the production models. There is also strong evidence that per capita income influences import demand patterns for chicken, corn, and tomatoes. More importantly, the results highlight that trade openness has been the key driver of per capita import demand of all agricultural commodities studied, notably tomatoes, and this agrees with other findings (*e.g.*, de Haea, 2003; World Bank, 2008). The quantity of a good produced domestically also is important for import patterns of field crops including corn and tomatoes.

Conclusion

This background paper makes three inter-related contributions that enable a better understanding of the trends and drivers of production and imports of sixteen agricultural products that are important in several regions. First, we review production and import data for selected agricultural commodities between 1961 and 2006. Second, we collect and analyze data that describe key factors that have been suggested as drivers of agricultural production and trade. Third, we estimate economic relationships that exist between key drivers and production and import demand using regression techniques. Most of the published work that provides forecasts for production and trade patterns of agricultural commodities in the U.S. and elsewhere focuses on animal products, grains, oilseeds, cotton, and sugar. We

reexamine the drivers in these markets, but also begin some much-needed analysis of these issues for Mediterranean and tropical products. A more thorough set of production and trade projections are needed for various understudied, yet important, horticultural products.

Our regression results do not tell the same story across the four production models. Commodity price effects appear to be much stronger for chicken and coffee, whereas input price effects are more notable for chicken and corn. Production levels of all commodities are all sensitive to changes in quantities of water, land, and technology. The import demand models highlight that prices are more important determinants of import demand (relative to production). In addition, per capita import demand typically shows a positive and statistically significant relationship with per capita income and trade openness; diet matters most for per capita import demand of corn. Of these three factors, the level of trade openness is a very important determinant of import demand, especially for tomatoes.

Some multicollinearity exists between the explanatory variables used in our analysis (*i.e.*, one explanatory variable is highly correlated with another explanatory variable). Although the presence of multicollinearity does not affect the overall predictive power of the model, it will affect the reliability of specific estimated coefficients. In the production models there is some multicollinearity between prices; in the import demand models there is multicollinearity between the per capita income variable and both the calorie consumption variable and the trade openness variable. Future work might consider finding different proxies for these variables, or instruments that capture the effect of the quality of diets and a nation's willingness to participate in open markets, but are less correlated with per capita income levels.

Comparing our results to data from the *World Development Report* (World Bank, 2007), we find that our regression analysis coincides with the World Bank's forecasts for future global agricultural trends. For example, the World Bank's assessment of available arable land shows the greatest capacity for increased production in Europe and Latin America. Based on our regression results, we would expect those increases to be in meat and grain commodities, as they require more land. Our results indicate that even though arable land is decreasing in South Asia and Sub-Saharan Africa, coffee production should increase, since coffee has an inverse relationship to land availability. Regarding water availability and its influence on production, our results are again in line with the World Bank report. Water scarcity is more severe in the Middle East and North Africa, but at the same time tomato production significantly increased in North Africa between 1976 and 2006 (FAO, 2008). This corresponds with our finding of an inverse relationship between tomato production and water availability. Similarly, coffee production, which is positively related to water use, is increasing in South America, a region that is not suffering from water shortage.

On the import side, the World Bank's prediction that cereal imports will increase in developing countries over the next 20 years is supported by our regression results that demonstrate a positive and statistically significant relationship between per capita income and import demand. This is already evidenced by the income growth and increased food consumption in developing countries, particularly China and India. The World Bank report also shows that developing countries have reduced tariffs on agricultural products since 1980. Because trade openness was statistically significant

for all commodities, we would expect that as developing countries reduce trade barriers, imports will continue to increase.

¹ The top producing countries for chicken, corn, tomatoes, and coffee are as follows:

Chicken – United States, China, Brazil, Mexico, Japan

Corn – United States, China, Brazil, France, Argentina

Tomatoes – China, United States, Turkey, India, Italy

Coffee – Brazil, Colombia, Indonesia, Vietnam, México

² The top importing countries for chicken corn, tomatoes, and coffee are as follows:

Chicken – China, Russia, Japan, Saudi Arabia, Germany

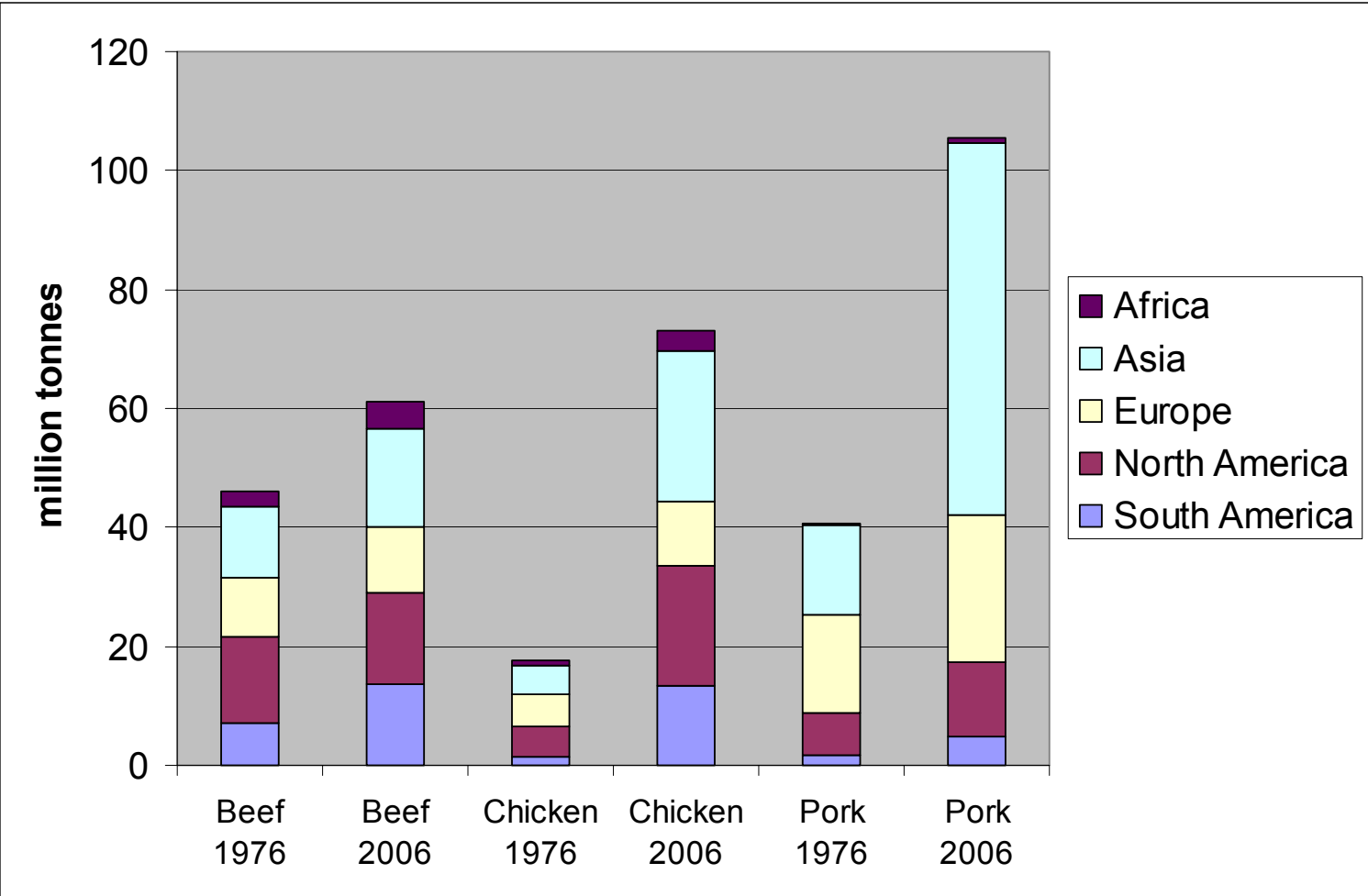
Corn – Japan, Korea, China, Mexico, Egypt

