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(February 2010)
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Services Liberalization and Computable General Equilibrium Modeling: Beyond Tariff Equivalents

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Authors:
Tani Fukui and Christine McDaniel[1]

Abstract

The services sector is the next frontier in trade liberalization, and progress in this area is likely to bring enormous economic gain to developed and developing economies. A major impediment to services trade liberalization, however, is the lack of rigorous analytical work on its potential impact. Our aim in this paper is to propel the policy relevant research forward. Restrictions on services trade are far more complex than those on goods. While goods trade liberalization is relatively straightforward to model and its implications are fairly well understood, the same is not true for services. Services trade policy is often opaque and does not fit easily into computational models. Our survey of the current literature reveals a set of stylized facts that we hope will be useful in this area of computable general equilibrium modeling research: (1) barriers to trade in services are complex and heterogeneous across sectors; (2) services have significant effects on downstream industries; (3) market structure assumptions are crucial; (4) foreign presence is often necessary for services trade; and (5) many barriers are entry or fixed cost barriers that restrict foreign and domestic new entrants.

[1] Tani Fukui (Tani.Fukui@usitc.gov) and Christine McDaniel (Christine.McDaniel@usitc.gov) are economists at the U.S. International Trade Commission, Washington, DC. The views presented in this article are solely those of the authors and do not necessarily represent the opinions of the U.S. International Trade Commission or any of its Commissioners.

Introduction

Liberalizing trade in services is important for economic growth both in the United States and abroad. As an economy develops, services tend to increase as a share of gross domestic product (GDP) and as a share of trade. Like many advanced industrialized economies, the United States has a global competitive advantage in services and can benefit from services liberalization abroad by gaining access to markets and increasing foreign market share. But the largest gains may be realized by developing countries, in which trade liberalization in services can bring transformative change to the broader economy, increasing productivity at the firm, industry, and economy-wide level.

Despite the immense potential benefits from services liberalization, services remain highly protected in most countries. One impediment to liberalization has been the difficulty in assessing the effects of services liberalization, both qualitatively and quantitatively. Recent efforts to pursue liberalization have spawned a number of studies on the economic effects of such reforms. In this article, we explore recent empirical evidence of services liberalization efforts and economic effects. We aim to translate key findings into useful stylized facts for computable general equilibrium (CGE) modeling efforts in this area.

Services, which include sectors such as telecommunications, express delivery, transportation and storage, and financial and business services, generate 68 percent of world GDP but account for just under 20 percent of world trade. Not all services are easily traded, and perhaps we should not expect the share of services of trade to match its share of GDP. Still, technological advances in information communication technology have allowed an increasing number of services to be delivered internationally. Over the past decade, international trade in services has grown 8 percent, outpacing world GDP growth of 5 percent.[2]

Not only do services sectors represent the majority of GDP value-added in most economies today, they are crucial inputs throughout the economy. Information communication and telecommunications play a vital role in diffusing knowledge and digitizing products. Transport services drive the cost of shipping goods and facilitate the movement of workers. Business and professional services such as accounting, engineering, financial, and consulting and legal services can reduce transaction costs and foster business process innovations. Retail and wholesale distribution services link producers and consumers within and across countries.

[2] Data from World Bank Development Indicators (1998–2008).

Despite—or perhaps because of—their importance, services face restrictions on trade at least as high as those on goods trade. Indeed, a number of careful studies using different methodologies, such as Dee (2005), Bradford (2005), and Dihel and Shepard (2007), have shown up to an order of magnitude of difference between barriers to services trade and barriers to goods trade, and consequently much larger payoffs from services trade liberalization than from goods trade liberalization.

Policies that restrict services trade and competition are not the same across all service sectors. For example, a recent survey by the World Bank (Gootiiz and Mattoo 2009) of the extent of discriminatory policies restricting entry by foreign firms in 30 developing countries found significant heterogeneity across individual service sectors. Still, the consensus among economists is that the tariff equivalents of prevailing restrictions on services trade are a multiple of those that restrict merchandise trade.

This paper aims to survey the literature on how economies respond to an increase in services trade and to reform in the services sector that leads to increased competition from domestic and international competitors. We consider theoretical predications and empirical findings. Then we consider how CGE modeling efforts have captured services liberalization. Finally, we conclude by proposing a set of stylized facts that indicate the way forward for future modeling efforts.

State of policy

Removing restrictions on services trade is expected to generate larger gains than removing those on goods trade. While actual estimates may vary across individual studies, relatively larger gains—often by an order of magnitude—from services trade liberalization is a finding that emerges fairly consistently from a survey of modeling results.[3]

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[3] CGE modeling results are sensitive to a number of factors, such as the initial level of protection, the assumed liberalization scenario, model structure, elasticities, and various other assumptions of the model. For instance, multilateral liberalization brings a larger payoff than preferential, and the higher the level of initial protection, the greater the benefit from liberalization. Assumptions on model structure include whether capital ownership is differentiated between domestic and foreign, whether capital accumulation can occur, and whether productivity can be affected by liberalization. Piermartini and Teh (2005) present a detailed survey of the literature on services trade liberalization.

The payoff to the United States from global services liberalization has been estimated to be between 1.68 and 4.3 percent of GDP, compared to an estimated gain of 0.03 to 0.1 percent of GDP from remaining goods liberalization.[4] Most developing countries also stand to gain more from services liberalization. For instance, in a careful analysis of India, Chadha, Brown, Deardorff, and Stern (2000) estimate the annual gains from services liberalization at 1.6 percent of GDP ($12 billion in national income each year), compared to 0.4 percent of GDP ($3.4 billion) from goods liberalization. Similar findings for other developing countries are reported in a series of CGE papers discussed in section 5. The larger gains from services liberalization reflect greater restrictions on trade in services than in goods, as well as the larger role played by services in most economies.

Trade barriers for goods have been largely dismantled, while trade restrictions in services remain high. According to the Organisation for Economic Co-operation and Development (OECD), the average ad valorem tariff for manufactured goods is 6.2 percent for OECD countries and 13.5 percent for developing countries. A broad survey of existing barriers for services reveals tariff equivalents of 25 to 50 percent for most service sectors and up to 100 to 200 percent for others, such as transportation, storage, and communications (Deardorff and Stern 2004).

Despite large potential gains from services liberalization, much of the Doha negotiations have focused on manufactured goods and agriculture. World Trade Organization (WTO) observers report that offers to date provide no greater market access in services, but rather a weak assurance that access will not get worse. Gootiiz and Mattoo (2009) articulate the current state of negotiations and describe some of the best offers as merely locking in levels of "liberalization" that do not provide more openness than the policies currently in place. While this does not suggest countries will be increasing trade restrictions, it does indicate a reluctance to make binding commitments to liberalize trade in services.

The discrepancy between progress in the negotiations and expected economic payoffs reflects a number of factors. Liberalization targets in services are less objective than in goods or agriculture. Negotiating tariff cuts or subsidy levels is straightforward, and the effects are fairly easy to measure. By contrast, the opaqueness of services policies means that it is unclear to negotiators how much more market access may be gained from offers in this area, resulting in a complex and slow request-offer negotiating process. Further, not all countries are convinced of the benefits of services liberalization, and

[4] See Brown, Deardorff, and Stern (2003), Robinson, Wang, and Martin (2002), and Anderson, Martin, and van der Mensbrugghe (2006).

many policymakers fear the potential costs of adjustment, particularly for domestic labor markets.[5]

In the General Agreement on Trade in Services (GATS), the WTO distinguishes among four modes of supplying services: cross-border trade, consumption abroad, commercial presence, and presence of natural persons. Cross-border trade (mode 1 in WTO parlance) and commercial presence (mode 3) together account for over 80 percent of services trade.[6] We focus our attention on these two modes of services trade.

Theoretical considerations

The foundational body of theoretical research on trade and growth does not explicitly account for the characteristics distinctive of the services sectors, although many lessons of general trade theory apply to services. A more recent body of literature models some key features of services sectors, and examines channels through which liberalization of services can affect the domestic economy.

Broadly speaking, several types of channels are involved. Services are inputs into production and can both increase the productivity of capital and labor inputs (producing level-growth effects) and affect total factor productivity (producing long-run steady-state growth effects). We should expect increased access to low-cost and high-quality services to foster productivity increases in firms that consume those services, as well as in the broader economy as resources are reallocated toward more efficient sectors (or sectors that improve their efficiency as a result of trade liberalization in services).

Endogenous growth models developed by Romer (1986) and Lucas (1988) show that international trade can spur a "level effect" on economic growth that can create positive growth effects over a transitory period of time. These models encouraged a host of empirical studies on the impact of international trade on economic growth, documenting positive productivity effects of technology diffused

[5] The adjustment costs associated with services liberalization may be lower than those associated with goods liberalization. Konan and Maskus (2006) link lower adjustment costs to the local provision of services. Because services will continue to be produced locally following reform and liberalization, they argue, these sectors will continue to generate demand for local labor, resulting in fewer sectoral labor shifts than we might expect with goods trade liberalization.

[6] Pindyuk and Woerz (2008) and Magdeleine and Maurer (2008) each estimate the sum of commercial presence and cross-border trade to be between 80 and 90 percent. A detailed discussion on the presence of natural persons can be found in Winters (2008), and a more general discussion of the modes of services supply can be found in Mattoo et al. (2008).

through international trade in goods. In the services context, Hoekman and Javorcik (2006) assert that technology diffused through factor flows, such as increased services trade and competition, should affect TFP growth as well.

Another channel through which a country's economy may benefit from increased liberalization of services is through altering its comparative advantage. Comparative advantage is at the basis of international trade theory, which has historically assumed a dominant role for goods, predicting that trade will flow from low-cost exporters to high-cost importers. A study by Fink, Mattoo, and Neagu (2002) suggests that services reform can affect the composition of trade. The authors found that differentiated products (as opposed to homogeneous products) are disproportionately affected by communications costs. Improvements in communications therefore can help countries move up the value chain in international trade toward more complex goods.

A third channel is via knowledge spillovers from foreign direct investment (FDI). One key difference between goods and services is that for services firms, FDI is an important way to deliver products to overseas consumers, particularly those products that require face-to-face interaction. Hence, we cannot expect to understand services reform without clarifying the role played by FDI in services. FDI is a powerful channel for knowledge spillovers, as it involves the transfer of not only of capital but also of technology and know-how to a foreign country. Since the mid-1990s, sales of services by foreign affiliates of U.S. firms (outward FDI) have grown more rapidly than cross-border trade. In their canonical work on technology transfer via trade, Grossman and Helpman (1994) discuss a variety of ways technical knowledge can be transferred across borders. Their work is general to trade rather than specific to services, but aspects of the channels they discuss have been examined in the services context by Javorcik (2004) for FDI and Mattoo, Rathindran, and Subramanian (2001) for the financial and telecommunications sectors.

Markusen, Rutherford, and Tarr (2000) consider the importance of restraints on foreign providers of producer services for welfare and growth in developing countries. They develop a theoretical model that allows the formation of foreign firms that provide intermediate services. In their model, foreign service providers import an input (a composite of foreign skilled labor and specialized technology) and economize on the use of domestic skilled labor, compared to domestic firms that provide the substitute service. They find relatively large gains (3 to 15 percent of GDP) to the host country from liberalization. The source of these large gains is that additional intermediate service firms provide more choice of specialized expertise; this increases the productivity of the final goods sector that uses these firms' services as intermediate inputs. Their model shows how domestic skilled labor and specialized foreign input workers can be complements.

Increased international competition is another channel that may promote gains within an economy. Competitive pressures can reduce prices and/or raise the quality of services, resulting in the so-called pro-competitive effects of trade. Particularly beneficial is the dismantling of monopolies. Although in theory a monopoly may be dismantled without opening borders (for example, by splitting it into several smaller companies), in many countries and for many sectors, the large economies of scale required imply that services liberalization must be part of the process. In a paper that illustrates this mechanism, Konan and van Assche (2007) examine the theoretical implications of dismantling the telecommunications monopoly in Tunisia, which required the entrance of foreign players to apply competitive pressure to the incumbent firm.

Other effects may provide opportunities for increased productivity. Deardorff (2001) examines "network effects"—i.e., the effects of improved efficiency on other sectors of the economy. In this case, he models transportation costs as a real resource cost that functions like a tariff but which involves transfers to factors of production rather than to the government. Shipping costs are paid to the transportation providers to cover the increased cost of resources that are required for the additional transportation services. Similar arguments have been made for telecommunications and other business-enabling services.

The prevalence of fixed-cost, or entry, barriers are one way in which services barriers differ dramatically from goods barriers. In his typology of barriers, Hoekman (2006) organizes regulatory policy according to those with fixed- versus variable-cost effects. Entry costs set up by regulatory policies, such as obtaining licenses or setting up legal entities to operate in the country, comprise a hurdle with implications different from a variable cost barrier. Fixed costs imply firms may need to reach a certain size before market entry becomes profitable, or that the market within a country needs to be large enough to cover the fixed costs. There is a substantial literature in the general trade literature using the concept of fixed costs in an increasing returns to scale framework dating back to Krugman (1979). More recently, Melitz (2003)—also in the general trade literature rather than that specifically related to services—has launched a branch of the literature that uses the concept of fixed costs including, as is frequently the case in services, a fixed cost of exporting to each country.

Empirical Evidence

While there is far less empirical evidence on the impact of liberalizing trade in services than in goods, a survey of the existing body of work reveals certain regularities in the data. Services products pervade an economy, particularly as inputs into the manufacturing process. There is compelling evidence that increased competition and trade liberalization in services can improve the performance of domestic firms, particularly downstream manufacturing sectors, and more broadly, lower trade costs and increase trade volumes.

In one study that highlights this effect, Arnold, Javorcik, and Mattoo (2006) find that services liberalization affected the performance of domestic manufacturing firms in the Czech Republic that relied on services inputs. Services liberalization and reform efforts involved privatization and the presence of foreign providers, both of which increased the level of competition. The authors' empirical strategy was to measure total factor productivity (TFP) at the firm level, and see whether and to what extent the share of foreign presence in service sectors used by each firm was related to TFP performance. Together, services liberalization and reform were key channels through which services liberalization helped to improve the performance of downstream manufacturing sectors.

Using similar methods, Fernandes (2007) uncovers a relationship between productivity and liberalization. In econometric work focusing on Eastern European and Central Asian economies, Fernandes obtains evidence of the positive effects of services liberalization both on the services sectors themselves and on downstream manufacturing. In a later paper, Fernandes and Paunov (2008) find a similar downstream effect on manufacturing in Chile. Their econometric work shows that increased FDI in the services sector had a positive effect on manufacturers that use those services.

In another firm-level paper, Arnold, Mattoo, and Narciso (2006) find that improvements in services industries—specifically, communications, electricity, and financial services—also improved performance in manufacturing firms. The authors use firm-level data for 1,000 firms in sub-Saharan African countries, including data on each firm's access to communications, electricity and financial services, and calculate the TFP for each firm. The authors find a positive and significant relationship between firm productivity and service performance in all three services sectors analyzed.

Transport, communications, and distribution are key services sectors and tightly linked to trade costs. A day of delay in shipping time has been equated with an 0.8 percent ad valorem tariff (Hummels 2001). Potential gains from "trade services" are likely to be large because transport-related costs are likely larger than those related to merchandise trade. Transport costs generate real resource costs, are far reaching, and can affect downstream pricing.

Infrastructure-related services can affect several sectors throughout the economy. Research by Djankov, Freund, and Cong (2006) suggests they are a key determinant in the competitiveness of exporters. The authors have data on the number of days it takes to move standard cargo from the factory gate to the ship in 126 countries. They find that on average, each additional day that a product is delayed before being shipped reduces trade by at least 1 percent. Delays have an even greater impact on developing country exports and exports of time-sensitive goods.

Eschenbach and Francois (2005) find that both domestic liberalization of the banking sector and foreign participation in the sector (via FDI) are significantly associated with growth. Using a set of 130 countries, including 26 transition economies, they replicate findings from prior studies linking financial development, banking sector competition (but not capital account openness), and growth.

Bayraktar and Wang (2008) investigate the channels by which foreign entrants to a country's financial sector affect the domestic economy. They examine direct channels (e.g., providing domestic firms with cheaper, more efficient sources of financing) and indirect channels (e.g., knowledge spillovers and competitive pressures on the domestic banking sector). Both effects are found to be statistically significant. For services, FDI is an important way to deliver products to consumers, particularly those products that require face-to-face interaction.

The communications sector, as demonstrated by Fink, Mattoo and Neagu (2002) is a source of significant trade costs, and can influence trade patterns. The authors use a gravity-type estimation framework. Using per-minute country-to-county calling prices charged in importing and exporting countries as a proxy for bilateral communication costs, the authors find that the impact of communication costs on trade in differentiated products is larger than on trade in homogeneous products (e.g., commodities such as cement, steel or tobacco)—by as much as one-third. Small increases in telecommunications costs, therefore, will have larger effects on the trade of other services, which tend to be heterogeneous. Jensen (2008) examines the attributes of services sectors, particularly with respect to employment. A key feature that he notes is the high share of "tradable occupations" in nontradable industries. This is clear, for example, in the outsourcing of back office operations in industries that are otherwise domestically oriented. This suggests that the liberalization of services can result in the unbundling of tradable and nontradable elements in a particular production process; as tasks are taken up by countries possessing a comparative advantage in the area, additional income gains from liberalization can be realized.

Kox and Nordas (2007) assess the costs and benefits of regulations in the context of international trade in services. In general, aggregate regulatory indices are negatively correlated with service imports, but a number of other interesting findings emerge. They show that regulatory measures can affect either the fixed costs of entering a market or the variable costs of servicing that market or both. Home market regulation is strongly related to domestic firms' export performance in business and financial services. Taking care to discriminate among trade-enhancing and trade-restricting regulations, the authors show that excessive domestic regulation restricts foreign suppliers from entering the domestic market and to a greater extent can restrict domestic suppliers from entering foreign markets. In contrast, well-regulated domestic markets can enhance the competitiveness of local service suppliers; and, regulations aimed at correcting market failure, such as ensuring appropriate standards, can positively affect trade. The authors also show that trade liberalization and reform can affect the size of the average firm depending on how such changes affect fixed and variable costs. Higher barriers to entry and restrictive regulations tend to deter small and medium size enterprises (SMEs) firms from engaging in international trade in services, while regulations that promote harmonization, integration and mutual recognition among markets can promote SMEs involvement in trade. Further, improvements in communication technology stimulate trade in services.

Unlike with goods, there is a great deal of cross-country heterogeneity in services provided and in the restrictions on providing those services. A review of the *Report on Foreign Trade Barriers* by the Office of the U.S. Trade Representative (2009) reveals a host of trade barriers, varying by country, for U.S. lawyers wishing to provide legal services to potential customers in nearly all of our major trading partners. Such restrictions may encompass establishments, equity participation, nationality or citizenship, licensing or accreditation, quotas, advertising and fee setting, and multidisciplinary practices, among others. A particular service can also vary by country. For instance, a specific legal service performed in the United States is not the same as that service performed in, say, Australia or Japan.

Finally, in a recent study, Borchert and Mattoo (2009) find that trade in services has weathered the financial crisis relatively well, particularly when contrasted with the downturn in goods trade. While some services sectors, such as travel and transportation, have seen decreases in trade, others such as professional business services have held steady or expanded. The authors posit that services' less cyclical nature and lower dependence on trade finance (relative to goods trade) are possible reasons.

The empirical evidence surveyed here suggests that services liberalization, like goods liberalization, can foster productivity gains, but also that services barriers differ in several substantial ways from goods barriers. The high degree of differentiation across services sectors and the complexity of the barriers in use indicate that tariff equivalents, as used in the CGE literature, may be misleading when modeling services barriers. This work further suggests that services liberalization should be modeled with more attention to inside-the-border phenomena. Lower production costs to downstream domestic firms,higher productivity of those firms, and salient effects like lower trade and transportation costs are modeling issues that deserve attention.

Reconciling empirical evidence with CGE modeling

CGE models are often employed to assess the economy-wide effects of trade liberalization, which can be useful in policy deliberations. A body of work has employed CGE models to illustrate some of the theoretical considerations described above. The rich general equilibrium framework enables us to trace the effects of liberalization on other sectors affected by reform and to estimate its effects on economic welfare and real income. A common analytical approach is to take estimates from econometric studies that can yield per-unit effects of services trade restrictions, and then convert these effects into tax equivalents. In terms of operational ease, tax- or tariff-equivalent price wedges can be fairly easily incorporated into a CGE framework. However, these estimates involve at best a great deal of subjectivity and are sometimes simply "best guesses," leaving the interpretation of the CGE results open to question.

For instance, Chadha, Brown, Deardorff, and Stern (2000) employ a CGE model to assess the impact of future liberalization on India's economy. For their analysis of services liberalization, the authors model barriers to services trade as tariff-equivalent price wedges, using ad valorem barriers that they describe as "ad hoc guestimates" from earlier work (Hoekman 1995). They acknowledge that barriers to services trade are likely more complex than tariff barriers, but describe their approach as a first approximation. They estimate that India's real income would rise by 1.6 percent following services reform (higher than the real income gain of 0.7 percent for goods liberalization).

In a broad survey piece, Whalley (2004) assessed the quantitative literature on the effects of potential services trade liberalization for developing countries. He highlighted the importance of firm and worker mobility, the heterogeneity of services, and the relatively large effect of capturing capital flows, typically in the form of FDI. Whalley called for more empirical evidence on the benefits of services liberalization for developing countries. A number of careful case studies have attempted to fill this gap, although much work remains to be done.

In their study on Tunisia, Konan and Maskus (2006) also employ a CGE approach to quantify the economy-wide effects of services trade liberalization, although with explicit treatment of foreign investment in service production. The barriers to services trade are modeled as price wedges, with 10 to 50 percent price wedges for most service sectors, and 200 percent for the communications service sector. The price wedges are based on interviews and educated guesses, with resulting values that are magnitudes greater than most tariffs on goods (consistent with much of the literature). By contrast with the standard 0.5 to 1 percent real income gain from goods trade liberalization, the authors obtain 6 to 8 percent real income gains from services liberalization. The economic effects of services liberalization are thought of as a reduction in the market power of cartels, or a "cost inefficiency effect." Their model is designed to capture several static effects of services trade liberalization, including efficiencies from production reallocation, pro-competitive gains from reducing cartel power, and efficiencies from adopting best-practice technologies. Their results highlight the removal of barriers against FDI as an essential component of potential welfare gains in services liberalization.

When Jensen, Rutherford, and Tarr (2007) model Russia's potential accession to the WTO, they also include explicit treatment of FDI. They estimate economic welfare gains equivalent to 11 percent of GDP and find FDI to be a key channel of economic gain. In related work, Rutherford, Tarr, and Shepotylo (2005) examine the reforms associated with Russia's WTO accession, including lifting barriers against FDI in business services, reduced exposure to antidumping duties on Russia's exports, and tariff cuts. They find real income effects from liberalization to be in the range of a 2 to 25 percent increase, with a decomposition of the results indicating that FDI liberalization is a principal component of the welfare gains.

In later work, Jensen, Rutherford, and Tarr (2008) illustrate the importance of coordinated domestic regulatory and trade reform in services. The authors employ a CGE model to assess the potential impact of liberalizing regulatory barriers against foreign and domestic service providers in Tanzania. In decomposing their results, the authors reveal that the largest gains to Tanzania derive from liberalizing nondiscriminatory barriers. In addition, their model illustrates that greater access to business services improves the productivity of labor and capital in all sectors of the economy, and that in the long run, the increased productivity of capital induces capital accumulation and an increase in the capital stock, which results in a general expansion of Tanzanian manufacturing.

Following the model structure of Jensen, Rutherford, and Tarr (2007), Balistreri, Rutherford, and Tarr (2008) evaluate the potential impact of liberalizing service barriers for the Kenyan economy. They allow FDI in business services as well as cross-border trade. The largest gains emanate from reducing regulatory barriers against potential service providers, both foreign and domestic, again illustrating the importance of coordinated domestic regulatory and trade reform in services.

In order to better calculate services trade barriers, there have been numerous recent attempts to transform the regulatory restrictions on services into credible price wedges. The principles behind the main methodology for estimating price wedges originated with Findlay and Warren (2000). The method uses indices representing policy variables quantified in some way as explanatory variables within an econometric specification to understand the impact of the barriers on trade. This approach is labor-intensive, however, often involving surveys of industry representatives and subjective analysis of the policy variables.[7]

The results thus far have been less than robust, revealing wide ranges across research efforts within particular sectors and often with either the "wrong sign" (e.g., restrictive policy variables explaining positive movements in trade volume) or with very large standard errors. For instance, Dihel and Shepard (2007) find price wedge point estimates for mobile telecommunications of 1 to 24 percent over a set of middle-income countries, while Doove, Gabbitas, Nguyen-Hong, and Owen (2001) find a range of 6 to 56 percent for the same sector with a similar set of countries. Herfindahl and Brown (2007) estimate price effects on nontariff impediments to trade in banking services. They find tariff-equivalent barriers that vary from 6 to 96 percent across countries in 1999.[8]

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[7] Dee (2005) provides a comprehensive overview of the literature to date. Dihel and Shepard (2007) perform an exhaustive analysis of several industries by mode of service delivery. The OECD (2009) is conducting a large-scale project on a services trade restrictiveness index that is still in its early stages.

[8] Herfindahl and Brown (2007) estimate that GATS rules changes that were proposed in 2005 would have brought barriers to between 11 and 92 percent. They estimate that the most liberalized country, Japan, would have had tighter barriers under the 2005 proposal due to a reduction in length of stay under mode 4 (presence of natural persons).

Most CGE literature on services liberalization examines solely border effects, modeled as barriers in the form of tariff-equivalent price wedges. This method is taken directly from the goods literature. Results suggest that the larger the tariff equivalents, the larger the effects. Applying this approach to services is more complicated than is the case for goods, due to at least two distinguishing features. First, the computation of these price wedges remains quite uncertain: although many methods have been applied, estimates of these wedges still vary widely. There is as yet no clear or rigorous measure of restrictions in services that can be converted so as to be usable in a CGE framework. This methodological uncertainty at least partly reflects the lack of production and trade data on services, as well as on the policies that govern the provision of services. Deardorff and Stern (2004) present a thorough survey of these issues.

Stylized Facts

Notwithstanding the methodological difficulties, several stylized facts emerge from the theoretical and empirical literature surrounding services trade that could be useful in future CGE estimates of trade policy effects.

First, **services barriers differ substantially from goods barriers**. The ways in which barriers to services trade manifest can vary by country, the high degree of differentiation across services sectors, and the complexity of the barriers in use all indicate that using the tariff equivalents found in the CGE literature may be misleading when trying to assess the economic effects of dismantling services barriers.

Second, **services sector reform may raise the productivity of downstream domestic manufacturing firms**. Lower production costs to downstream firms, higher productivity of those firms, and salient effects like lower trade and transportation costs are modeling issues that deserve attention.

Third, **the computation of the welfare effects of services trade liberalization can depend on the internal market structure of the liberalizing economy**. In many services sectors, the domestic market before liberalization is dominated by a single monopoly supplier. Breaking up such a monopoly and eliminating the monopoly rents reduces costs for downstream customers of the supplied services, which in many cases, such as telecommunications and transportation, means that it will affect nearly all producers. Reform may also address other market imperfections, such as cartels or pricing agreements among producers. Hence, in order to incorporate policy-relevant services liberalization, modelers need to recognize that market access restrictions affect not only new foreign entrants but domestic new entrants as well.

Fourth, **services trade frequently consists of sales by affiliates of multinational companies**. FDI in services sectors can foster pro-competitive effects, reduce production costs for the industry, and encourage productivity improvements in linked industries and throughout the economy.

Fifth, **fixed costs appear to play a larger role in restricting new entrants—both foreign and domestic—in services sectors than in goods**. This results from the greater quality verification measures (e.g., certification and licensing) required for services, and the need to establish a local presence. Applying high fixed costs rather than their tariff equivalent may result in significantly different predictions about the effects of liberalization policies. For example, small firms may be disproportionately assisted by a reduction of fixed-cost barriers. Alternatively, sectors with large economies of scale may be less affected by further cuts in fixed-cost barriers.

To capture these stylized facts, a number of CGE model enhancements are necessary. For instance, the importance of FDI makes it important to identify on a sectoral basis the factors of production that move across borders—e.g., capital that crosses borders, who owns that capital, and how that capital is financed.[9]

Another point that emerges from the literature is the heterogeneity across services sectors. The world's major services sectors differ sharply from one another in a number of important characteristics, particularly in terms of regulations that affect trade and competition. Subsequently, sector-specific studies are often the only way to gain insight into the economic effects of a policy change in services. In a relatively new policy area like services, information from such studies can be helpful in informing trade policymakers and practitioners about the economic consequences of services trade barriers. Yet the heterogeneity of services presents a conundrum for CGE modeling as industry-specific findings do not lend themselves easily to economy-wide CGE assessments of general services liberalization. Restriction measures that are estimated across industries are more easily integrated into a CGE framework for economy-wide experiments, although estimation exercises of this scale present its own challenges.

[9] Working from a theoretical standpoint, Dee (2003) carefully describes special features of services to be taken into account in modeling services trade. Many of these have been borne out by recent empirical evidence.

While CGE models are often used in trade policy analysis, they are not without limitations. Building and maintaining CGE models is time- and resource-intensive. Even the best computational models are constrained by the data and services data on production and trade are not nearly as complete as goods data. CGE models are less testable than other more traditional analytical approaches, such as econometric analysis. In econometric studies it is necessary to control for all other factors affecting performance and still deal with simultaneity issues. Econometric models have the advantage of simplicity, but are unable to deal with the richness and detail of the underlying structures involved. Consequently, econometric results could be misleading in the face of structural change, a common phenomenon which often coincides with services liberalization and reform.

Conclusion

Services are deeply integrated into the production process. When such services are poorly provided, the rest of the production chain suffers as well. Opening services trade to increased competition is projected to benefit both developed and developing countries. For developing countries in particular, access to improved services may be a critical step in the development path.

To enable services liberalization, policymakers need to understand the potential ramifications of reform. CGE modeling has provided a thorough and detailed analytical approach to understanding trade liberalization in goods. The same work must now be done in services.

In this paper we have identified several stylized facts that have been explored in the theoretical literature and consistently supported by empirical evidence. Until now, the main approach to services modeling has been the use of tariff equivalents. In fact, services and their barriers are sufficiently different from goods barriers that several other modeling approaches, in concert or separately, are called for. Entry, or fixed-cost, barriers are more prevalent in services and should be modeled to understand their effects on trade. Inside-the-border impediments, such as regulatory barriers that affect both domestic and foreign suppliers, are also more prevalent in services. Market structure, including monopolies, plays a significant role in many services industries. Linkages to other industries, particularly downstream manufacturing, must be taken into account. Finally and perhaps most importantly, the effects of FDI, including technology diffusion and knowledge spillover, are of particular relevance to the services sector. These stylized facts, as robust characteristics of services sectors, should be considered in the implementation of future CGE modeling. The body of literature is still far from complete. Further empirical evidence that identifies specific channels of the economic effects of services trade liberalization, as well as corresponding directions in CGE modeling, will be vital for this area of international trade and trade policy. It is our hope that such work will provide the analytical support for key policy reform.

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China's Vision for Renewable Energy: The Status of Bioenergy and Bioproduct Research and Commercialization

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Authors[1]:
Elizabeth R. Nesbitt[2]
Paul Thiers
Johnway Gao
Sharon Shoemaker
Manuel Garcia-Perez
Julie Carrier
Joy Doran-Peterson
John Morgan
Guangyi Wang
Pierre Christian Wensel
Shulin Chen[3]

Abstract

The Chinese government is vigorously promoting commercialization of renewable energy and bioproducts, given environmental issues plus food, energy, and national security concerns, according to Chinese industry experts at the August 2010 "China Bioenergy Workshop" and its related technical tours. Goals include replacing 15 percent of conventional energy with renewable energy by 2020 and providing necessary investment of about $800 billion. Government policies cited include financing (given

[1] The views presented are solely those of the authors and do not represent the opinions of the Commission or any of its Commissioners, nor do they represent the opinions of the other authors' organizations. The authors are U.S. Department of Agriculture (USDA)-Washington State University (WSU)-China Agricultural University (CAU) Workshop participants. Affiliations of authors are as follows. Nesbitt: International Trade Analyst for Biotechnology and Nanotechnology, U.S. International Trade Commission (the Commission); Thiers: Washington State University; Gao: CatchLight Energy, LLC, A Chevron/Weyerhaeuser Joint Venture; Shoemaker: Energy Institute, University of California, Davis (UCDavis); Garcia-Perez: Washington State University; Carrier: University of Arkansas; Doran-Peterson: Bioenergy Systems Research Institute, The University of Georgia; Morgan: Purdue University; Wang: University of Hawai'i at Mānoa; Wensel: Washington State University; Chen: Washington State University.

[2] Corresponding author (*elizabeth.nesbitt@usitc.gov*).

[3] Shulin Chen was the USDA-WSU-CAU Workshop organizer. Hereinafter called either the "USDA-WSU-CAU Workshop" or "the workshop," it was made possible through a

the lack of venture capital); financial and taxation incentives; carbon taxes and credits; and mandatory usage requirements, but the speakers said more can and will be done. Although not yet released at the time of the workshop, the speakers expected the 12th 5-Year Plan to expand the momentum generated under the 11th 5-Year Plan. This article highlights novel issues gleaned from the experts' unique, "on-the-ground perspective" of current and future bioenergy and bioproduct research and commercialization in China.

Introduction

This article highlights novel information about China's bioenergy and bioproducts industries presented during the Chinese Bioenergy Research Workshop (Beijing, China, August 13–23, 2010). Except for background information about existing grain ethanol facilities and conclusions reached by the workshop participants, almost all the information presented by the workshop speakers is either new, published only in Chinese-language journals, or unpublished. A few highlights are shown below.