Tomatoes – United States, Germany, France, United Kingdom, The Netherlands

Coffee – United States, Germany, Japan, Italy, France

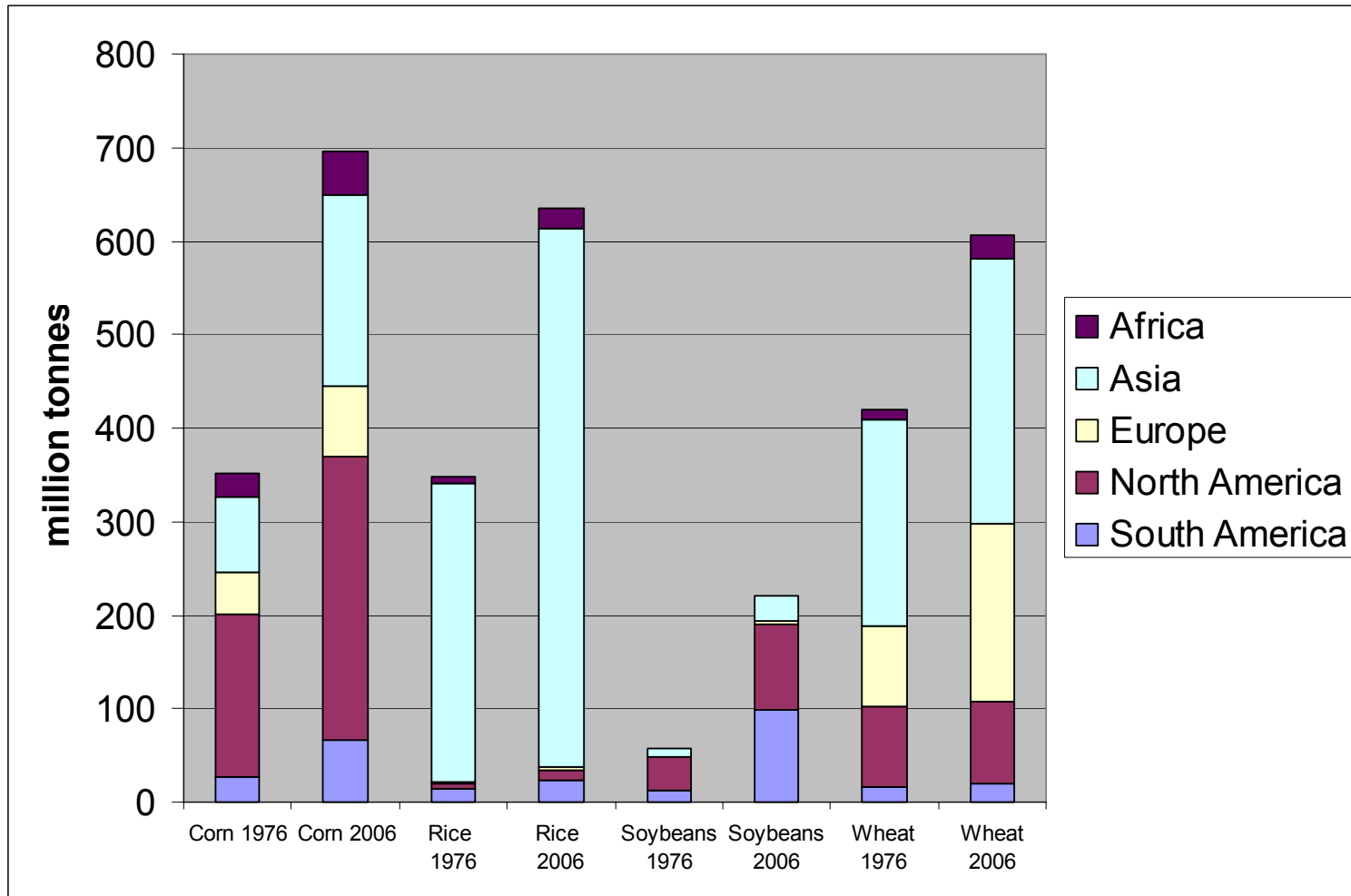
³ Beef was selected as a substitute for chicken due to the minimal pork consumption in Saudi Arabia. Bananas served as a substitute for tomatoes because both are fruit products commonly consumed in developing countries.