For example, workshop speakers confirmed that China is continuing to invest significant resources and funding in renewable energy and biobased chemicals. During the 11th 5-Year Plan, covering 2006 through 2010, renminbi (RMB) 5–10 billion (about $700 million–$1.4 billion) was invested in clean energy, of which 50 percent focused on research and development (R&D) for renewable energy. Workshop speakers indicated that investment in green energy is expected to increase substantially to RMB 5.4 trillion (almost $800 billion) from 2009 through 2020.

[3] Continued--2008 grant from the USDA International Science and Education Program, National Institute of Food and Agriculture, entitled "Enhancing Bioenergy Education and Business Development Capabilities via Access to International Resources and Technologies." Professor Shu-lin Chen was also the grant's project director. The authors appreciate the logistical assistance provided by CAU and the insights and helpful input of Professor Dong and Assistant Professor Zhou. The authors also appreciate the comments provided by the editor and the anonymous reviewer, and the input from Andrew David of the Commission.

The speakers and the technical tours also illustrated the growing convergence of the biofuels and chemicals industries, as more companies develop integrated biorefineries to produce biofuels as well as biobased chemicals such as biobutanol and polyethylene.[4] Moreover, biobutanol is being developed in China for chemical applications rather than for use as a liquid biofuel. However, one company's biobutanol plant was temporarily shut down at the time of the workshop because of reduced cost competitiveness, given the high cost of the corn feedstock and the low cost of crude petroleum, a competing end product.

Workshop participants also concluded that restrictions on the use of grain; technical and economic difficulties associated with alternative feedstocks; and potential alternative uses of available biomass, may hinder China's ambitious ethanol expansion targets. The limited amount of available land may also result in a growing reliance on imported cassava and sugarcane as feedstocks.

Workshop background

This USDA-sponsored workshop allowed the authors to meet with prominent industry, association, government, and academic experts in bioenergy and bioproducts who are actively shaping the industry's future and providing input to ongoing Chinese governmental planning and coordination policies and programs. Although not yet released at the time of the workshop, the speakers expected the 12th 5-Year Plan (2011 to 2015) to strengthen and expand upon bioenergy momentum generated under the 11th 5-Year Plan.

The speakers candidly shared their knowledge of technical, economic, and policy-related aspects of China's renewable energy and biobased chemical industries. This information, combined with the two technical tours and the two related scientific conferences, allowed for a unique, "on-the-ground perspective" on current and future research and commercialization in open and productive exchanges. Also, the workshop participants were drawn from academia, industry, and government on the basis of their overall knowledge of China's growing bioeconomy, allowing for further in-depth discussions and sharing of detailed industry information.

The workshop, the main component of a USDA grant awarded to Washington State University (WSU) in 2008, was organized by WSU in collaboration with China Agricultural University (CAU). In addition to presentations by industry experts, the workshop provided technical tours of two state-owned enterprises (SOEs)—Henan

[4] Chemical coproducts are expected to make new biofuel ventures more economically feasible.

Tianguan Enterprise Group Co., Ltd. (Tianguan) and North China Pharmaceutical Group Corporation (NCPC) SINOWIN Co., Ltd.[5] The goal was to ascertain the status of Chinese R&D and deployment of bioenergy and bioproducts, and to develop an international collaboration program in bioenergy research, education, and training with China. The workshop was held in conjunction with two related conferences (the Environment Enhancing Energy Forum (E2 Energy) and the International Conference on Biomass and Energy Technologies (ICBT2010)) to maximize interaction between participants and Chinese experts.

China Agricultural University (CAU)

CAU, the workshop host, is one of the leading universities in China for bioengineering; its Biomass Engineering Center, founded in 2004, is supported by the central government (Dong 2010). In opening comments, Professor Tao Wang, Director of the center, said China's focus on urbanization during the next decade will use bioenergy to offset bottlenecks encountered in extending commercial energy supplies to small towns and cities. Also, under the Renewable Energy Law, the government can buy renewable energy from all sources, including biofuels produced by SOEs such as Sinopec, COFCO, and others.[6] These opportunities are spurring international bioenergy collaborations (Wang 2010).

Organization of the article

The first section of this article describes how Chinese government policies are promoting production and use of renewable energy and reductions in energy consumption. The second section provides examples of research and commercialization in several bioenergy industry segments. The third section discusses the impact of increased use of renewable energy on China's expanding and changing energy infrastructure. The fourth section highlights examples of how research and development in renewable energy is being financed. The last section highlights examples of domestic and international collaborations and strategic alliances at both the industry and university levels.

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5 See the reference list for speakers' titles and affiliations; the technical tour representatives are listed before the reference list.

6 Professor Tao Wang, Vice President of China Agricultural University, and Director of the Biomass Engineering Center, CAU.

Renewable energies are generally derived from "sustainable raw materials and waste products" (Bug 2010). The term "conventional energy" usually refers to fossil fuels such as gasoline and diesel. In China, the terms "renewable energy" and "green energy" include not only hydropower, solar, wind, and biomass/biofuels, but also nuclear energy. Biorefineries—production facilities for liquid biofuels such as bioethanol and co-products (e.g., biobased chemicals)—can be considered analogous to petroleum refineries but use renewable resources as inputs instead of fossil fuels. Examples of renewable biomass inputs include agricultural and forestry residues, municipal waste, and energy crops.

Government policies/goals promoting renewable energy

China is proactively promoting production and use of renewable energy and reductions in energy consumption.[7] Acknowledging China as a leading source of global greenhouse gases (GHG) in 2009, particularly from energy consumption,[8] Professor Dinghuan Shi said that China's growing economy has driven increased energy consumption and GHG emissions, primarily by the coal-fired plants and other industrial energy sources essential to China's economic development (see figure 1 for sectoral energy consumption during 2000–2050 under two energy reduction scenarios[9]). Large increases in the number of vehicles and in consumption of manufactured goods have exacerbated the situation (Lin 2010 and Shi 2010). This thirst for energy is currently satisfied by coal[10]—which accounts for 70 percent of China's energy consumption—and crude petroleum; China imported almost 55 percent of its consumption of crude petroleum in the first quarter of 2010 (Lin 2010). This is considered a threat to energy security and national security, as well as to the environment.

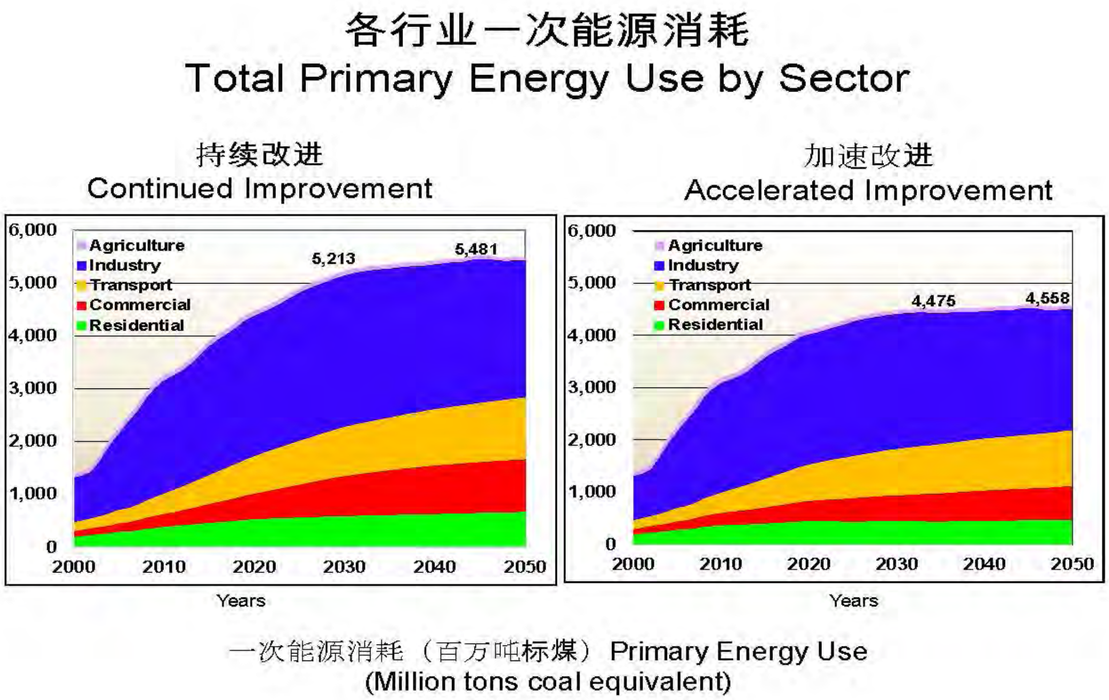
[7] Unless otherwise noted, comments in this section were made by Professor Dinghuan Shi.

[8] See also U.S. Energy Information Administration (EIA), "International energy statistics," January 2011.

[9] According to Dr. Mark Levine of the Zhou et al. report team, "continued improvement" refers to the future progression of energy efficiency of products and industrial processes progresses at the same rate as in the past few decades. In comparison, "accelerated improvement" addresses a "much more rapid move to greater energy efficiency in products and industrial processes . . . reaching today's most efficient products within two decades or less." (Pers. comm., April 29, 2011)

[10] Coal is considered to be a nonsustainable energy source. It is not only nonrenewable but it also emits pollutants and GHGs—including a significant amount of carbon dioxide (CO2)—when burned.

FIGURE 1 China's Total Primary Energy Use from 2000 through 2050 under Two Energy Reduction Scenarios



Source: Zhou et al., *China's Energy and Carbon Emissions Outlook to 2050*, April 2011, 32; Levine, "Will China Overwhelm the World with Its Greenhouse Gas Emissions?" April 5, 2011, 32. Reprinted with permission.

Policy goals

These scenarios prompted China's top leaders to set a goal of replacing 15 percent of conventional energy with renewable energy by 2020, with parallel goals of increasing energy efficiency and reducing energy consumption (Shi 2010). The Renewable Energy Law, for example, implemented January 1, 2006, is intended to increase energy supplies, enhance energy security, and protect the environment (Huang 2010). The 2007 Medium and Long-Term Development Plan for Renewable Energy enumerated renewable energy targets for 2010 and 2020 (box 1). Speakers considered it likely that the 12th 5-Year Plan would expand policy support for renewable energy.

Box 1 Some goals of the 2007 Medium- and Long-term Development Plan for Renewable Energy

	2010 target	**2020 target**
Biodiesel	0.2 million ton/year (t/year)	2 million t/year
Fuel ethanol	2 million t/year	10 million t/year
Biomass power generation:		
– From agricultural and forestry residue and energy crops:	4 gigawatts	24 gigawatts
– From municipal solid waste:	500 megawatts	3 gigawatts

Source: Sun, "Biomass Energy Development in China," 2010.

China is said by one source to be the "global manufacturing leader of most renewable energy technologies, and the largest user of clean energy" (EESI/WRI 2011). It also became the world's leader in installed clean energy capacity in 2009, followed by the United States, the previous leader, and Germany (Pew 2011). Renewable energies emphasized during 2009 through 2020 include hydro and wind power (the two largest in terms of Chinese capacity in 2009), solar, biomass, biogas, and nuclear. Installed Chinese hydropower capacity exceeds that of the United States and Canada combined (Shi 2010). Also, Chinese wind energy capacity has more than doubled each year during 2006 and 2009, exhibiting a faster average annual growth rate than that of the United States. China manufactures most of the turbines used domestically, including small ones used in cities and villages, but is currently a limited exporter of the products.

Professor Shi said that the many solar heaters on Chinese roofs have reduced carbon dioxide (CO2) emissions and, since 2008, central government stimulus spending "subsidized" the adoption of solar energy in rural areas.[11] China accounts for 50 percent of the world's solar water heaters and is promoting new policies that bring electricity to rural areas and, in some regions, integrate multiple power sources (e.g., biogas with solar; wind energy with solar-powered batteries). China is also the world's largest producer of photovoltaic modules, exporting 90 percent of output (Shi and J. Zhang, 2010).

[11] Workshop speakers generally referred to various types of monetary support and incentives as "subsidies."

China invested RMB 5–10 billion (about $700 million–$1.4 billion) in clean energy during the 11th 5-Year Plan with 50 percent focused on R&D for renewable energy (Shi 2010).[12] Speakers confirmed that the government would continue to invest substantial amounts in renewable energy in 2009 through 2020. Dr. Jie Zhang's comments, in particular, provided a window onto the National Development Reform Commission's (NDRC) interest in attracting outside investment to help it accomplish the country's bioenergy goals. Investment of RMB 5.4 trillion (almost $800 billion) is expected, with about one-third dedicated to China's smart grid and the largest shares thereafter to hydro, wind, and nuclear power, respectively (J. Zhang 2010).[13] Projected "green energy" capacity and investment levels in these years are shown in figures 2 and 3, respectively.

Policy measures to promote bioenergy production and consumption

The Chinese government has implemented several measures supporting supply and demand of biofuels. For example, on the supply side, government-authorized biofuel producers receive a variety of operating incentives, including monetary incentives. Demand side measures include mandatory use regulations for E10.[14] Expected increases in the production and consumption of bioenergy, including biofuels, will require the following measures (Shi 2010):

- ✓ R&D investment in renewable energy needs to be increased;
- ✓ More demonstration projects need to be constructed;
- ✓ Standards need to be formulated;

12 Currencies were converted using the time period's average of about RMB 7.2 per U.S. dollar (IMF, "Exchange Rate Query"). Currency conversions later in this article were obtained from this source for the specified time periods.

13 Dr. J. Zhang said that China will become the largest market for clean energy within the next decade; China welcomes international collaboration; and that the Energy Research and Development Center provides energy advice and policy information to the NDRC.

14 E10 is a gasoline blend containing 10 percent ethanol.

- ✓ An environmental monitoring system needs to be established;
- ✓ State renewable energy programs are needed; and
- ✓ New rules and regulations are needed to encourage venture capital.

FIGURE 2 Green power capacity, 2009 and 2020

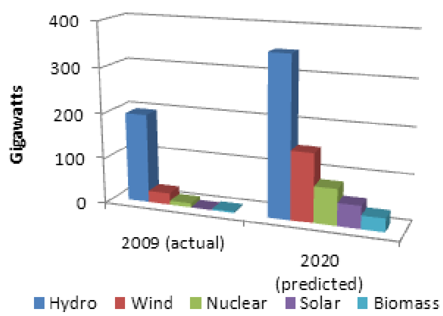
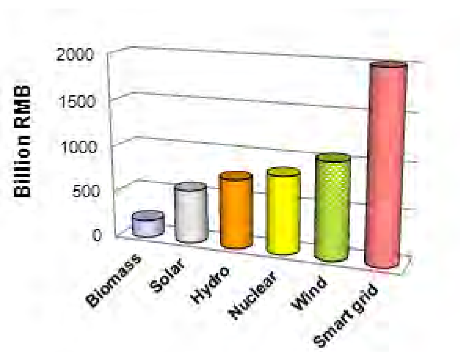


FIGURE 3 Green power investment: Total 2009–20 (5.4 trillion RMB)



Note: China includes nuclear energy in its green power and renewable energy classifications.

Source: Capacity and investment data, J. Zhang, "Green Energy: Development and Investment Opportunities in China." 2010.

In regard to bioenergy projects in general, workshop speakers cited "policy-related subsidies" provided by the National Development and Reform Commission (NDRC) and the Ministry of Finance for "large-scale engineering" projects and the provision of tax-free status for power projects utilizing renewable energy (Huang 2010). In early 2010, the NDRC also identified the bioindustry as a "Strategic Energy Industry" to support a sustainable industry/economy (*People's Daily Online 2010*).

Research and Commercialization

Several industry segments, including starch-based ethanol, alternative feedstocks, other biofuels, and biobased chemicals, are under study and/or being commercialized. As with other countries, in regard to biofuels and biobased chemicals, most of China's activities and policies relate to biofuels despite significant domestic production of biobased chemicals. In 2007, the value of biobased chemicals manufactured in China using industrial biotechnology reportedly exceeded $60.5 billion (versus about $2.5

billion in 2003), with annual sales expected to grow thereafter by about 10 percent (Nesbitt, 2009).

Research

Workshop speakers emphasized the importance of basic and applied research to the Chinese bioenergy program, noting that it builds upon the country's long history of using fermentation (e.g., in the manufacture of beverages, food, and chemicals). The technology being commercialized originated in the Chinese Academy of Sciences (CAS),[15] universities within China, individual companies, and international sources. Workshop participants considered the official systematic reporting of the current status of Chinese bioenergy a relatively new development.

Ongoing industrial and academic research in China addresses a wide variety of topics, ranging from feedstocks to process development (Lin 2010). Substantial research is underway on production of 2nd generation ethanol from nongrain and cellulosic biomass feedstocks, including development of biomass pretreatment; enzyme systems and microorganisms (e.g., those metabolizing a variety of sugars besides glucose); and fermentation processes. Although scaled-up from lab bench to demonstration-scale facilities, this research has not been commercialized yet (Xing 2010). Professor Tianwei Tan (2010) described another promising technology: a fungal lipid production system (35–60 percent intracellular lipid content), which could be easily converted to biodiesel using a standard conversion technology.

In addition to grain-based ethanol, commercialized feedstocks and technologies include alternative fuels such as cassava. For example, cassava is the main feedstock for a commercial fuel ethanol plant built in 2006 with a capacity of 200,000 metric tons per year (t/year) of ethanol (or about 67 million gallons per year). Other technologies already commercialized include biomass for electricity and biodiesel from waste oil.

Commercial production of starch-based fuel ethanol in China

China, like other countries, has produced ethanol for chemical use for decades. The focus on fuel ethanol, however, developed largely during the last decade. As of 2010, there were five authorized state-owned commercial-scale fuel ethanol plants using starch-based feedstocks such as corn and wheat grains or cassava. Several speakers mentioned that these facilities receive a variety of operating incentives, including government "subsidies" estimated at about $0.45 per gallon of ethanol and about

15 Workshop speakers said that the CAS is a government institution comparable to the U.S. National Laboratories.

$0.10 per gallon of biodiesel. Also, workshop speakers considered it unlikely that more fuel ethanol producers would be designated as "authorized," with its associated incentives, even those developing 2nd-generation feedstocks and technologies. This was an interesting observation for two reasons: (1) this information has not been widely disseminated outside China; and (2) it was unexpected, given the amount of work underway on 2nd–generation technologies. It is not deterring 2nd–generation development; however, most of this development is by currently authorized starch-based ethanol producers and their partner companies, all SOEs.

The starch-based ethanol facilities are located along the east and southeast coasts of China, largely because of feedstock availability (Lin 2010). Their output amounted to 1.72 million metric tons in 2009, or about 576 million gallons.[16] All but one are joint ventures between large SOEs such as COFCO, PetroChina, and Sinopec (Fu 2010).[17] The technology is essentially like that used in the United States: starch hydrolysis, fermentation of the resulting monomeric sugars into ethanol, and distillation of the ethanol-containing fermentation broth. Fuel ethanol has not been exported since 2006, largely because the export tax rebate was revoked (X. Zhang, 2010). Tianguan's grain ethanol facility is shown in figure 4.

[16] Production of 576 million gallons of starch-based ethanol requires about 200 million bushels of grain, harvested from over 1.4 million acres.

[17] When asked about job creation related to bioethanol production, Dr. Lin (COFCO) said that the number of jobs created is limited but, with about 600 people per plant, some growth is likely; other speakers said that such data were not collected. Also cited was a 2009 Novozymes-McKinsey report stating that China's conversion of agricultural residues to bioethanol could reduce gasoline consumption and CO2 emissions, and create about 6 million direct jobs and income of about RMB 32 billion (or about $4.7 billion). See also Novozymes, "Commercial production of cellulosic biofuel on fast track in China," May 27, 2010.

Figure 4. Henan Tianguan Enterprise Group Co., Ltd.'s commercial fuel ethanol biorefinery. The feedstocks are grain (corn and wheat), molasses, and cassava. Tianguan plans to upgrade this facility to produce bioethylene, biogas and biodegradable plastics. (Reprinted with permission from Tianguan.)

Alternative feedstocks

Although most commercial ethanol production in China is from corn, food security concerns have led to the central government implementing policies that cap the use of corn for biofuels and restrict expansion of food grains for fuel ethanol production.[18] During the workshop, Professor Shi characterized the initial emphasis in China on corn as a feedstock for fuel ethanol as "a mistake." The feedstock restrictions have spurred development of alternative inputs such as cassava and sweet sorghum, and 2nd generation cellulosic feedstocks (e.g., agricultural residues, such as corn stover and wheat straw, and forestry residues; box 2). The workshop speakers did not express support of using herbaceous energy crops, such as switchgrass, perhaps because of the limited amount of available land.

[18] Land use is limited; only 14 percent of land in China is arable. Moreover, China's population is about 1.3 billion and most food produced is consumed domestically.

Box 2 Examples of agronomy studies and some findings

Given the restrictions on using corn, use of alternative feedstocks such as sweet sorghum and agricultural residues have been studied by many organizations. As reported by Dr. Lin, several studies have been undertaken regarding sweet sorghum. Solid and liquid fermentation pilot studies addressing sweet sorghum were conducted at Tsinghua University and Guangxi Science and Technology Institute for Light Industry, respectively. The reported results were that, as in the United States, fresh sorghum conversion has limited usefulness as a feedstock because the freshly extracted juices can be contaminated by other microorganisms, depleting the sugars. Fresh stalks are limited to a 2 month storage period; and concentrated syrup storage is limited to 8 months (Lin 2010). Another study, conducted by British Petroleum and the Hebei Agro-Science Institute, examined parameters such as variety selection, planting density, and fertilizer and irrigation requirements; however, no results were reported in the workshop.

Although demonstration-scale 2nd–generation ethanol plants are rapidly being deployed, commercial production is not expected for at least 3–5 years (Lin 2010) because of the high processing costs. Despite lower feedstock costs for 2nd–generation production, estimated at about RMB 200–300 (about $29–44) per ton corn stover and wheat straw (Fu 2010), the cost of producing corn-stover ethanol in China is currently about 1.5–2 times the cost of corn ethanol, largely because of pre-treatment and enzyme costs (Fu, Xing 2010). The tabulation below, entitled "Comparison of Transportation Fuels Policy and Practice," presents a uniquely detailed comparison of current and future production of liquid transportation fuels (bioethanol and biodiesel) in China and the United States, juxtaposed with national consumption and policy information. In the next 10 years, bioethanol production is projected to increase in China at twice the rate it is projected to increase in the United States.

Tianguan operates a state-of-the-art 2nd-generation ethanol facility which uses corn stover and wheat straw feedstocks, the major agricultural residues in its geographical area (box 3). Another 2nd-generation ethanol facility producing about 3 million gallons per year of ethanol from corn stover will be brought onstream in late 2011 by Sinopec, COFCO, and Novozymes (Novozymes 2010). The process will be based on the technology used at COFCO's existing 2nd-generation facility located in Zhaodong, which is somewhat similar to that of the National Renewable Energy Laboratory's (NREL; Golden, CO) dilute acid process. The biofuel production process can also create value-added chemicals as co-products.

Comparison of Transportation Fuels Policy and Practice

	China[1]	USA[1,2]
TODAY		
Population	1300 M	300 M
Number of Vehicles	200 M	256 M
PETROLEUM Consumption		
Today	24 BG (72 MT)	140 BG
Gasoline	46 BG (140 MT)	40 BG
Diesel		
BIOFUELS Consumption Today	As E10, B10	As E6, E10, E85,
In Gasoline	0.4 BG (1.2 MT)	B5, B20
In Diesel	0.0001 BG (0.37 MT)	9.6 BG
		0.3 BG
BIOFUELS Production Today		
BioEthanol	0.56 BG (1.7 MT)	10 BG
BioDiesel	0.17 BG (0.5 MT)	0.7 BG
TOMORROW Production	Non-grain	Cellulosic EtOH
By 2010-2012	0.73 BG (2.2 MT) EtOH	
By 2020-2022	4 BG (10 MT) EtOH	36 BG** EtOH
	0.7 BG (2 MT) Biodiesel	
By 2030		60 BG EtOH (30% total demand)
**Breakdown of 36BG EtOH		
1st gen: Conventional Biofuels		
Ethanol from cornstarch		15 BG by 2022
		1 BG by 2022
Biomass-based diesel		16 BG by 2022
		4 BG by 2022
2nd gen: Cellulosic Biofuels		
3rd gen: Other Adv Biofuels		

Notes:
Numbers are estimates and are on an annual basis. (BG = billion gallons; MT = million tons; E5.7 = 5.7% ethanol in petroleum, etc.; B5 = 5% biodiesel in petroleum; EtOH is ethanol; etc.)

Color code: Targets from Policy/law, Consumption, Production.
Primary references: [1] USDA-WSU-CAU Workshop, 2010; [2] EISA of 2007.

***Source*:** Shoemaker 2010. Reprinted with permission.

Box 3 Tianguan Cellulosic Ethanol Production: A Leading-Edge Demonstration-Scale Plant in China

Infrastructure--In addition to producing commercial amounts of ethanol from grain, Henan Tianguan Enterprise Group Co., Ltd., (Tianguan) is currently operating a pilot demonstration-scale 2nd generation plant, using corn stover and wheat straws as feedstock and steam-explosion pretreatment, with a reported capacity of 10,000 t/year. The facility currently uses residual lignin and commercially-purchased coal to fuel the pretreatment. The capital needed to build the cellulosic ethanol demonstration plant was about RMB 85 million, or about $12.5 million (compared with about RMB 1 billion for the company's commercial-scale grain ethanol facility—with a capacity of 500,000 t/year). Tianguan started construction of the demonstration plant in 2006 and brought it onstream in 2008.

Feedstock--The company's corn stover collection, which is purchased on a spot basis at market prices, uses about one-third of the corn stover available within a 20–25 kilometer radius. It was mentioned that distributors who transport the corn stover from the farm to the storage facilities have entered the market. During the workshop, however, Dr. Lin (COFCO) indicated that these distributors profited more than the farmers. He added that a new system is being considered that would be more beneficial for the farmers.

Expected cellulosic expansion--Given the decentralization of feedstock supplies, Tianguan plans to build a few new cellulosic ethanol plants before 2013, with a total cellulosic ethanol capacity of up to 120,000 metric tons. These plants could be south of the existing demonstration plant and located near feedstock supplies. The company is applying for construction permits but, according to the Tianguan representative, the economic feasibility of the project will depend on the availability of subsidies from the Chinese government because otherwise the plants won't be profitable (company officials estimated that ethanol fuel prices would have to rise by nearly 30 percent before their current production would be commercially viable). The facilities will be relatively small, about 10,000-30,000 metric tons depending on the financial resources, making it easier to collect feedstock from farmers. The production of biobased chemical coproducts could make the venture feasible.

Future biorefinery plans--Tianguan is also planning for the future. The Tianguan representatives stated that whereas the current biorefinery produces fuel ethanol, protein meals, animal feed, dietary fiber, and fertilizer, planned expansions would allow for the production of chemicals such as 1,4-butanediol, biodegradable plastics, and ethylene from ethanol. It was stated that production of ethylene from bioethanol is at an early stage; to be profitable, 1 million t/year would need to be produced.

Source: Tianguan representatives, technical tour, August 17, 2010.

The Chinese government projects production of 3.6 billion gallons per year of fuel ethanol by 2020. With the ambitious ethanol expansion targets, restrictions on the use of grain, and technical and economic difficulties associated with alternative feedstocks, 3.1 billion gallons will need to be produced from nongrain and 2nd–generation ethanol processes since starch-based ethanol production is capped at 525 million gallons. Throughout the workshop, the value of available biomass in China was estimated at around 300 million tons, translating to potential production of about 25 billion gallons of ethanol.[19] However, it is not clear how much would be available for fuel ethanol, given competition from other uses, including other bioenergy applications. The continued dependence of most pilot facilities on steam explosion pretreatment also indicates that financial and energy costs will be difficult to overcome without significant technical breakthroughs. The steam explosion process still needs to be optimized and its efficiency validated in a precommercial stage before expansion to commercial scale.

In light of these constraints, a continued and growing reliance on imported cassava and sugarcane seems likely, as land pressure within China will limit domestic supplies of these alternatives. Several speakers confirmed that importation of cassava is already underway; for example, 30–50 percent of the cassava used at the Beihai ethanol facility in Guangxi is imported from Thailand and Vietnam.[20] This information was of great interest to workshop participants who, until now, had to rely on informal reports of such imports. Efforts are also underway to increase Chinese supplies of jatropha, but consumption demands are also likely to be met with imports during the near term.

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[19] Using a conversion factor of 1 ton of biomass produces 80 gallons of ethanol.

[20] In 2010, Thailand, the world's largest cassava supplier, is said to have marketed 98 percent of its cassava chip exports to China for use in biofuels. This demand has contributed to substantial growth in Thailand's exports of cassava chips since 2008, as well as in the price of cassava (Rosenthal 2011, A1).

Other biofuels/sources of energy

The Chinese Ministry of Agriculture has promoted family-scale biogas production and consumption since the 1960s, making biogas a small, but significant, source of energy in rural China. Professor Dong and others stated that large-scale commercialization of biogas is only now occurring, as reflected by a few large projects coming onstream in 2009 and 2010. The Chinese government invested about RMB 20 billion (about $3 billion) in biogas production from 2003 through 2009 (Huang 2010).

Biogas uses waste materials as inputs, including animal waste. The first and largest of China's high profile, large-scale biogas demonstration projects is the Anaerobic System at the Chicken Farm of MinHe, in Shandong Province, which has 2–4 million chickens (Sun 2010). The grid-connected project's capacity is about 6,000 kilowatt hours per day from the anaerobic digestion of 300 tons of manure and 500 tons of waste water; the residue can be used as a fertilizer. U.S. and Chinese technology are used (e.g., General Electric (GE) Energy, a partner, provided three turbines that generate electricity from the biogas; GE is also working with a second Chinese farm on another biogas project) (GE 2009, Sun and J. Zhang 2010).

An egg production farm in northwestern Beijing—Beijing DQY Agriculture Technology Co., Ltd., with almost 3 million chickens—uses four large biodigesters to generate electricity for the grid (Shi 2010). This plant was constructed by a Chinese company using German technology. Both the Shandong and Beijing plants receive feed-in tariff subsidies mandated by the central government and GHG emission reduction payments through the Clean Development Mechanism of the Kyoto Protocol.

Aviation biofuels are also being studied. PetroChina, Tianguan, and NCPC all mentioned that they are entering the aviation biofuels market. Although one feedstock will be algae, NCPC is also looking at biobutanol with DuPont as a biofuel and potential hydrocarbon for jet fuel use (NCPC 2010).

As for biodiesel, China is planting oil plants such as jatropha and *Pistacia chinensis* that could eventually produce as much as 5 million t/year (1.5 billion gallon/year) of the fuel (Tan 2010). Although biodiesel capacity and production data vary, production capacity reportedly amounted to about 200,000 t/year (60 million gallon/year) in 2008 with chemical conversion accounting for the majority because of the low costs (Tan 2010). Professor Tan described biodiesel production from waste oil, estimating that enough waste oil and fats exist to eventually produce 2 million t/year (600 million gallon/year) of the fuel. Most Chinese biodiesel is exported (Sun 2010).

New technology also plays a role in biodiesel production. Enzymatic conversion processes are being studied, and a facility using lipase as a catalyst and waste oil as a feedstock was started up in October 2007 (Tan 2010). Although more costly, the enzymatic conversion process is considered environmentally friendly (in comparison, the chemical process reportedly results in waste water and high energy consumption). There isn't much production yet of biodiesel from microalgae.

Production of biobased chemicals and other bioproducts in China

Biobased chemicals are often not only more environmentally sustainable than their fossil-fuel counterparts but may also make the production of liquid biofuels more economically feasible as coproducts. Companies are increasingly integrating production capability for downstream biobased chemicals into biorefineries, including biobutanol.[21] For example, Tianguan is upgrading its grain ethanol facility in Henan Province by adding a biobutanol production facility, with plans to import the needed grain. The product is, however, like many other such biobutanol ventures in China, intended for chemical use; the Tianguan representative (2010) mentioned that the company is focusing on a "more cost-effective application; biofuels are still too expensive an application" for biobutanol. Another upgrade to Tianguan's grain ethanol facility is to increase the size of the recovery unit for CO2 to increase CO2 capture to as much as 40 percent, versus 10 percent currently; some of the recovered CO2 will be used to make biodegradable plastics, significantly reducing petroleum use.

Workshop participants visited NCPC SINOWIN's sorbitol and biobutanol facility in Shijiazhuang; again, the biobutanol produced is for chemical use. Company representatives stated that the corn-based biobutanol plant had been temporarily shut down because of the high cost of corn and the low cost of crude petroleum (which makes their product less cost competitive). Alternative feedstocks such as sweet potatoes, cassava, and molasses are being considered. But the NCPC representatives added that the separation of the biobutanol is one of the main costs and that this is likely to remain so until a microorganism is developed that will produce higher yields of biobutanol, thereby reducing the separation costs. Box 4 highlights novel aspects of Tianguan's and NCPC's development of biobased chemicals.

[21] Biobased chemicals are usually either produced in a biorefinery as coproducts of a biofuel or produced using biobased inputs.

The NCPC SINOWIN representatives stated that whereas subsidies are needed for ethanol production, they are not needed for biobutanol, and that the Chinese government is studying how to address biobutanol demand in China. In their opinion, it is price dependent: if the price of biobutanol is very similar to that of ethanol then biobutanol will have a market in China and its costs could be offset by the production of hydrogen and CO2, each of which can be used as inputs to produce other chemicals within the company (NCPC SINOWIN 2010). Workshop participants noted that the companies' production of biobutanol as a chemical also means they are not subject to Chinese biofuel restrictions.