Figure 1. Production of Selected Meats, 1976 and 2006



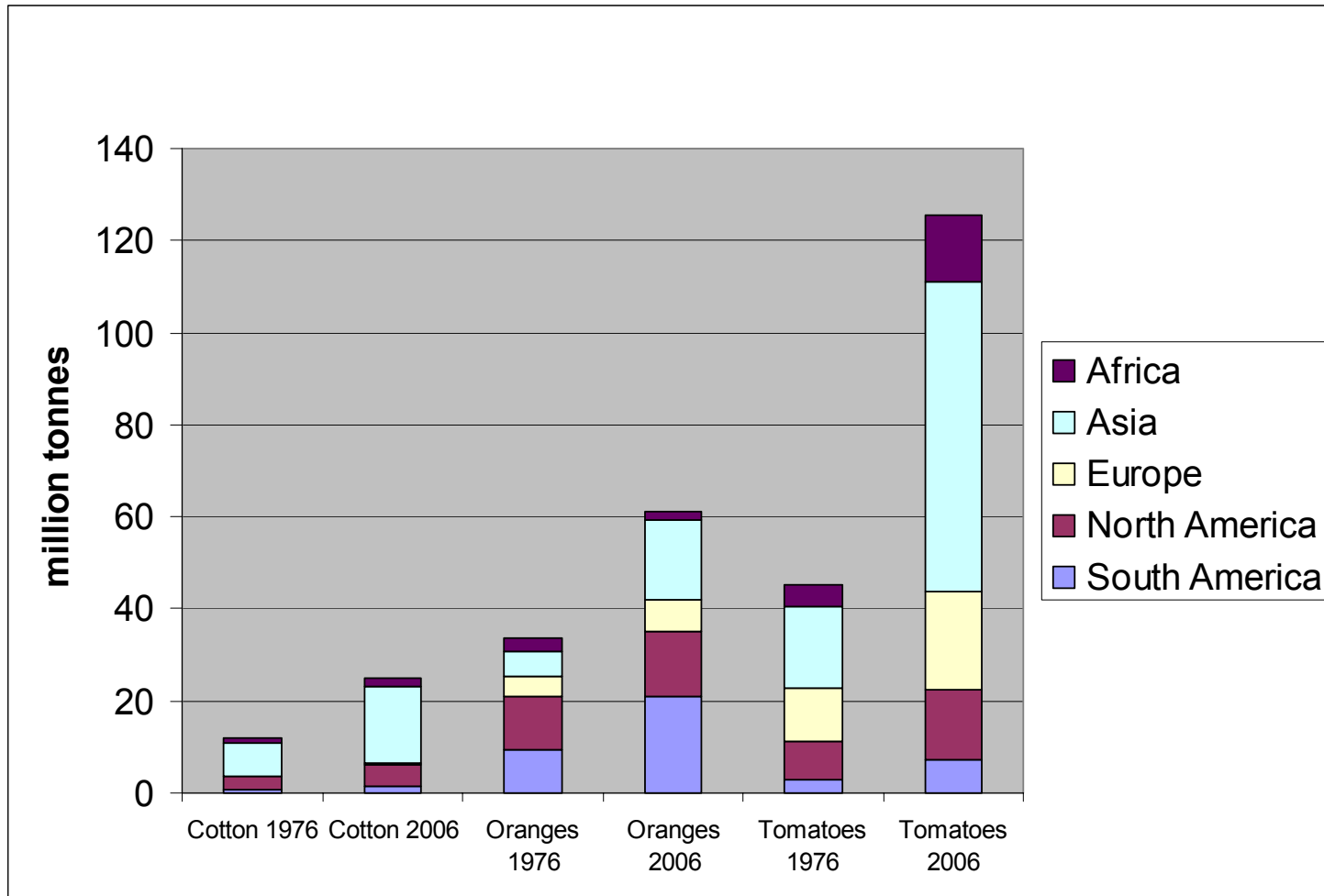
Source: Food and Agriculture Organization of the United Nations, Production Statistics

Figure 2. Production of Selected Grain and Oilseed Crops, 1976 and 2006



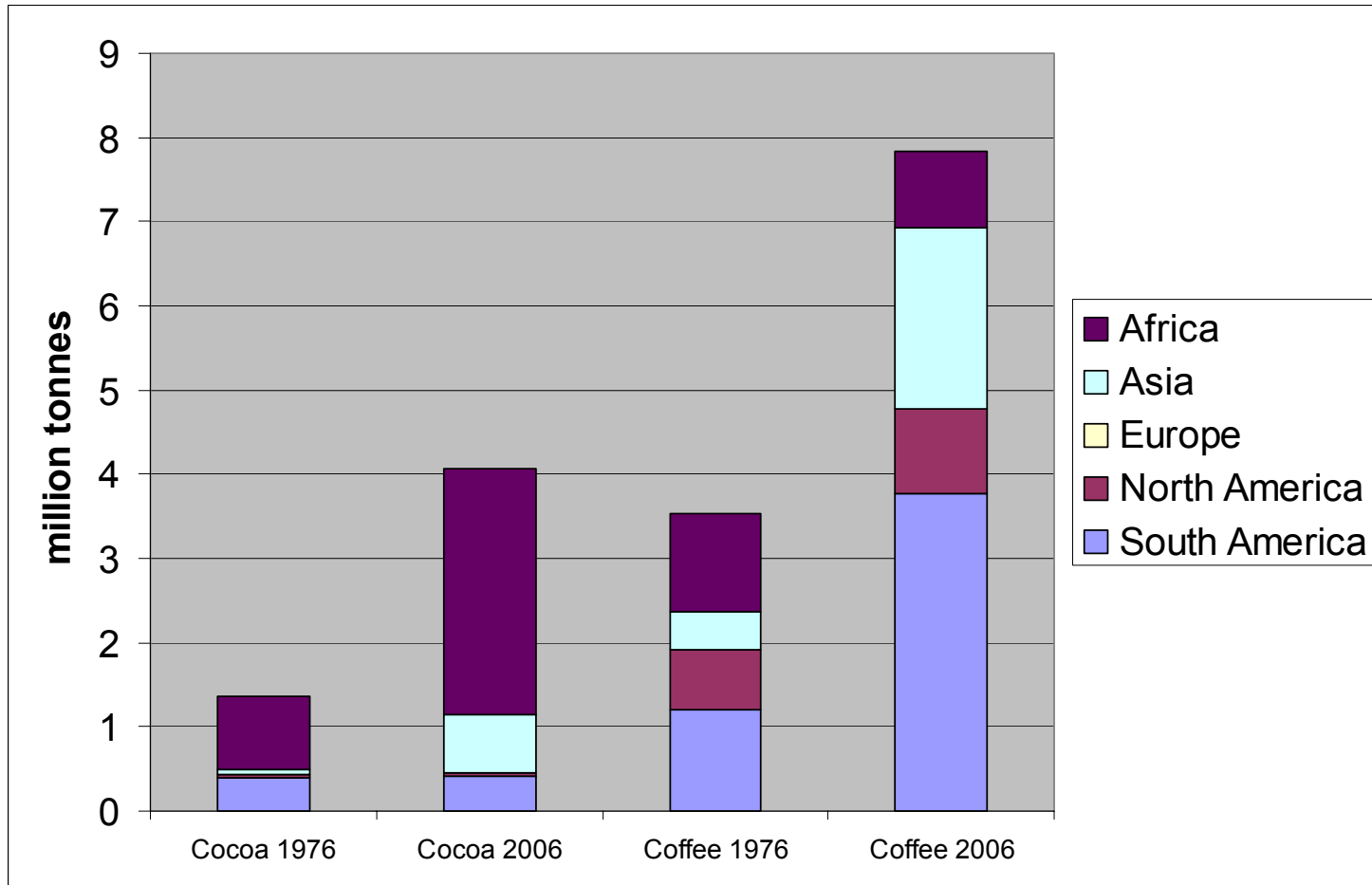
Source: Food and Agriculture Organization of the United Nations, Production Statistics