One example of biobased chemical production mentioned by several workshop speakers, the conversion of glucose to succinic acid, is garnering attention worldwide because of its potential as an intermediate for several downstream chemicals, including biodegradable plastics (Xing 2010). Another biobased chemical produced by fermentation is 2,3-butanediol.[22] Other biobased chemicals mentioned in the workshop as being either studied or produced in China include bioethylene, acrylamide, lactic acid, 1,3-propanediol, sorbitol, and bioplastics such as polylactic acid and polyhydroxyalkenoates. In addition to the major bioprocess currently used (fermentation), enzymatic biocatalysis is being studied, with input from foreign collaborators.[23]

Infrastructure

China's energy infrastructure is expanding and changing, particularly in response to the increased use of renewable energy. Achieving the 2020 goal of replacing 15 percent of energy consumption with clean energy will require increased renewable energy capacity (e.g., hydropower is projected to increase to 350 gigawatts; wind to 150 gigawatts; and solar to 50 gigawatts) (J. Zhang 2010). Meeting the goals is also likely to require changes to the existing energy production and distribution infrastructure to accept new sources of energy.

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[22] The fermentation steps would be glucose or xylose to 2,3-butanediol followed by esterification to 1,3-butdiene or followed by dehydration to 2-butanone.

[23] In biocatalysis, enzymatic bioprocesses are used either in lieu of or in addition to conventional chemical processes. The production processes for several pharmaceuticals in the United States and the European Union, for example, including those for some blockbuster products, integrate biocatalytic processes. USITC, Industrial Biotechnology, 2008, 2-7 and 3-15.

Box 4 Current and future production of biobased chemicals by Tianguan and NCPC

Tianguan's Future Biorefinery Production--Tianguan's industrial grain ethanol plant (400,000–500,000 t/year) uses starch-rich materials such as corn, wheat, and cassava as feedstocks. During the technical tour, Mr. Xiao Yang Zhang (the president of the company) spoke of plans to convert the company's grain ethanol plant into an integrated cellulosic biorefinery producing several high-value products (e.g., biodegradable plastics, ethylene, polyethylene, biobutanol, polytrimethylene terephthalate, and biodiesel). Tianguan is developing many of the emerging technologies needed. Novel perspectives about three products from the proposed biorefinery are:

> *Polyethylene from ethanol:* The Chinese ethylene market in 2010 amounted to more than 2.6 million tons but China's current ethylene production is less than 50 percent of demand, resulting in significant import dependency. Thus, according to Tianguan representatives, converting their ethanol production (current market price $810–830 per metric ton) to ethylene ($1,220–1,310 per metric ton) and then to polyethylene ($1,400–1,500 per metric ton) could be economically feasible. Bioethylene production is also considered a critical step in developing the polyethylene industry in central China. Moreover, Sinopec (a Tianguan stakeholder) reportedly built a 9,000 t/year pilot plant in the 1980's to produce ethylene from ethanol and is said to be planning to upgrade this plant as part of a consortium to develop bioethylene biorefineries. Chinese universities and research centers are also working to address reported technical problems associated with the production of ethylene from ethanol.
>
> *Biobutanol:* Tianguan plans to import the needed grain for its biobutanol production facility. The product is intended for chemical use as "biofuels are still too expensive an application" for biobutanol.
>
> *CO_2:* Will increase CO_2 recovery to 40 percent and to use some of the CO_2 to produce biodegradable plastics would reduce use of petroleum-based plastics significantly.

NCPC SINOWIN Co., Ltd.–The company is the biofuels subsidiary of the North China Pharmaceutical Group Corporation (NCPC), an SOE. NCPC SINOWIN is both a drug development center and an environmental research center. Its annual commercial-scale production capacity for biobutanol is about 12,000 t/year. The company temporarily stopped biobutanol production in 2010 because the price of its corn feedstock became too high and the price of crude petroleum was too low (the company representatives candidly noted that their biobutanol is price competitive at crude petroleum prices of more than $120 per barrel). Among other process modifications, the company is studying alternative feedstocks for biobutanol, including cassava, sweet potato, and molasses, to help offset price swings in corn; they found, however, that sweet sorghum is not an effective alternative.

Box 4 Current and future production of biobased chemicals by Tianguan and NCPC-Continued

NCPC SINOWIN uses a *Clostridium* organism that has the ability to release the glucose from the starch feedstock and then convert it to acetone, butanol, and ethanol (ABE). The process yields about 23 percent by weight on the sugar substrate—3 parts acetone; 6 parts butanol; and 1 part ethanol. Sixteen fermenters are used, each having 300,000 liter capacity. Feedstock costs account for the largest share of total production costs (60-70 percent), followed by separation costs (20–30 percent). NCPC's goal is to develop a microorganism that will yield a higher concentration of butanol, thereby reducing separation costs. They said that U.S. companies use membrane separation but this is very costly.

Speaking of the future of biobutanol in China, the NCPC representatives said biobutanol will have a place in China if its price is similar to that of ethanol. But, they said, China's version of the U.S. Environmental Protection Agency would have to approve it before use and that blending approval would also be needed. They stated that the production costs for the biofuels could be offset by coproducts such as CO_2 and hydrogen; CO_2 can be used as a precursor for some of the petrochemicals to be produced and hydrogen can be used directly in the company's sorbitol production process.

Sources: Technical tours: Tianguan, August 17, 2010, and NCPC, August 20, 2010; various workshop speakers; Professor Pingkai Ouyang (president, Nanjing University of Technology), plenary speech at ICBT 2010; "ICIS Pricing: Ethanol (Asia)," May 5, 2010, "ICIS Pricing: Ethylene (Asia Pacific)," April 30, 2010, "ICIS Pricing: Polyethylene (Asia Pacific)," April 30, 2010.

Infrastructure expansion efforts underway in rural and urban areas are diverse, ranging from household solar and biogas projects to commercial-scale ventures, and each has its own challenges. For example, ethanol is extremely hygroscopic and will easily absorb water, affecting storage and distribution. As such, one infrastructure question related to the national rollout of E10 is whether high humidity levels in southern China would require a new infrastructure for distribution and use, rather than using existing gasoline distribution networks. In contrast, biobutanol, if used as a transportation fuel, is far less hygroscopic and can be more easily integrated into existing networks.

New biofuel production facilities are also being brought onstream. As with other technologies, China is rapidly developing such sites, particularly 2nd-generation, and standardizing them to the extent possible.[24] This speed parallels the development of fossil fuel refineries in China; 6 new 200,000 barrels per day refineries (or about 8.4 million gallons per day)[25] will be built by 2020, with one built every 18 months using a "cookie cutter" approach (Fu 2010).[26]

Financial considerations

Professor Shi stressed the importance of funding R&D if China's renewable energy goals are to be met, mentioning that RMB 5–10 billion (about $700 million–$1.4 billion) has been invested in clean energy during the 11th 5-Year Plan, with 50 percent focused on R&D for renewable energy. Investment in clean energy will have to increase as capacity grows. Chinese investment levels in green energy from 2009 through 2020 are expected to total RMB 5.4 trillion (about $800 billion) (J. Zhang 2010).

As in other countries, capital is necessary for the construction of precommercial and commercial facilities and, for some companies, in crossing the "Valley of Death" while bringing a product to market.[27] Funding sources in China vary, especially given the relative lack of domestic venture capital.[28] Tianguan, for example, an SOE, said it funds its own facilities. Another avenue for financing is foreign investment. Many foreign investors are said to have shown great interest in China's "inviting market" (Shi 2010), and there is considerable foreign investment in the bioenergy and biobased chemicals industries. Although, per the "Industrial Catalog for Foreign Investment (2007 Amendment)," foregin investment in the production of liquid biofuels such as

[24] Although this speed could reflect efficient coordination of projects and use of high-quality imported technology, such as the world-class fermentation plant control systems produced by Siemens and used in the Tianguan facility, quality may become an issue if it is not controlled well. One workshop participant said that China needs to monitor such situations closely.

[25] Using a conversion factor of 1 barrel of crude petroleum equals 42 gallons.

[26] China is also focusing on establishing and expanding industrial production sites. One proposal calls for the development of a "green valley" (an industrial park) near the Great Wall that will have solar, biomass, and other clean energy projects.

[27] The "Valley of Death" is the "funding gap" in the transition from research to commercialization of a product. Ford, Koutsky, and Spiwak, "A Valley Of Death In The Innovation Sequence: An Economic Investigation," September 2007.

[28] Professor Shi said that new rules and regulations are needed to encourage venture capital.

bioethanol and biodiesel is restricted in that the Chinese partner must hold the majority of the venture, at the time this article was prepared the 2007 catalog was expected to be updated but specific information was not yet available. Another source of funding—stimulus funding—was also said to be available for infrastructure projects during the economic downturn.[29] Also, as detailed more fully in an article from a Chinese journal, the CAS's "BiotechnologyInnovation & Bio-Industry Promotion Program" is expected to increase collaborative synergy between government, industry, academia, and finance.[30]

Government funding is available for research and commercialization. Examples include the National Basic Research Program 973, which covers the extension into applied research, and the National High-Tech Program 863, which supplies funding for applied research and then the next level—pilot scale tests. The National Supporting Program and the National Development and Reform Commission also provide funding for pilot plants and, in combination with company funding, support commercialization. Government funding to universities has also increased. In regard to CAU's funding for R&D, for example, Professor Dong stated that CAU received almost eight times more funding in 2009 than in 2001, a total of RMB 890 million (about $131 million) versus RMB 102 million (about $12 million).

Government funding methods cited by workshop speakers for commercial-scale projects include monetary incentives for biogas and ethanol projects and tax incentives for clean energy power projects, including biomass power generation (Huang and Shi 2010). In 2006, for example, the subsidy for fuel ethanol from grain was RMB 1,373 per ton of ethanol (or about $172 per ton) (J. Zhang 2010). In 2009, the government increased the subsidy to RMB 2,056 (about $302) before decreasing it to RMB 1,659 (about $244) in 2010. In addition to the facility's annual performance, one factor that affects the amount of the subsidy is whether companies are exceeding the allowed levels of grain; those that are will receive lower subsidies (J. Zhang 2010).

[29] China reportedly allocated about $47 billion in stimulus spending in 2008–09 to clean energy, versus about $67 billion in the United States. It was projected that much of the allocated funds would be spent in 2010–11. The Pew Charitable Trusts, "Who's winning the clean energy race?" March 2010, 11, 14, 20.

[30] Science and Technology Daily, "中科院生物技术创新与生物产业促进计划初显成效," June 17, 2010. The article was shared with the authors in follow-up discussions to the workshop.

Although some sources have speculated about the future removal of such monetary incentives, they continue to be an important factor affecting the competitiveness of biofuels. When asked about the break-even point past which E10 would be considered competitive, a representative of Henan Tianguan Enterprise Group Co., Ltd., stated about RMB 9,000 per ton (with the observation that they are currently at about RMB 7,000 (about $1,029 at the time of the workshop)).[31] While this figure is an estimate for only one facility, it was considered an unusually candid conformation of the continued significance of monetary incentives and support to the industry. The production of co-products such as bio-based chemicals is also expected to make the biorefineries more cost-effective.

Carbon credits and a carbon tax are other sources of clean energy funding in China. GE, referring to the Anaerobic System in the Chicken Farm of MinHe project, says, "Backed by the International Bank for Reconstruction and Development, the project is receiving financial support through the sale of carbon credits called Certified Emission Reductions (CERs)."[32] Dr. J. Zhang said that a carbon tax was collected in 2009 from petroleum and coal companies to subsidize clean energy projects. He added that the government has not developed such policies for nongrain production, though, because such projects are "currently part of the energy mix" and that good policies are needed to strengthen the biomass industry and to meet the 2020 goals. Dr. Xingguo Fu (2010) also stated that the National Bureau of Energy is interested in an aviation fuel program and it is likely there will be a carbon tax of about RMB 500 (about $74) per metric ton of CO2 if biofuels are not used.

Funding for clean energy projects is also available through the Investment Association of China's Energy Research and Development Center, the public face of investment in NDRC-supported programs. Presenting information new to many of the workshop participants, Dr. J. Zhang said the projects are considered low risk for investors because they are NDRC projects. He added that RMB 300 million (about $44 million) was invested in 2009, much of it in solar energy projects.

[31] Tianguan representatives, technical tour, August 17, 2010. In this instance, the "break-even point" can generally be defined as the price point at which production or sales equals operating expenses without a profit or loss. Prices above the "break-even" point would generate a profit.

[32] "GE powers China's largest chicken waste biogas plant," September 25, 2009. In addition to being eligible for tax incentives, biomass power generation companies are also eligible for the sale of CER credits under the Kyoto Protocol.

Domestic and International Collaborations and Strategic Alliances

Domestic and international collaborations exist at the industry level, at universities, and in many combinations thereof. As is the case with many research-intensive high-technology industries (e.g., pharmaceuticals), such collaborations are initiated for numerous reasons, including: (1) efforts to mitigate the risks and costs involved in developing new technology; (2) the enhanced ability to share knowledge and technology within ongoing collaborations; and (3) the synergy generated by pooling individual companies/entities' specializations along the value chain, ranging from process technology to marketing.

Collaborations are underway at many Chinese universities. CAU is actively focusing on numerous international collaborations; it has "close relations" with USDA and research collaborations with many U.S. universities (Wang 2010). In 2006, Tianguan built a joint R&D center with Zhongshan University to develop biodegradable plastics from CO_2.[33] COFCO has collaborations with Tsinghua University, East China University of Science and Technology, Tianjin University, Harbin University of Technology, and others. CAS has also provided key contributions to the development of biofuels.

Chinese companies are participating in domestic and international strategic alliances, including 2nd-generation biofuel ventures, in part to defray costs and offset risks. International R&D collaboration is strongly promoted in China; China has historically entered into many collaborative ventures with countries such as Germany and the United States.[34] Professor Shi said that China and the United States should confront the "mutual crisis" by promoting renewable energy development, citing the U.S.-Chinese agreement to construct a clean energy research center as a step towards future sustainable development.

In one of NCPC's ongoing collaborations with DuPont, although not confirmed, the NCPC SINOWIN representatives said they sold the DuPont/BP biofuels venture its cell line—and the related details—for $500,000 (the cell line was developed by CAS). Tianguan is also very interested in establishing international collaborations outside China (Tianguan 2010). Foreign entities active in Chinese bioenergy and biobased

[33] Henan Tianguan, "Science," (accessed various dates).

[34] China has had projects with Germany since 1979; China also introduced U.S. technology converting sweet sorghum in the 1980s and has since improved the technology advancement process (Shi 2010).

chemicals technology exchange and alliances include Novozymes, Genencor,[35] UOP, and NREL, among others. In one example of information published in Chinese journals, international collaboration is also a focus of CAS' "Biotechnology Innovation & Bio-Industry Promotion Program."[36] Although China's recent indigenous innovation policies may impact innovations in bioenergy, several of the Chinese experts stated that China's international intellectual property collaboration will not be held up by such policies. When asked if these policies will affect joint ventures, representatives of NCPC SINOWIN, a bio-based chemicals producer, said that there are many mechanisms that can be used to enter the market.

In regard to collaborations and intellectual property rights, Dr. Lin of COFCO mentioned that work was underway on patenting the sweet sorghum varieties. He also mentioned Chinese and European patent activity related to COFCO's 2nd- generation ethanol production at its Zhaodong facility (feedstocks include straw or agricultural waste), with projected patent activity and/or technological development in India, Brazil, and the United States.

Conclusion

Speakers at the USDA-WSU-CAU Bioenergy Workshop and the technical tour representatives, all experts in bioenergy and bioproducts such as bio-based chemicals, provided a unique, "on-the-ground perspective" on current and future Chinese bioenergy and bioproduct research and commercialization. Drawing upon centuries of fermentation expertise, China is strongly promoting its bioeconomy, spurred in part by environmental issues, as well as food, energy, and national security concerns:

- ✓ China's primary energy source—coal—does not promote environmentally sustainable development;
- ✓ China's crude petroleum reserves are likely to be depleted after 11 years;
- ✓ As of the first quarter 2010, China's imports of crude petroleum reached 55 percent of its consumption;
- ✓ The country's burgeoning economy has boosted energy consumption significantly in many ways, ranging from increased manufacturing to use of a growing number of vehicles;

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[35] A Genencor press release, dated January 10, 2011, stated that DuPont had made a binding offer for Danisco A/S. Genencor is a division of Danisco.

[36] Scientific Times, "张知彬谈"中科院生物技术创新与生物产业促进计划," April 12, 2010. The article was shared with the authors in follow-up discussions to the workshop.

- ✓ China is not only providing electricity to rural areas but is also increasing power generation to towns and cities as the country undergoes continuing urbanization.

China is focusing on several types of renewable energy, including hydro, wind, solar, nuclear,[37] biomass, and biogas power generation, as well as liquid biofuels. The workshop speakers affirmed that China is investing heavily in renewable energy, with investment levels projected to increase to a total of RMB 5.4 trillion (about $800 billion) for the period 2009 through 2020. The central government is promoting supply-and-demand measures for bioenergy, as well as national funding programs to foster applied research and the transition to commercialization of bioenergy and other high-technology products. The NDRC also provides funding for pilot plants and, in combination with funding from companies, supports commercialization. The technology being commercialized originated in the CAS, in universities within China, in companies, or from international sources, as well as many combinations of these sources.