Figure 3. Production of Selected Mediterranean Crops, 1976 and 2006



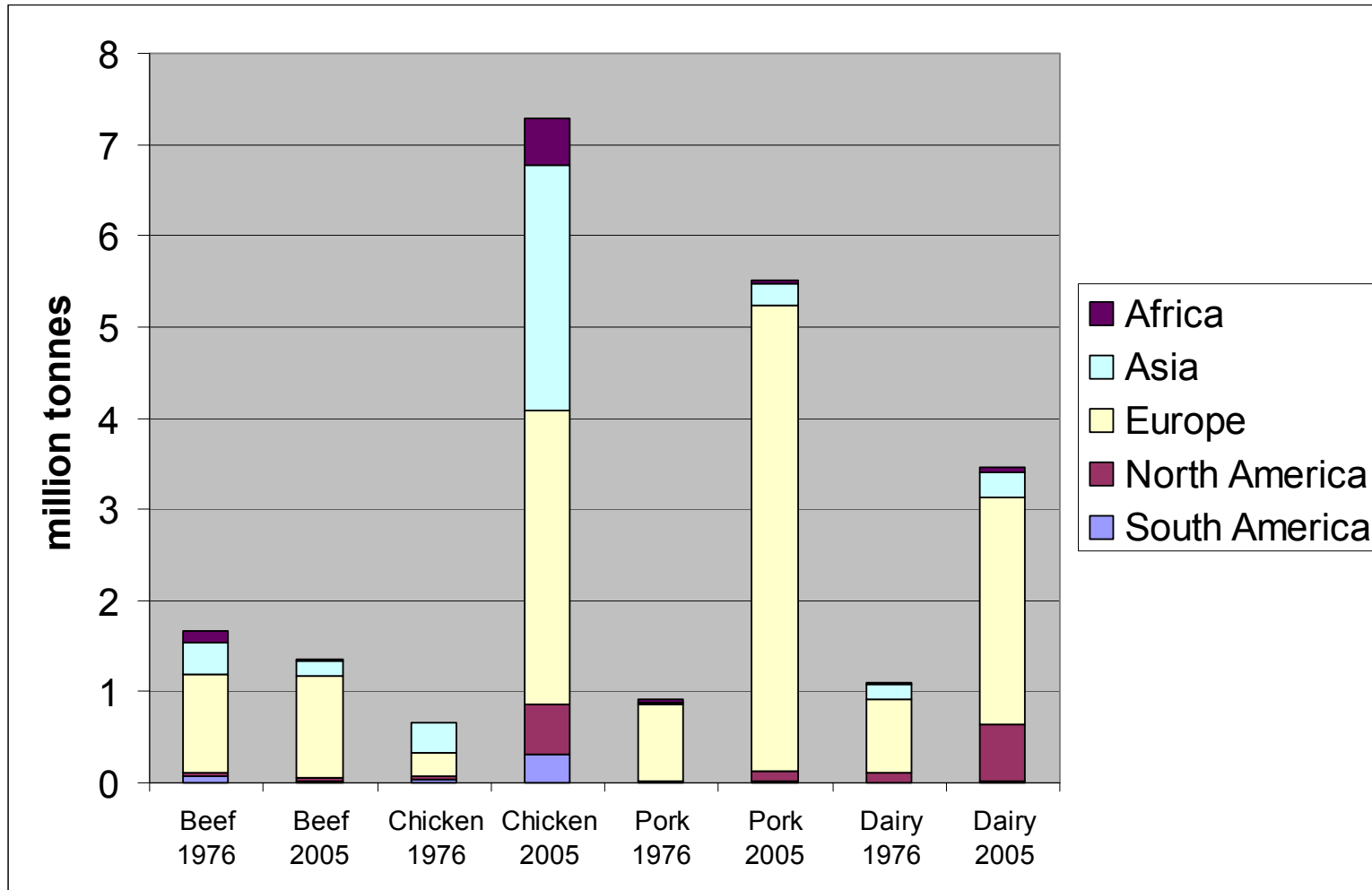
Source: Food and Agriculture Organization of the United Nations, Production Statistics