The cap on corn use in China because of food security concerns has spurred exploration and promotion of alternative feedstocks as biomass inputs for liquid biofuels, including, for ethanol, cassava and sweet sorghum and lignocellulosic inputs such as agricultural and forestry residue; various oil plants for biodiesel; and algae for aviation biofuels. Given the limited land available to supply many alternative crops, however, workshop speakers confirmed that imported feedstocks are also being used to meet Chinese demand in the near term (e.g., cassava). Throughout the workshop, the amount of available biomass in China was estimated at around 300 million tons, translating to potential production of about 25 billion gallons of ethanol.[38] However, it is not clear how much of this biomass would be available for fuel ethanol, given competition for other uses, including other bioenergy applications. The continued dependence of many pilot facilities on steam explosion pretreatment also indicates that financial and energy costs will be difficult to overcome without significant technical breakthroughs.

The production of biobased chemicals is being emphasized and expanded, either as co-products of biofuel production in integrated biorefineries or as stand-alone products with biobased inputs. In addition to the major bioprocess currently used (fermentation), enzymatic biocatalysis is being studied, with input from foreign collaborators. Biobutanol is increasingly being produced for chemical applications as companies do not consider it cost-effective as a biofuel.

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[37] China includes nuclear energy in its green power and renewable energy classifications. In comparison, the EIA defines nuclear energy as "nonrenewable." EIA, "Energy Kids," n.d.

[38] Using a conversion factor of 1 ton of biomass produces 80 gallons of ethanol,

The Chinese infrastructure for these products is growing accordingly, as is financing (with an emphasis on promoting venture capital) and standards development. Workshop speakers provided an unusually candid confirmation of the continued importance of monetary incentives and support, stating that E10 prices at the time of the workshop were still RMB 2,000 per ton (or almost $300 per ton) below the break-even point. They also stated that feed-in tariff subsidies mandated by the central government and GHG emission reduction payments are provided through the Clean Development Mechanism of the Kyoto Protocol. Carbon credits and a carbon tax are other sources of clean energy funding in China.

Demonstration plants in biofuels are also being brought onstream rapidly; biogas is being commercialized; and various sources of bioenergy are being combined to optimize power generation, particularly in rural areas. Domestic and international collaborations are expanding, spurring current and future innovations in liquid biofuels, bioenergy, and bioproducts, both for use in China and for export.

Technical Tour Representatives

Henan Tianguan Enterprise Group Co., Ltd.

Zhang, Xiao Yang
Senior Engineer, Senior Economist
Deputy to the 11th National People's Congress
Henan Tianguan Enterprise Group Co., Ltd. - President - General Manager
Henan Tianguan Fuel Ethanol Co., Ltd. - President

Wang, Lin Feng
Deputy General Manager, Senior Engineer
Director of Project Department
Henan Tianguan Enterprise Group Co., Ltd.

Du, Feng Guang
Chief Engineer
Henan Tianguan Enterprise Group Co., Ltd.

North China Pharmaceutical Group Corporation (NCPC) SINOWIN Co., Ltd.

Li, Li Qiang
General Manager, Senior Engineer

NCPC SINOWIN Co., Ltd.

Liu, Liqiang, Ph.D.
North China Pharmaceutical Biofuel Research Institute

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United States International Trade Commission
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The U.S. International Trade Commission's High-Technology Trade Roundtable

Discussion Summary

Web Version:
October 2011

Authors:
Falan Yinug and
Natalie Mabile[1]

Abstract

On June 22, 2011, the U.S. International Trade Commission hosted a roundtable discussion on high-technology trade and issues related to it. The roundtable drew participation from industry, government, and think tank representatives who provided their views on a number of current and future high-tech trade issues.

Introduction

The U.S. International Trade Commission (USITC) held the roundtable on high-technology (high-tech) trade to provide an informal forum for participants to discuss current and potential issues of interest in the high-tech trade area. The first part of the discussion was focused on high-tech trade issues in Asia; the second, on the impact

[1] Falan Yinug (Falan.Yinug@usitc.gov) is an international trade analyst from the Office of Industries. Natalie Mabile is an intern from the Office of Industries. This article summarizes views expressed by roundtable participants. These views are strictly those of the participants and do not represent the opinions of the U.S. International Trade Commission or of any of its commissioners. Even though the summary often cites instances of general agreement among some participants, this does not necessarily reflect a consensus view of every participant.

of global supply chains on high-tech trade. The participants addressed a number of major issues, including indigenous innovation, network security and standards, intellectual property (IP) infringement, and such supply-chain challenges as security, counterfeiting, tariff barriers, and risk mitigation. The following is a summary of the discussion.

High-Tech Trade Issues in Asia

Indigenous Innovation

Roundtable participants offered differing perspectives on the risk China's indigenous innovation policies pose to the United States. Several participants considered it too early to accurately evaluate the impact of these policies, and expressed interest in developing a better template to quantify the threat of harm to U.S. industries. Some attendees noted that the direct impact of China's innovation policies appears small so far, and that the policies may have a more deleterious effect on other Asian countries than on the United States, while others noted that these policies are already significantly hampering market access for U.S. companies. Participants noted that indigenous innovation policies linking government procurement to products whose IP is locally owned and developed have had the most direct harm to the U.S. high-tech industry thus far, but there is a broad array of other indigenous innovation policies that pose significant market access threats and could eliminate U.S. trade opportunities. Some said that any policy that shortchanges IP rights could obstruct global economic growth in the high-tech industry.

Additionally, roundtable speakers remarked that if other governments emulate China's indigenous innovation policies in their own countries, the result could be formidable for U.S. companies. The Governments of Brazil, India, and Russia are already reportedly considering policies similar to those emerging in China. However, one participant suggested that China's approach provides an opportunity for other countries in Southeast Asia to compete by offering an investment climate unlike China's.

Network Security

Participants noted that the impact of network security requirements on competitiveness in the high-tech sector is of great concern. Participants stated that in Asian markets, particularly China and India, the rationale for improved security is being used in part to restrict market access and to bolster indigenous companies. They said that while the General Agreement on Tariffs and Trade includes exceptions designed to allow governments to take certain measures related to security and privacy concerns, it does not justify many of China's restrictions. Addressing the challenge of dealing with restrictions based on improved security, some participants also reported the challenge of operating in countries where their own networks and data are not secure, especially from the host government. A suggested tactic to counter such practices is to increase transparency about them. One speaker claimed that if more companies reported attacks on their networks, the government would have more authority in telling the Chinese Government, for example, that such practices are unacceptable.

An emerging issue in network security is the requirement in some countries, such as Kazakhstan, that companies locate their data centers within those countries in order to operate in those same countries.

Noting that data regulation was not a major part of past trade agreement negotiations, participants recommended that the U.S. Government develop a more complete set of domestic and international policies on property rights and contracts. Participants agreed that the basis of an agreement with Asian nations concerning network security will be comprehensive domestic policies. Without providing specifics, participants said that until the United States has settled current issues within its domestic legal institutions, it will be difficult to negotiate global network security provisions.

The Trans-Pacific Partnership (TPP) and Encryption Standards

Participants discussed the potential role of the TPP as a model for new trade agreements, especially as a means of standardizing encryption regulations. Attendees noted the significance of the growing number of software and integrated products containing cryptographic capabilities. According to one participant, these capabilities are included due to great customer demand globally. Attendees urged the United States to emphasize to China and other Asian countries that implementing encryption standards that are in line with established international standards will ease the flow of important commercial products.

The Impact of Global Supply Chains on High-Tech Trade

Security Versus Trade Facilitation

Roundtable participants discussed the ability of producers of high-tech products to balance needs for safety and security with those for reliable and efficient supply chains. Attendees suggested that security and efficient supply chains need not be framed as competing needs; if a global supply chain is managed properly, it will increase security while also effectively facilitating the free flow of compliant goods. For example, it was mentioned that a certified importer program is reportedly in the works to establish end-to-end certification of a supply chain, which is intended to ensure product safety and the integrity of the supply chain. The program is initiated by a coalition consisting of high-tech companies, pharmaceutical firms, the U.S. Food and Drug Administration, and other organizations.

Some attendees noted that partnerships between the private sector and the government are necessary to make these types of systems work. Two participants asserted that to the extent government discussions of supply chains are classified, it creates a problem as companies often do not understand what risks exist, and therefore, do not change their practices to address those risks.

Counterfeit Goods and IP Infringement

Some participants expressed concern about counterfeit high-tech goods coming into the United States. Others noted concern about goods coming into the United States incorporating stolen U.S. technology (through IP infringement or other means). Companies reportedly continue to take advantage of the low costs associated with buying from suppliers who use stolen technology, despite U.S. regulations. In particular, counterfeit semiconductors and the use of unlicensed software by foreign businesses that export to the United States are said to be widespread, impeding fair competition. Some participants indicated the need to examine the trade tools available to address this problem. One suggested approach was to revive Section 301 of the Trade Act of 1974; however participants were not specific in how Section 301 ought to be used in this case. One participant suggested that the USITC work to enhance cooperation between U.S. Customs and Border Protection and the U.S. semiconductor industry to better enforce restrictions and to facilitate judicial action against counterfeiters and suppliers of infringing products.

Tariff Barriers

Speakers noted that while much of the discussion in the high-tech industry focuses on nontariff barriers to trade, the industry continues to face tariff issues, despite the Information Technology Agreement (ITA). One participant noted that the ITA has failed to deal entirely with these issues because some members have not fully respected the agreement, and because the ITA does not currently cover all high-tech goods. Participants agreed, however, that the ITA provides a suitable platform on which to build. Several attendees suggested that the U.S. Government should push for an expansion of the ITA, noting that expansion would take care of the next-generation trade problem of product convergence, allow for zero tariffs on many more products, and make global supply chains operate more cleanly and smoothly.

Globalization

Participants repeatedly mentioned the risks associated with using global supply chains, including natural disasters, physical piracy, IP piracy, and government regulatory efforts. However, some attendees suggested that such risks can be solved by more, rather than less, globalization, adding that globalization lowers transaction costs and reduces reliance on any one factory or company. Regardless of the associated risks, some attendees argued that a global supply chain system is more secure than a purely domestic system.

Final Comments

This summary focuses on the major issues raised by the majority of the speakers. Other issues mentioned, but not covered in detail during the roundtable included state-owned enterprises, the role of the internet in facilitating global exports, restricting sourcing from certain countries, and tools for spurring domestic innovation.

List of external participants at the USITC's High-Tech Trade Roundtable held on June 22, 2011

Name	Title/Affiliation
Grant Aldonas	Principal Managing Director Split Rock International
Bob Boorstin	Director of Corporate and Policy Communications Google Inc.
Meredith Broadbent	Senior Adviser and William M. Scholl Chair in International Business Center for Strategic and International Studies
Dorothy Dwoskin	Senior Director, Global Trade Policy and Strategy Microsoft Corporation
Becky Fraser	Senior Manager, Greater China U.S. Chamber of Commerce
Ed Gresser	Director, ProgressiveEconomy GlobalWorks Foundation
Vicki Hadfield	Senior Vice President, Global Public Policy TechAmerica
Marc Mealy	Vice President U.S. ASEAN Business Council
Michael Mullen	Executive Director Express Association of America
John Neuffer	Vice President for Global Policy Information Technology Industry Council
David Ohrenstein	Director of Public Policy and Emerging Markets Business Software Alliance
Michelle O'Neill	Deputy Under Secretary for International Trade U.S. Department of Commerce, International Trade Administration

Ryan Ong	Director of Business Advisory Services U.S.-China Business Council
Jim Sanford	Assistant U.S. Trade Representative for Small Business, Market Access, and Industrial Competitiveness Office of the U.S. Trade Representative
Ian Steff	Director, Government Affairs and International Trade Semiconductor Industry Association
David Weller	Partner WilmerHale

United States International Trade Commission
Journal of International Commerce and Economics

Can We Apply Lessons From the German Trade Balance With China to the United States?

Web Version:
January 2012

Author:
John B. Benedetto[1]

Abstract

In recent years, Germany has had higher per capita exports to China than the United States has had. Some policymakers and analysts have argued that the United States should attempt to replicate Germany's success in exporting manufactured products to China, or that Germany's relative success at exporting to China refutes those who attribute the U.S. trade deficit with China to Chinese government policies. This paper analyzes trade data and finds that a majority of Germany's exports to China likely consist of (1) mechanical and electrical intermediate and capital goods that are likely used in China's exports to other countries and (2) luxury cars. The paper then argues that, given this export profile, Germany's example does not offer a way for the United States to substantially reduce its trade deficit with China in a manner consistent with reducing global imbalances, and is potentially consistent with a model of the world in which some governments' policies exacerbate global imbalances.

[1] This article represents solely the views of the author and not the views of the United States International Trade Commission or any of its individual Commissioners. This paper should be cited as the work of the author only, and not as an official Commission document. The author thanks Michael Ferrantino and an anonymous referee for their comments. All errors are those of the author. Please direct all correspondence to John Benedetto, Office of Economics, U.S. International Trade Commission, 500 E Street, SW, Washington, DC 20436, email: John.Benedetto@usitc.gov.

Can We Apply Lessons From the German Trade Balance With China to the United States?

Over the last decade, German exports to China have been part of a relatively balanced trade relationship between China and Germany. Some policymakers and policy advisors have used the German example of a high-wage, developed country that is able to have high per capita exports to China as a potential model for other developed countries (including the United States, United Kingdom, and "peripheral" European Union countries). These policymakers and advisors have argued that the German trade relationship with China shows that a developed country can use policies designed to increase exports to China in order to balance high imports from China. Others have used Germany's trade relationship with China as an admonition for those in the United States who attribute the U.S. trade deficit with China to Chinese government policies, *i.e.*, if Germany can have a relatively balanced trade relationship with China, then the United States should be able to as well.

Are German exports to China really a potential model for the United States and other developed countries? This paper examines German exports to China at a 4-digit HS level, and finds that the majority of German exports to China fall into two categories: (1) inputs likely used to build or supply Chinese factories, many of which are producing for export; and (2) luxury motor vehicles. Although this export profile is different from the profile of U.S. exports to China, the paper finds that the German export model is likely not a model for other countries that wish to decrease their trade deficits with China in a manner consistent with reducing global trade imbalances. Exporting inputs to China does not resolve trade imbalances between China and the world, and luxury vehicles are an inherently limited market. Furthermore, the nature of German exports to China is consistent with a model of world trade in which global trade imbalances are created or exacerbated by Chinese (and other) governments' economic policies, and thus global trade imbalances cannot be reduced by having other developed countries imitate Germany.

I. The Recent German vs. U.S. Trade Relationship with China

Popular media accounts attribute an "economic renaissance" in Germany to Chinese demand for German-made products. For example, a 2010 *Washington Post* article described successful German exports of kitchens and kitchen appliances for the mass Chinese market (Faiola 2010). This trade relationship is sometimes contrasted to the U.S. trade relationship with China, in which there has been more tension over the large U.S. trade deficit with China (Hall 2010).

Germany runs a trade deficit with China, but it is not as large as the U.S. trade deficit with China, and per capita German exports to China are higher (and grew more quickly over 2005-2010) than per capita U.S. exports to China. These facts are shown in tables 1 and 2, and figure 1, which shows the ratio of German to U.S. per capita exports to China.

TABLE 1 U.S. and German Trade Deficits with China, 2004-2010

	German trade deficit with China		U.S. trade deficit with China	
Year	percent of GDP	billions of dollars	percent of GDP	*billions of dollars*
2004	0.4	9.7	1.4	162.3
2005	0.6	17.4	1.6	202.3
2006	0.7	20.4	1.7	234.1
2007	0.8	26.4	1.8	258.5
2008	0.7	25.0	1.9	268.0
2009	0.3	10.8	1.6	226.9
2010	0.4	12.4	1.9	273.1

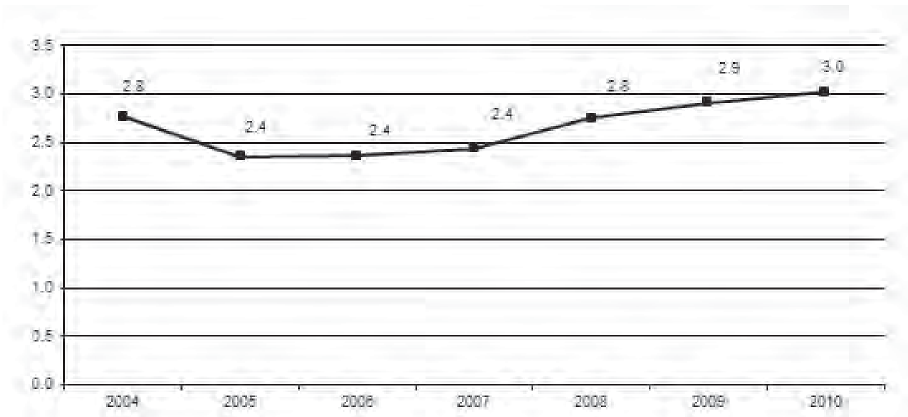
Sources: Global Trade Atlas, IMF (GDP data), and staff calculations.

TABLE 2 German and U.S. exports to China, in values and per capita, 2004-2010

	German exports to China		U.S. exports to China	
Year	billions of dollars	dollars per capita	billions of dollars	dollars per capita
2004	25.9	313.9	34.4	113.3
2005	26.1	316.1	41.2	134.3
2006	33.8	410.3	53.7	173.3
2007	40.5	491.3	62.9	201.2
2008	50.1	608.5	69.7	220.9
2009	52.2	635.3	69.5	218.0
2010	71.1	865.9	91.1	285.6

Sources: Global Trade Atlas (trade data), United Nations (population data), and staff calculations.