Figure 4. Production of Selected Tropical Crops, 1976 and 2006



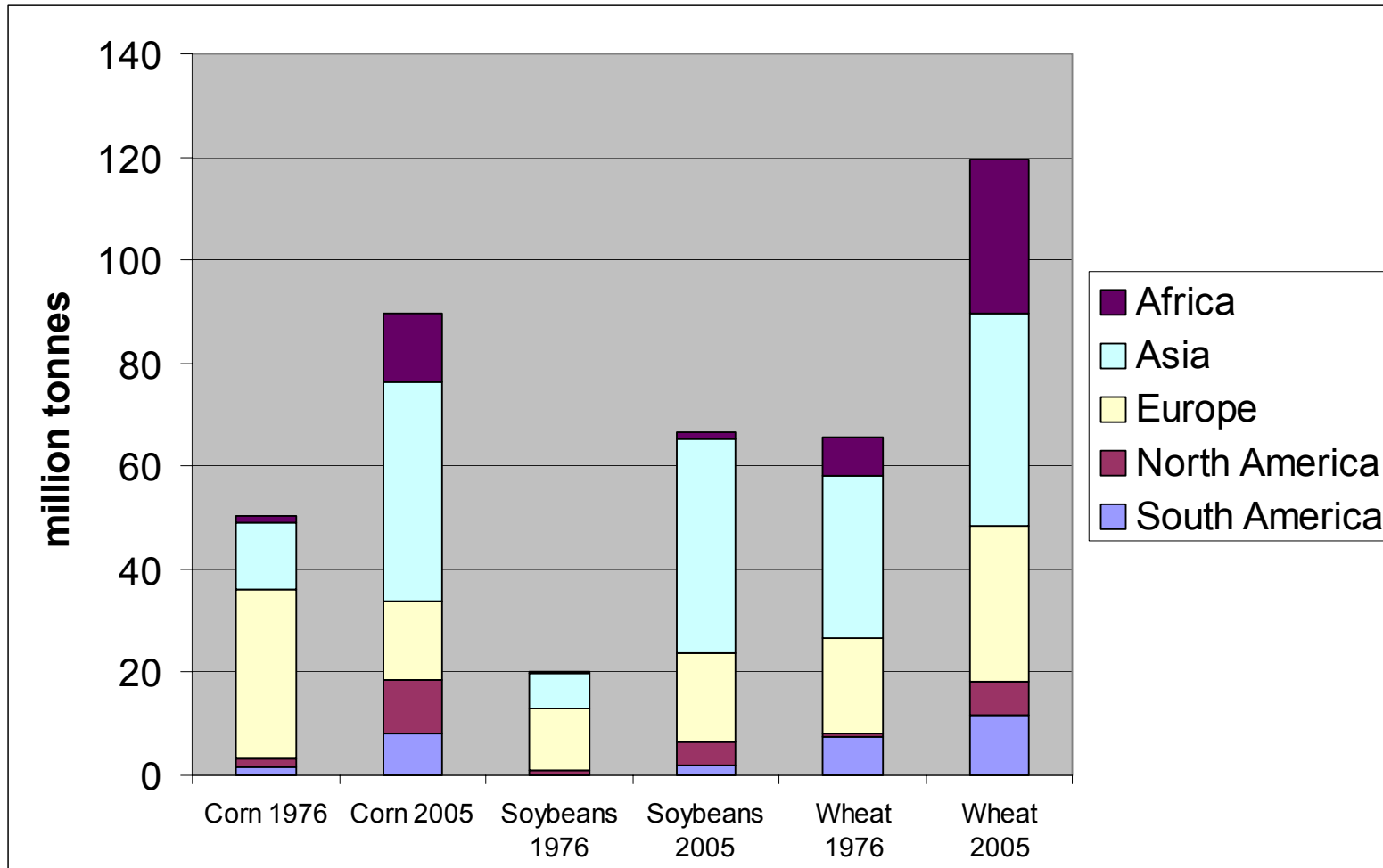
Source: Food and Agriculture Organization of the United Nations, Production Statistics

Figure 5. Imports of Selected Animal Products, 1976 and 2005



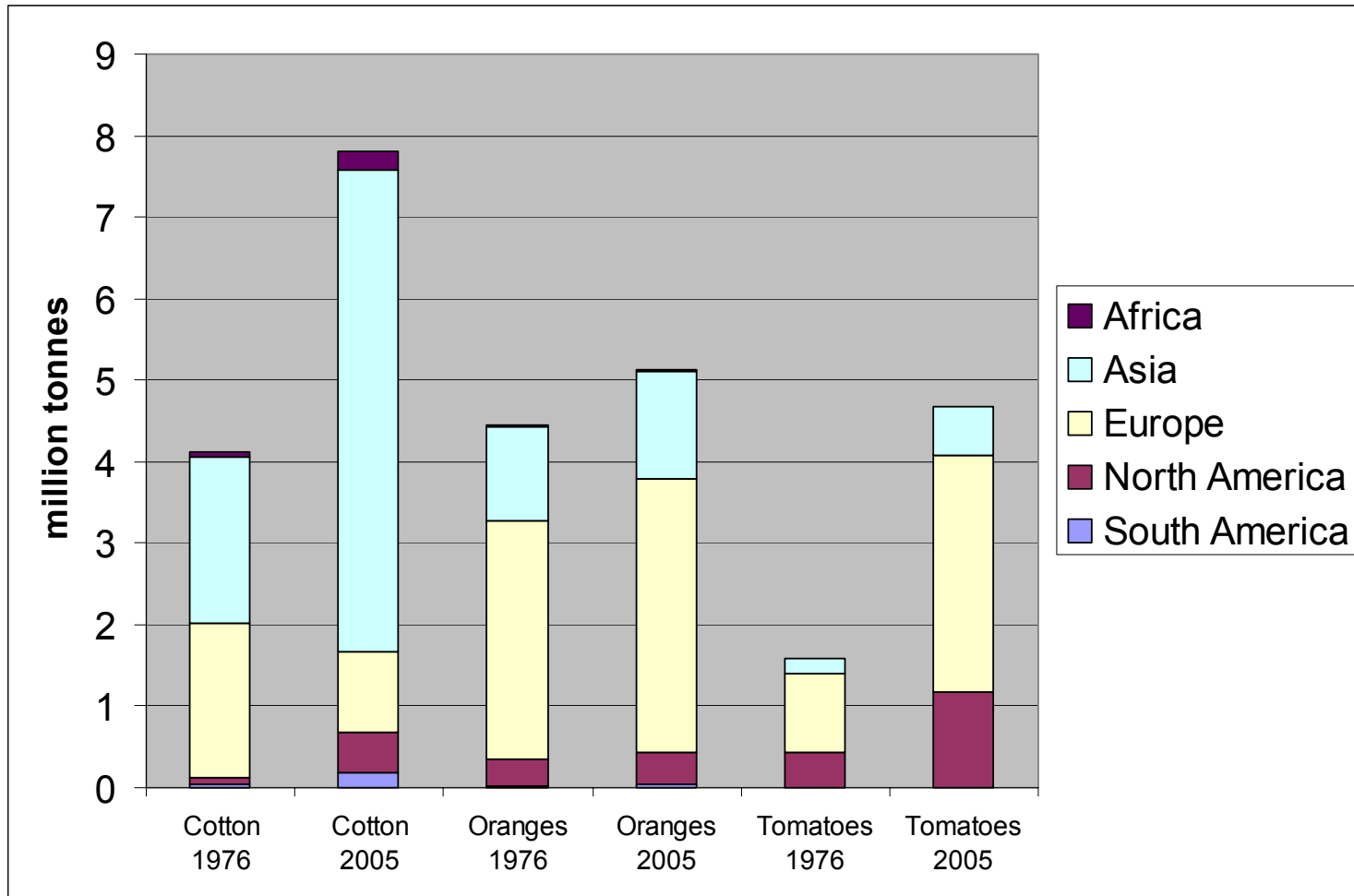
Source: Food and Agriculture Organization of the United Nations, Trade Statistics