FIGURE 1 Ratio of per capita German exports to China to per capita U.S. exports to China



Sources: Global Trade Atlas, United Nations, and staff calculations.

It could be argued that Germany's trade relationship with China is merely an extension of its trade relationship with the world. Germany runs a merchandise trade surplus with the world as part of a current account surplus that stretches back to 2001.[2] Should we not simply see Germany's trade surplus with China as an extension of the German propensity to save, and not a policy question?

A current account surplus comes from government and corporate savings as well as household savings, and so we should not assume that German household savings explains German trade surpluses. Indeed, German household savings, as a percentage of national income, have been relatively stable since 1997, starting at 10.1 percent in 1997, hitting a low of 9.2 percent in 2000 and then reaching a high of 11.2 percent in 2008, while the German current account surplus has grown substantially.[3]

Meanwhile, the German government has run small financial deficits of up to 3.8 percent of GDP (in 2004) and a few small financial surpluses (as large as 1.3 percent of GDP in 2000).[4] It is possible that both German government and corporate savings rates have played a major role in German national savings, and these rates may be affected by some of the policies discussed later in this paper. Similarly, for the United States and China, national savings rates will be a function of corporate and government savings, and thus potentially affected by policies.

[2] OECD Factbook 2010 (2010).
[3] Ibid.
[4] OECD Economic Outlook (2011).

For example, policies to increase corporate profits in particular sectors could increase corporate savings, or policies to purchase other countries' currency could not only increase the government savings of the purchasing country but also lower interest rates (and possibly saving) in other countries.

Thus, for purposes of this paper, the question of whether the United States should attempt to replicate Germany's trade relationship with China will still be relevant whether global imbalances are framed as a national savings issue or as a trade balance issue.

II. Calls for Imitating the German Model

Popular media, think tanks, interest groups, and economists have called for the United States (and other developed nations) to study and imitate the German model for exporting to China. Among such popular media calls, *Newsweek* attributed the 2010 rebound in the German economy to its success in exporting to the Chinese economy, and asked if China's consumption could "jump-start the West" (Theil 2010). Similarly, *Time* concluded that Germany's export success in China showed that a "high-cost" economy could create jobs and export to China (Schuman 2011), and *The New Republic* instructed readers on how to learn from Germany's exports to China (Wagner 2010).

Among think tanks and interest groups, the American Chamber of Commerce in Shanghai published a September 2010 report on U.S. exports to China. The report bemoaned an alleged U.S. "underperformance" in exporting to China, and added that Germany was a "model for export promotion [in China]."[5] Ed Gerwin of the Third Way[6] used a *Wall Street Journal* blog to claim that "[w]hen it comes to exports, the United States could learn something from Germany," and called on U.S. policy to support U.S. exports of the kinds of capital goods that Germany exports (Gerwin 2010). Similarly, Katherine Newman, writing for the New America Foundation, uses Germany's exports of industrial products to China as a potential model for the United States (Newman 2011).

Some of these calls have also come as criticism of U.S.-based commentators who have attributed at least part of the U.S. trade deficit with China to Chinese government

[5] American Chamber of Commerce in Shanghai (2010).

[6] Third Way describes itself as a "a think tank that creates and advances moderate policy and political ideas." See http://www.thirdway.org/about_us , downloaded September 28, 2011.

policies. For example, Robert Roche of the American Chamber of Commerce in Shanghai has questioned those U.S. policymakers that wish to respond to Chinese currency policy by asking whether the United States ought not instead look at why other developed countries, including Germany, have been able to export successfully to China (Hall 2010). Additionally, German Finance Minister Wolfgang Schauble has criticized U.S. calls for a lower valued U.S. dollar as a boost to U.S. exports. He has instead attributed German success in exporting to China to the "increased competitiveness of companies" while the United States has been "neglecting its small and mid-sized industrial companies" (Spiegel 2010).

Beyond the United States, there have been calls for European countries, especially those that run large trade deficits, to follow the German model. Economists Jesus Felipe and Utsav Kumar argue that Europe's "periphery" (i.e., Greece, Ireland, Italy, Spain, and Portugal) need to move away from producing the type of products produced by China and instead "should look upward and try to move in the direction of Germany" by exporting the types of products that Germany exports (Felipe 2011). Similarly, John Lucas, trade policy advisor at the British Chambers of Commerce, has called for British policymakers to "target" increasing manufacturing exports to China, as he claims that Germany has done (Lucas 2010).

Finally, the Obama Administration has called for an increase in U.S. exports, and while not always citing exports to China in particular, has also noted Germany's success as a potential model. In January 2010, the Obama Administration announced its National Export Initiative with the goal of doubling U.S. exports by 2015 (Cooper 2010). While a member of the President Obama's Economic Recovery Advisory Board, General Electric CEO Jeff Immelt stated that "Germany is the model" for developing U.S. exports to China (Carney 2010).

Analysts have noted multiple German policies that may have helped the German manufacturing sector, including German laws requiring worker representation on company boards, restrained German wages even as productivity rose (DeNardis 2010), increased labor force flexibility, and German infrastructure spending.[7] Additionally, Germany's inclusion in the euro has provided it with a currency worth less than the value of what the deutsche mark would be worth today if it still existed.[8] Thus, the euro may give Germany a large net export advantage over other countries. Interestingly, one additional policy that is not mentioned often but might have also provided a

7 For example, see "NYSE Merger: Lessons from Germany Inc.", the Monitor's View, Christian Science Monitor, February 10, 2011.

8 Steven Rattner reports that if Germany left the euro, some estimate that its currency would appreciate 30 to 40 percent (Rattner 2011).

competitive advantage is the large, longtime, state ownership of major German firms such as Volkswagen.[9]

However, this paper does not discuss which German policies, if any, have led to Germany's trade relationship with China, nor whether these policies are worthy for other reasons. This paper also does not discuss whether reducing the U.S. trade deficit with China is a worthwhile policy goal, instead taking the goal as a given. The paper does ask what Germany exports to China, and whether that export outcome is one that the United States should seek to emulate if it wishes to increase its own exports to China in a manner consistent with reducing global imbalances.

III. What Does Germany Export to China?

German Exports of Inputs to China

In order to understand whether the United States or other developed countries should follow Germany's model of exporting to China, it is first necessary to understand what Germany exports to China. WITS data show that most German exports to China are capital goods (table 3).

To address the goal of increasing U.S. exports to China, we would like to distinguish not only capital goods from intermediate goods, but "final" goods (*i.e.*, goods that go from Germany to China and stay there) from "input" goods (*i.e.*, goods that go from Germany to China and are then used to produce another product that is in turn exported out of China). The importance of this distinction is to answer the question of whether German exports to China are building and fueling China's export machine, or whether those products are staying in China to supply Chinese consumption.

[9] From 1960 until at least 2007, the German state of Lower Saxony, in which most of Volkswagen's German employees live, was guaranteed by law to have at least 20 percent of voting shares in Volkswagen. In addition, labor representatives typically hold 50 percent of supervisory board seats of large German companies. See "VW Wheels, Porsche Driver?" Bloomberg Businessweek, October 23, 2007.

TABLE 3 German Exports to China by Category

Type of export	2008	2009	2010
		percent	
Raw materials	2.9	2.5	2.1
Intermediate goods	15.2	15.9	13.3
Consumer goods	19.9	20.9	25.9
Capital goods	62.0	60.8	58.8

Sources: WITS and author's calculations.

Note: Percentages may not sum to 100 for each year due to rounding.

For example, if Germany exports semiconductor-making equipment to China, and China uses that equipment to make products that stay in China for Chinese consumption, then the German export (of semiconductor-making equipment) can be part of a balanced trade relationship between China, Germany, and the world. On the other hand, if (as is more likely with semiconductor-making equipment) the German exports are helping China produce even more products for export to the world, then the German exports may exacerbate global imbalances (because they would necessarily be producing even more Chinese exports).

Thus, for the purposes of this paper, a Chinese final-use product is defined as one that is consumed in China, whether it is a household product, a capital good used to produce products for domestic consumption, or an intermediate product, *e.g.*, materials that go into a Chinese construction project for domestic use. Final-use products are distinguished from inputs, which (for the purposes of this paper) are capital goods and intermediate products used to produce exports.[10]

Trade data can not tell us with complete certainty which Chinese imports are used for Chinese domestic uses and which are used for producing exports. For example, an imported air conditioner might be used for a household; alternatively, it might be

[10] This question is similar to those asked by Koopman, Wang and Wei (2008) in their paper on value-added in Chinese exports to the United States, a paper that examines how much Chinese value-added is in Chinese exports to the United States. This paper examines whether a German export to China stays in China or produces more Chinese exports to other countries. Using their methodology, it may be possible in the future to take results from more recent Chinese data and identify how much German exports to China contribute to Chinese exports to the world. The methodology used here has the advantage of not relying on Chinese data and of being more current. It has the disadvantage of relying on the author's judgment as to which German exports to China are likely consumed in China versus contributing to Chinese exports.

used for a factory producing for export. Likewise, an imported semiconductor might be put into a computer consumed in China, and it might be put into a computer produced for export.

However, the lack of perfect certainty should not prevent some reasonable assumptions. This paper assumes it is reasonable that most semiconductors imported by China are incorporated into products exported from China, a large exporter of products that use semiconductors. It also assumes that most air conditioners imported by China are used for household use (although they could also be used in factories producing for export).

Thus, in order to determine the share of German exports to China that consists of inputs, a set of HS codes was constructed as a proxy for many of the inputs that are likely used primarily in the production of other Chinese exports. The codes used were contained in HS 84 (nuclear reactors, boilers, machinery and mechanical appliances, parts thereof) and HS 85 (electrical machinery and parts thereof). Obviously, input products are likely present in other two-digit codes; restricting analysis to just these two codes allows us to make a conservative estimate of German exports of inputs to China.

In order to try to isolate inputs, 4-digit subcodes that covered likely final-use products were removed from HS 84 and HS 85. Table A-1 in appendix A summarizes the codes removed from HS 84. Most of the exclusions are likely to be final use products; 8407 and 8409 are likely products that go into motor vehicles. China does export some motor vehicles, but runs an overall trade deficit in motor vehicles. In the interest of a conservative estimate of inputs, these codes were also classified as final goods. Similarly, table A-2 lists which HS 85 4-digit codes were classified as inputs and which codes were classified as final goods (and thus excluded). As with codes 8407 and 8409 above, codes 8511 and 8512 were excluded as automotive-related final goods, as parts that may go into motor vehicles.

Using these modified HS codes, table 4 shows that mechanical and electrical intermediate and capital goods represent a substantial share of Germany's exports to China over 2005-2010, while not accounting for as large a share of U.S. exports to China over the same period. Appendix B presents the values of German and U.S. exports under these modified HS codes. Additionally, the top ten German products exported under HS 84 and HS 85 to China are presented in Appendix C.

TABLE 4 Selected mechanical and electrical intermediate and capital goods as a percent of all U.S. and German exports to China

Country	2005	2006	2007	2008	2009	2010
	Selected mechanical and electrical intermediate and capital goods as a percentage of all exports to China					
Germany	47.0	43.0	43.1	43.7	41.6	37.8
United States	25.2	27.2	25.3	24.4	20.6	20.3
	Selected mechanical and electrical intermediate and capital goods as a percent of all exports to countries other than China					
Germany	20.7	20.8	20.5	21.1	20.2	20.2
United States	22.6	22.1	19.9	18.6	18.3	18.3

Sources: Global Trade Atlas and author's calculations.

Note: Selected mechanical and electrical intermediate and capital goods consists of selected parts of HS codes 84 and 85 (see Appendix A), and represents inputs.

As can be seen from table 4, mechanical and electrical intermediate and capital goods represent at least 37 percent of German exports to China in every year from 2005-2010, while representing one-fifth to one-quarter of U.S. exports to China in any year.[11] As we shall see later, the declining share of these products in German exports to China is largely due to a sharp increase in the share of German motor vehicles to China, and not to reduced exports of these products (as can be seen in Appendix B).

German Exports of Motor Vehicles to China

One of the other most successful areas for recent German exports to China is in the automotive sector, and especially in vehicle exports, as can be seen in table 5. German exports have surged from $1.3 billion in 2005 to $9.6 billion in 2010, and now account for roughly one-sixth of German exports to China.

[11] Other large U.S. exports to China include those falling under HS codes 12 (oil seeds- mostly soybeans to China), 88 (aircraft and parts), 90 (precision instruments and parts), 87 (motor vehicles and parts, discussed below), metals under codes 72 (iron and steel- mostly waste and scrap to China), 74 (copper- mostly waste and scrap to China) and 76 (aluminum- mostly waste and scrap to China).

TABLE 5 German Exports of Motor Vehicles to China and the Rest of the World

	German Exports of Motor Vehicles to China		German Exports of Motor Vehicles to All Countries Except China	
Year	*Billions of dollars*	*As a percent of all German exports to China*	*Billions of dollars*	*As a percent of all German exports to all countries except China*
2005	1.3	5.0	107.1	11.4
2006	2.3	6.7	113.6	10.6
2007	3.4	8.5	136.9	10.7
2008	5.0	10.0	136.0	9.7
2009	5.8	11.1	97.9	9.2
2010	12.0	16.9	117.8	9.9

Source: Global Trade Atlas data and author's calculations.

However, the unit value data for these exports suggest that German exports of motor vehicles to China are likely to be chiefly luxury vehicles, and not vehicles for the mass market. Table 6 compares unit values for German exports of motor vehicles (HS 8703) to selected countries. As the table shows, German exports of motor vehicles to China are priced similarly to those exported to Oman, Ecuador, Kuwait, and Uganda rather than those exported to the United States, Australia, France, Italy, or the United Kingdom (countries with developed mass markets).[12]

It should also be noted that foreign-produced vehicles remain a small part of the Chinese automotive market.[13] Germany may be capturing a substantial portion of that small import share through its sales of what are likely luxury vehicles, but it is

[12] The relatively high price of German motor vehicles to China does not seem to be due to engine capacity. The 2010 average unit value for exports of large-capacity German motor vehicles to China was $82,246, compared to $61,723 for German exports to the world. Similarly, the 2010 average unit value for exports of small-capacity German motor vehicles to China was $41,579, compared to $25,808 for German exports to the world. Thus, China is buying more expensive Germany vehicles of both large and small engine capacities.

[13] According to the China Association of Automobile Manufacturers, Chinese sales of passenger automobiles were 13.8 million units in 2010. However, data from Global Trade Atlas show that Chinese imports of automobiles over the same period were only 0.8 million units, or less than 6 percent of the total Chinese automobile market. See Global Trade Atlas and *http://www.caam.org.cn/AutomotivesStatistics/20110121/1105051627.html* (Downloaded August 12, 2011).

not clear whether the United States would gain much from copying this approach. If the import market share of the Chinese automotive market is small and luxury-car-

TABLE 6 2010 Average Unit Values of German Exports of Motor Vehicles to Selected Countries, in U.S. dollars

Country	Average Unit Value for HS Code 8703
Oman	$51,639
Ecuador	49,637
China	**47,845**
Uganda	47,777
Kuwait	47,455
United States	33,735
Australia	31,569
France	25,598
Italy	24,688
United Kingdom	23,666

Source: Global Trade Atlas using code 8703 for German exports to China.

oriented because of Chinese government policy, then there is an upper limit on potential exports without taking policy steps to further open this market.

Inputs and Luxury Cars

German exports of inputs and German exports of automotive vehicles that likely supply the luxury car market in China together represent at least 49.7 percent, and usually a majority, of German exports to China in every year from 2004-2010. These products represent a smaller share of U.S. exports to China, as can be seen in table 7. To some extent, these differences reflect differences in German and U.S. exports to the rest of the world, but as Table 7 shows, there is a larger difference between German and U.S. exports to China than there is between German and U.S. exports to the rest of the world. German and U.S. exports to China, then, differ in that Germany has enjoyed greater success in exporting inputs and luxury vehicles to China. If the United States is to imitate the German example, it will need greater exports of inputs and luxury vehicles to China.

TABLE 7 Passenger motor vehicles and selected mechanical and electrical intermediate and capital goods as a percent of all U.S. and German exports to China

HS	2005	2006	2007	2008	2009	2010
	Passenger motor vehicles and selected mechanical and electrical intermediate and capital goods as a percent of all exports to China					
Germany	52.0	49.7	51.6	53.8	52.7	54.7
United States	26.2	28.3	26.6	26.0	22.2	24.1
	Passenger motor vehicles and selected mechanical and electrical intermediate and capital goods as a percent of all exports to all countries except China					
Germany	32.1	31.4	31.2	30.8	29.3	30.1
United States	26.2	25.6	23.9	22.7	21.1	21.3

Sources: Global Trade Atlas and author's calculations.

Note: The data presented consist of selected parts of HS codes 84 (see Table 3), selected parts of 85 (see Appendix A), and 8703.