Figure 6. Imports of Selected Grain and Oilseed Products, 1976 and 2005



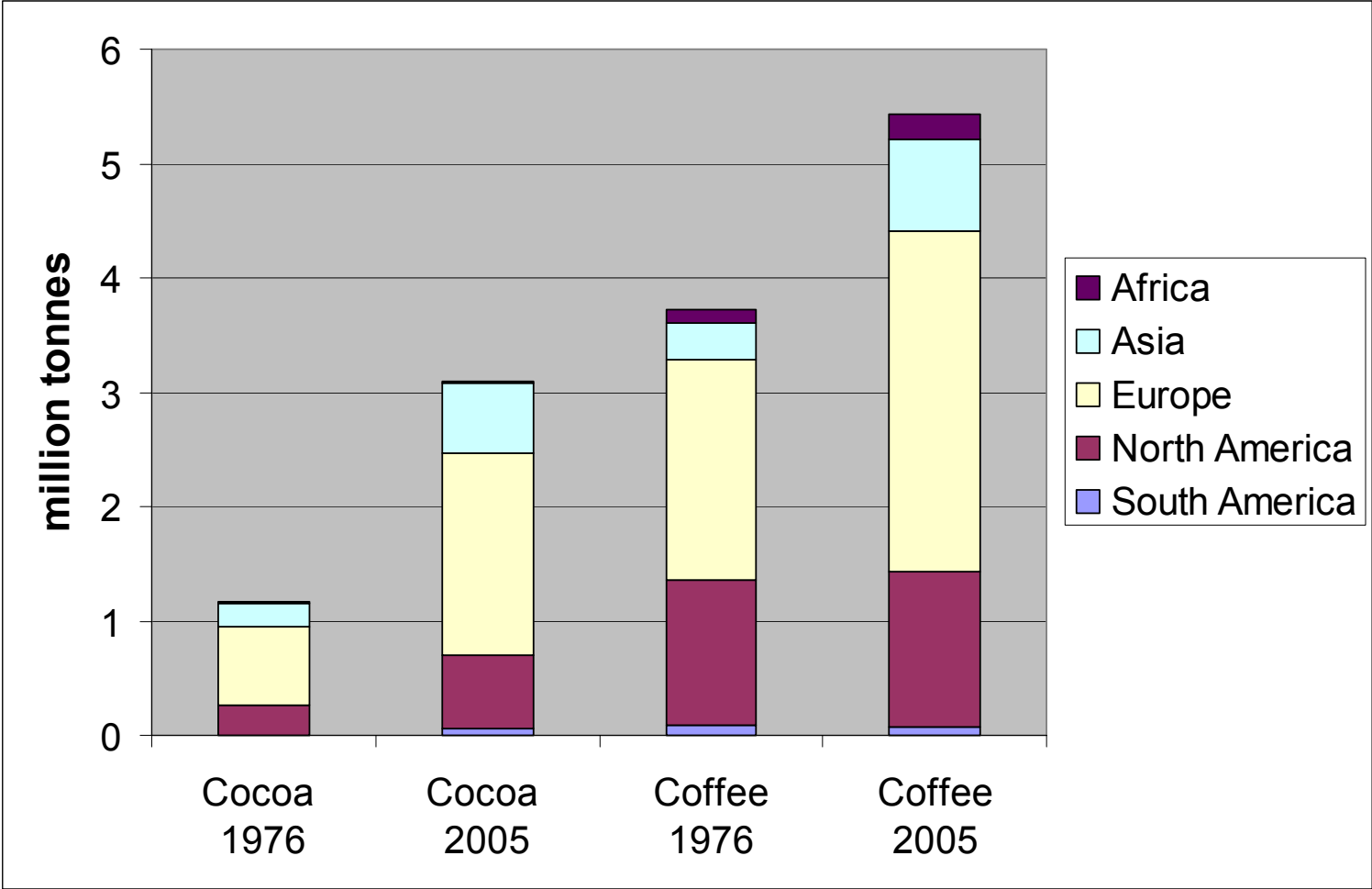
Source: Food and Agriculture Organization of the United Nations, Trade Statistics

Figure 7. Imports of Selected Mediterranean Products, 1976 and 2005



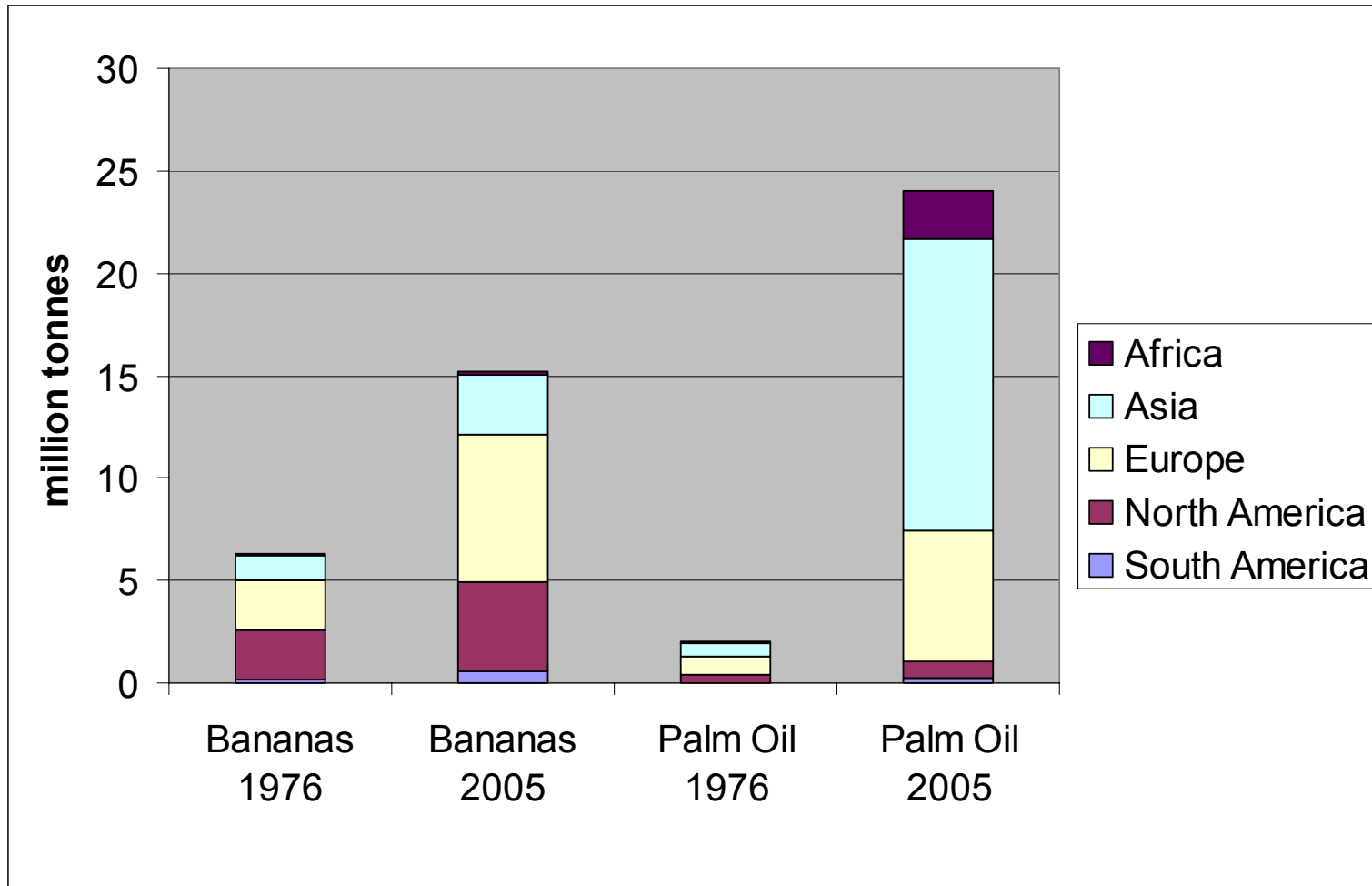
Source: Food and Agriculture Organization of the United Nations, Trade Statistics

Figure 8. Imports of Cocoa and Coffee, 1976 and 2005



Source: Food and Agriculture Organization of the United Nations, Trade Statistics

Figure 9. Imports of Bananas and Palm Oil, 1976 and 2005



Source: Food and Agriculture Organization of the United Nations, Trade Statistics

Table 1. Regression results for production models, 1991 to 2006^a

Explanatory variables	Dependent variable <i>Production of:</i>			
	Chicken	Corn	Tomatoes	Coffee
N	73	73	60	73
Adjusted R ²	0.98	0.97	0.71	0.41
Constant	-28.98 (0.03)	-21.79 (0.19)	-83.70 (0.01)	-61.26 (0.12)
Own price	-0.51 (0.01)	0.15 (0.24)	-0.73 (0.01)	0.86 (0.01)
Price of production substitute	0.15 (0.11)	0.06 (0.72)	0.05 (0.74)	-1.17 (0.01)
Price of fuel input	0.33 (0.01)	0.26 (0.02)	-0.17 (0.35)	-0.27 (0.13)
Price of labor input	0.13 (0.01)	0.12 (0.01)	0.05 (0.04)	0.53 (0.01)
Water availability	0.24 (0.01)	-0.17 (0.05)	-0.46 (0.01)	0.56 (0.06)
Arable land	0.70 (0.01)	1.39 (0.01)	-0.21 (0.05)	-0.24 (0.02)
Technology (time trend)	0.02 (0.01)	0.01 (0.17)	0.05 (0.01)	0.04 (0.08)

^a The p-value for each estimated coefficient is shown in parenthesis; a p-value of 0.05 denotes statistical significance at the 5 percent level.

Table 2. Regression results for import demand models, 1991 to 2005^a

Explanatory variables	<i>Dependent variable</i> Import demand for:			
	Chicken	Corn	Tomatoes	Coffee
N	73	75	75	75
Adjusted R ²	0.78	0.72	0.86	0.74
Constant	20.53 (0.01)	-62.96 (0.01)	-17.68 (0.01)	-10.31 (0.01)
Import price	-1.07 (0.01)	-0.19 (0.64)	-0.79 (0.01)	0.08 (0.25)
Price of consumption substitute	-0.47 (0.01)	-0.77 (0.14)	0.31 (0.02)	-0.09 (0.56)
Per capita income	0.75 (0.01)	0.53 (0.01)	0.92 (0.01)	0.22 (0.25)
Diet proxy	-2.48 (0.06)	7.05 (0.01)	0.17 (0.78)	0.01 (0.92)
Trade openness	0.53 (0.03)	1.05 (0.01)	1.20 (0.01)	0.93 (0.01)
Domestic production	0.67 (0.01)	-0.15 (0.08)	-0.06 (0.01)	N/A

^a The p-value for each estimated coefficient is shown in parenthesis; a p-value of 0.05 denotes statistical significance at the 5 percent level.

References

- Brookins, C.L. 2007. "Major Forces and Factors Shaping Global Markets: The Emerging Agricultural World." *Journal of Agribusiness* 25(1): 1-16.
- Coyle, W., B. Gilmour, and W.J. Armbruster. 2004. "Where Will Demographics Take the Asia-Pacific Food System?" *Amber Waves* 3(2): 16-21.
- de Haen, H., K. Stamoulis, P. Shetty, and P. Pingali. 2003. "The World Food Economy in the Twenty-first Century: Challenges for International Cooperation." *Development Policy Review* 21(5-6) 683-696.
- EconStats. 2008. Foreign Exchange Rates. Available at <http://www.econstats.com/fx/index.htm>
- Federal Ministry for Economic Cooperation and Development (FMECD). 2007. International Fuel Prices, 5th Edition. Transport Policy Advisory Service. Available at <http://www.gtz.de/de/dokumente/en-international-fuelprices-final2007.pdf>
- Food and Agriculture Organization of the United Nations (FAO). 2008. FAOSTAT. Available at <http://faostat.fao.org/>
- Food and Agricultural Policy Research Institute (FAPRI). 2008. *FAPRI 2008 U.S. and World Agricultural Outlook*. FAPRI Staff Report 08-FSR 1. Available at <http://www.fapri.iastate.edu/outlook2008/text/OutlookPub2008.pdf>
- Halliburton, K., and S. Henneberry. 1995. "The Effectiveness of U.S. Nonprice Promotion of Almonds in the Pacific Rim." *Journal of Agricultural and Resource Economics* 20(x): 108-122
- Huang, J., S. Rozelle, and M.W. Rosegrant. 1999. "China's Food Economy to the Twenty-First Century: Supply, Demand, and Trade." *Economic Development and Cultural Change* 47(4):737-766.
- International Monetary Fund (IMF). 2008. World Economic and Financial Surveys: World Economic Outlook Database. Available at <http://www.imf.org/external/pubs/ft/weo/2008/01/weodata/index.aspx>
- Koo, W.W., and R.D. Taylor. 2007. Outlook of the U.S. and World Sugar Markets, 2006-2016. Agribusiness and Applied Economics Report No. 614, Center for Agricultural Policy and Trade Studies, North Dakota State University. Fargo, ND.
- Lanclos, D., S. Devadoss, and J. Guenther. 1997. "Impacts of Foreign Direct Investment and Advertising on the Export Demand for U.S. Frozen Potatoes." *Agribusiness* 13(2): 273-284.
- Le, C.T., H.M. Kaiser, and W. Tomek. 1998. "Export Promotion and Import Demand for U.S. Red Meat in Selected Pacific Rim Countries." *Agribusiness* 14(2): 95-105.

- Mattson, J.W., and W.W. Koo. 2006. Forces Reshaping World Agriculture. Agribusiness and Applied Economics Report No. 582, Center for Agricultural Policy and Trade Studies, North Dakota State University. Fargo, ND.
- Mueller, T. 2007. Slippery Business: The Trade in Adulterated Olive Oil. *New Yorker*. August 13, 2007.
- National Climatic Data Center. 2008. Global Historical Climatology Network Data. Available at <http://www.ncdc.noaa.gov/oa/climate/ghcn-monthly/index.php>
- Pingali, P. 2004. Westernization of Asian Diets and the Transformation of Food Systems: Implications for Research and Policy. ESA Working Paper No. 04-17. The Food and Agriculture Organization of the United Nations: Agricultural and Development Economics Division. Rome, Italy.
- Rickard, B.J., and G.C. Fox. 1999. "Have Grain Crop Yields in Ontario Reached a Plateau?" *Food Reviews International* 15(1):1-17.
- Rickard, B.J., and D.A. Sumner. 2006. "EU support reductions would benefit California tomato growers and processors." *California Agriculture* 60(4): 207-210.
- Rosegrant, M.W., M.S. Paisner, S. Meijer, J. Witcover. 2001. Global Food Projections to 2020: Emerging Trends and Alternative Futures. International Food Policy Research Institute. Washington, DC.
- Rosson, C., M. Hammig, and J. Jones. 1986. "Foreign Market Promotion Programs: An Analysis of Promotion Response for Apples, Poultry, and Tobacco." *Agribusiness* 2(1): 33-44.
- Srinivasan, C., X. Irz, and B. Shankar. 2006. "An assessment of the potential consumption impacts of WHO dietary norms in OECD countries." *Food Policy* 31(1): 53-77.
- Sumner, D.A. 2007a. U.S. Farm Policy and the White Commodities: Cotton, Rice, Sugar, and Milk. IPC Policy Focus, Farm Bill Series No. 5. International Food and Agricultural Trade Policy Council. Washington, DC.
- Sumner, D.A. 2007b. U.S. Farm Programs and African Cotton. IPC Issues Brief No. 22. International Food and Agricultural Trade Policy Council.
- United States Department of Labor, Bureau of Labor Statistics (USDOL-BLS). 2008. Consumer Price Index History Table. Available at <ftp://ftp.bls.gov/pub/special.requests/cpi/cpiat.txt>
- United States Department of Agriculture, Economic Research Service (USDA-ERS). 2001. Changing Structure of Global Food Consumption and Trade. Agriculture and Trade Report WRS-01-1. Edited by Anita Regni. Market and Trade Economics Division, Economic Research Service, USDA. Washington, DC.

United States Department of Agriculture, Economic Research Service (USDA-ERS). 2008. Agricultural Baseline Projection Tables. Available at:
<http://usda.mannlib.cornell.edu/MannUsda/viewDocumentInfo.do?documentID=1192>

United States Department of Agriculture, Foreign Agricultural Service (USDA-FAS). 2008. Attaché GAIN Reports. Available at
<http://www.fas.usda.gov/scriptsw/AttacheRep/default.asp>

World Bank. 2007. World Development Report 2008: Agriculture for Development. Washington, D.C. Available at <http://www.worldbank.org/wdr2008>

World Bank. 2008. World Development Indicators. Available at
<http://ddp-ext.worldbank.org/ext/DDPQQ/member.do?method=getMembers&userid=1&queryId=135>