IV. Policy Implications

A closer look at the trade data allows us to draw some conclusions about the German export record to China and its relevance to U.S. policymakers seeking to reduce the U.S. trade deficit with China.

First, to the extent that any popular description of Germany's success in exporting to China attribute that success to the export of finished goods to the Chinese mass market,[14] these descriptions are not an accurate reflection of most German exports to China, as the majority of such exports is either inputs or luxury vehicles.

Second, if the United States were to replicate German exports to China, the results would likely disappoint those who seek to reduce the U.S. trade deficit with China or to reduce global imbalances. To the extent German exports of inputs to China are used in China to produce products for export, such German exports do not reduce global imbalances; they exacerbate them. Thus, the export of inputs to China fuels more Chinese net exports to the rest of the world, with the United States being China's largest export destination. Even if other countries take some of the market share of German exports of capital equipment to China, they will likely only take Germany's place in globally imbalanced supply chains, not solve the underlying problem of global

[14] For example, see Faiola (2010).

imbalance. Indeed, the trade data offer some support for economist Sergio DeNardis' contention that "if all European countries tried to become like Germany, disruptive mercantilist attitudes would surely result."[15]

More informed descriptions of Germany's success in exporting to China do acknowledge that success has been based on capital equipment exports. For example, the aforementioned work by Gerwin and Newman as well as Felipe and Kumar acknowledge the fact that a large portion of German exports to China is capital goods and intermediate inputs, while still calling on the United States or peripheral Europe to imitate Germany's export pattern.[16]

The problem with even these more informed descriptions is that they lead to a policy conclusion that fundamentally conflicts with the notion of more balanced global trade: more developed countries cannot balance their exports and imports by shipping inputs to other countries, when those other countries are going to use those inputs to produce even more exports to the world.

Finally, German trade flows to China may provide some insight into German policymakers' statements on U.S. policy toward China. For example, Foreign Minister Schauble has criticized proposed U.S. action on other countries' currency policies, as well as describing the Federal Reserve's policy of monetary easing as "artificially depress[ing] the dollar exchange rate" (Spiegel 2010). Given what the trade data show, it is conceivable that the German Government's primary interest lies in helping its exporters that are building China's factories and producing luxury cars for those factories' Chinese owners and managers. Thus, these German Government criticisms may perhaps be viewed as coming from a party with an interest in the preservation of current global imbalances.

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[15] DeNardis here is referring to high German exports to the rest of the Eurozone, but his statement would also apply to other countries taking capital equipment exports to China away from Germany while global imbalances persist. See De Nardis (2010)

[16] Similarly, *The Economist* noted in 2010 that Germany's export success to China has been rooted in exports of capital goods and cars. However, *The Economist* too, in a vaguely worded recommendation, added that "other economies should perhaps think about the implications" of Germany's exports to China, perhaps indicating that other countries should imitate Germany's model. *See The Economist* (2010).

Appendix A
Definitions of Input Products in HS 84 and 85

TABLE A-1 Definitions of HS codes removed from HS 84

HS Code	Definition
8407	Internal combustion piston engines
8409	Internal combustion engine parts
8415	Air conditioning machines
8416	Furnace burners and mechanical stokers
8418	Refrigerators and freezers
8422	Dishwashing and other cleaning machines
8443	Printing machinery
8450	Washing machines
8469	Typewriters
8470	Calculating machines and cash registers
8471	Automatic data processing machines
8472	Office machines
8476	Vending machines

Source: Author's summary of Harmonized System codes.

TABLE A-2 Categorization of 4-Digit HS 85 codes as inputs or final goods

HS Code	Description	Input	Final
8501	Electric motors and generators (excluding generator sets)	X	
8502	Electric generating sets and rotary converters	X	
8503	Parts of electric motors, generators, generating sets, and rotary converters	X	
8504	Electrical transformers, static converters or inductors, power supplies for ADP machines or units; parts thereof	X	
8505	Electromagnets, permanent magnets and articles to be permanent after magnetization; electromagnetic or permanent magnet chucks, brakes, etc.; parts	X	
8506	Primary cells and primary batteries; parts thereof	X	
8507	Electric storage batteries, including separators thereof; parts thereof	X	
8508	Vacuum cleaners, parts thereof		X
8509	Electromechanical domestic appliances, with self-contained electric motor, other than vacuum cleaners; parts thereof		X
8510	Electric shavers and hair clippers and hair-removing appliances, with self-contained electric motor; parts thereof		X
8511	Electrical ignition or starting equipment used for spark-ignition or compression-ignition internal combustion engines, generators etc. therefor; parts		X
8512	Electrical lighting or signaling equipment NESIO, windshield wipers, defrosters, and demisters used for cycles or motor vehicles; parts thereof		X
8513	Portable electrical lamps designed to function on own energy source (dry batteries, storage batteries, magnetos) except for motor vehicles etc.; parts		X
8514	Industrial or laboratory electric furnaces and ovens; other industrial or laboratory induction or dielectric heating equipment; parts thereof	X	
8515	Electric laser, other light or photon beam etc. apparatus, for soldering or welding, etc.; electric machines for hot spraying of metals; parts thereof	X	
8516	Electric water heaters, etc., space and soil heating apparatus, electrothermic hair apparatus (curlers, etc.), hand dryers, flatirons, etc.; parts		X

Table continues on next page.

TABLE A-2 –*Continued* Categorization of 4-Digit HS 85 codes as inputs or final goods

HS Code	Description	Input	Final
8517	Telephone sets, including telephones for cellular networks or for other wireless networks; other apparatus for the transmission or reception		X
8518	Microphones and stands therefor; loudspeakers; headphones, earphones, etc.; audio-frequency electric amplifiers; electric sound amplifier sets; parts		X
8519	Sound recording or reproducing apparatus		X
8520	Magnetic tape recorders and other sound recording apparatus, whether or not incorporating a sound reproducing device		X
8521	Video recording or reproducing apparatus, whether or not incorporating a video tuner		X
8522	Parts and accessories suitable for use solely or principally with the apparatus of 8519 to 8521	X	
8523	Discs, tapes, solid-state non-volatile storage devices, “smart cards” and other media for the recording of sound or of other phenomena		X
8524	Records, tapes and other recorded media for sound or other similarly recorded phenomena, including matrices and masters for the production of records		X
8525	Transmission apparatus for radiobroadcasting or TV; TV cameras; still image video cameras and recorders		X
8526	Radar apparatus, radio navigational aid apparatus and radio remote control apparatus		X
8527	Reception apparatus for radio broadcasting, whether or not combined with sounds recording or reproducing apparatus		X
8528	Monitors and projectors, not incorporating television reception apparatus; reception apparatus for television, whether or not incorporating		X
8529	Parts for television, radio, and radar apparatus (of headings 8525 to 8528)	X	
8530	Electrical signaling, safety or traffic control equipment for railways, roads, inland waterways, parking facilities etc.; parts thereof		X
8531	Electric sound or visual signaling apparatus (bells, sirens, burglar or fire alarms, etc.) NESOI; and parts thereof		X

Table continues on next page.

TABLE A-2 –*Continued* Categorization of 4-Digit HS 85 codes as inputs or final goods

HS Code	Description	Input	Final
8532	Electrical capacitors, fixed, variable or adjustable (pre-set); parts thereof	X	
8533	Electrical resistors (including rheostats and potentiometers), other than heating resistors; parts thereo	X	
8534	Printed circuits	X	
8535	Electrical apparatus for switching or protecting electrical circuits, or for making connections to or in electrical circuits	X	
8536	Electrical apparatus for switching or protecting electrical circuits, or for making connections to or in electrical circuits	X	
8537	Boards, panels, etc. with two or more appartus for switching, etc., electrical circuits (heading 8535, 8536) or optical etc. instrument of chapter 90	X	
8538	Parts for electrical apparatus for switching etc. electrical circuits (of heading 8535 or 8536) and panels, boards, consoles etc. (of heading 8537)	X	
8539	Electric filament or discharge lamps, including sealed beam lamp units and ultraviolet or infrared lamps, arc lamps, parts thereof	X	
8540	Thermionic, cold cathode or photocathode tubes (vacuum, vapor, or gas filled tubes, cathode ray tubes, television camera tubes etc); parts thereof	X	
8541	Diodes, transistors and similar devices; photosensitive semiconductor devices; light emitting diodes; mounted piezoelectric crystals; parts thereof	X	
8542	Electronic integrated circuits; parts thereof	X	
8543	Electrical machines and apparatus having individual functions, NESOI; parts thereof	X	
8544	Insulated wire, cable and other insulated electrical conductors; optical fiber cables, of individually sheathed fibers, with conductors etc. or not	X	

Table continues on next page.

TABLE A-2 –*Continued* Categorization of 4-Digit HS 85 codes as inputs or final goods

HS Code	Description	Input	Final
8545	Carbon electrodes, carbon brushes, lamp carbons, battery carbons and other articles of graphite or other carbon used for electrical purposes	X	
8546	Electrical insulators of any material	X	
8547	Insulating fittings for electrical machines etc., primarily of insulating materials, conduit tubing etc. of base metal lined with insulating material	X	
8548	Waste and scrap of primary cells and batteries, spent primary cells and batteries, electrical parts of machinery or apparatus, NESOI	X	

Sources: Harmonized Tariff System and staff analysis.

Appendix B
U.S. and German Exports to China by Selected HS Categories

TABLE B-1 German exports to China by selected HS categories, *billions of U.S. dollars*

HS	2005	2006	2007	2008	2009	2010
	billions of dollars					
84[1]	8.9	10.1	11.9	14.8	14.8	18.4
85[2]	3.4	4.4	5.5	7.1	6.9	8.4
84, 85[3]	12.2	14.5	17.4	21.9	21.7	26.9
All	26.1	33.8	40.5	50.1	52.2	71.1

Sources: Global Trade Atlas and author's calculations.

Note: Lines 2 and 3 may not appear to sum to exactly line 4 due to rounding.

[1] Excludes exports under codes in table 3.
[2] Includes only exports of particular 4-digit codes; see table 3 and appendix A.
[3] The sum of all exports under the modified 84 and 85 categories.

TABLE B-2 U.S. exports to China by selected HS categories, *billions of U.S. dollars*

HS	2005	2006	2007	2008	2009	2010
	billions of dollars					
84[1]	5.1	6.1	7.0	7.7	6.9	9.3
85[2]	5.3	8.5	8.9	9.3	7.4	9.3
84, 85[3]	10.4	14.6	15.9	17.0	14.3	18.6
All	41.2	53.7	62.9	69.7	69.5	91.9

Sources: Global Trade Atlas and author's calculations.

Note: Lines 2 and 3 may not appear to sum to exactly line 4 due to rounding.

[1] Excludes exports under codes in table 3.
[2] Includes only exports of particular 4-digit codes; see table 3 and appendix A.
[3] The sum of all exports under the modified 84 and 85 categories.

Appendix C
Top German Exports to China of Mechanical and Electrical Intermediate and Capital Input Products

TABLE C-1 Top ten 2010 German exports to China of input products in HS codes 84 and 85

4-digit HS Code	Description	2010 Exports to China (billions of U.S. dollars)
HS 84		
8479	Machines and mechanical appliances[1]	1.6
8483	Transmissions, bearings, gears, etc.	1.2
8486	Machines and appliances for manufacturing semiconductors and flat panel displays	1.2
8481	Taps, valves, and shafts for pipes; boilers	1.0
8413	Pumps for liquids	0.9
8414	Air or vacuum pumps (air compressors)[2]	0.8
8477	Machinery for working rubber or plastics	0.8
8421	Centrifuges, purifying and filtering machinery	0.7
8419	Machinery for treatment of chemicals by change in temperature, including water heaters and parts	0.6
8482	Ball or roller bearings	0.6
HS 85		
8504	Electrical transformers	1.3
8537	Boards for switching electrical circuits	1.1
8536	Electrical apparatus for switching electrical circuits	1.0
8538	Boards for switching electrical circuits	0.7
8501	Electrical motors and generators	0.5
8542	Electronic integrated circuits	0.5
8541	Diodes, transistors, and photosensitive semiconductors	0.5
8543	Electrical machines and apparatus	0.4
8535	Electrical apparatus for switching circuits	0.3
8544	Insulated wire and cable and conductors	0.3

TABLE C-1–*Continued* Top ten 2010 German exports to China of input products in HS codes 84 and 85

Sources: WITS (for order of products), Global Trade Atlas (for data) and author's summary of HS codes.

Note: HS 8409, 8422, and 8443 would be the eighth-, tenth-, and eleventh-largest German exports (respectively) under 84, but are not included in this table because they were excluded from tables 4 and 7.

[1] Most of the German exports to China in this category are under 8479.89 (an "other" category), 8479.90 (parts of 8479), 8479.30 (presses for manufacture of particle board or treatment of wood), and 8479.82 (mixing and grinding machines).

[2] Most of the German exports to China in this category are under 8414.80 (air or gas compressors), 8414.10 (vacuum pumps), 8414.90 (parts of vacuum pumps), and 8414.59 (fans).

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Comment on "Innovation and Job Creation in a Global Economy: The Case of Apple's iPod," by Greg Linden, Jason Dedrick, and Kenneth L. Kraemer (*JICE* Vol. 3, No. 1, May 2011).

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Author:
José Alberro, Ph. D[1]
Berkeley Research Group

[1] This article represents solely the views of the author and not the views of the U.S. International Trade Commission or any of its individual Commissioners. This paper should be cited as the work of the author only, and not as an official Commission document.

Making Sure ALL Jobs are Counted

INTRODUCTION

In a nice paper recently published in this review, Greg Linden, Jason Dedrick, and Kenneth L. Kraemer look at the global value chain "that designs, builds, and brings iPods to consumers" and they estimate the jobs and wages sustained by this innovative product line.[2] As the authors state, their ulterior purpose is to shed light on the issue of innovation and job creation: how many jobs are created by industries that innovate? How many of those jobs are in the United States and how many abroad? Are some or all of those jobs well paid? Their conclusions are "that, in 2006, the iPod supported nearly twice as many jobs offshore as in the United States. Yet the total wages paid in the United States amounted to more than twice as much as those paid overseas."

Although the Linden, Dedrick, and Kraemer results are interesting, they incorporate neither the impact of interindustry relations nor the flows of economic transactions that result from those relations. Once those matters are taken into account, the total number of jobs in the United States increases significantly, materially deviating from the three authors' conclusions. In fact, the iPod supports two and one-half times as many jobs in the United States as the three authors have estimated.

INDUSTRIAL INTERDEPENDENCE AND JOB CREATION

The interdependence of industrial sectors has long been recognized as a feature of advanced economies, and Input-Output (I-O) Tables and Social Accounting Matrices (SAMs) are recognized as the proper methodology to estimate the impact of exogenous shocks. The use of I-O tables to address public policy issues related to job creation goes back to the 1940s and 1950s when the Bureau of Labor Statistics used the 1939 I-O table to analyze the degree to which different policies could contribute to full

[2] Linden, Dedrick, and Kraemer, "Innovation and Job Creation in a Global Economy," May 2011. The authors have declined to respond to this comment.

employment in the postwar years.[3] The association to the existence of unemployed resources is essential because in a full-employment economy the resources—including jobs—shift from nonperforming sectors to expanding ones with—by definition—no change in employment. The use of I-O tables and SAMs makes sense if and only if there are unemployed resources, which is precisely the context in which the innovation-employment tradeoff becomes relevant. If innovation did not cause unemployment, it would be unambiguously heralded for its positive effects on efficiency, growth, and welfare.

Linden, Dedrick, and Kraemer estimate that the iPod value chain creates 41,170 jobs—13,920 of them in the United States and 27,250 in the Asia-Pacific region. Table 1 offers the details. Notice that the inputs required to manufacture hard disk drives (HDD) are explicitly taken into account, but this is not the case for the inputs needed to produce the flash memory, the other chips, the PCB assembly, the display panels or the modules required to assemble an iPod. Input production can create more jobs than the final assembly of the product. Indeed, according to the authors, the former accounts for 6,585 jobs while HDD manufacturing *per se* requires 4,400 direct jobs. Although none of these jobs is in the United States, it is likely that part of the inputs required to manufacture the HDD inputs or the inputs of the flash memory, display panels, etc. does come from the United States. As the authors calculate, 60% of the production jobs are in China and, as the World Trade Organization points out, in 2005, 71% of U.S. exports to China were intermediate goods.[4]

What is more important for the discussion of the relationship between innovation and job creation is the fact that the 6,101 professional jobs (primarily at Apple's headquarters) and the 7,789 nonprofessional jobs (primarily in retail and distribution) are in the United States and that the jobs needed to produce the inputs necessary for those activities are NOT taken into account by Linden, Dedrick, and Kraemer.

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[3] Horowitz and Planting, *Concepts and Methods of the U.S. Input-Output Accounts*, 2009.

[4] World Trade Organization (WTO) and Institute of Developing Economies – Japan External Trade Organization (IDE-JETRO), *Trade Patterns and Global Value Chains in East Asia*, 2011.

Table 1 iPod-related jobs in the value chain, 2006

	United States	Non-United States	Locations
Hard-drive (HDD) manufacturing		2,200	China
		2,200	Philippines
HDD inputs		2,550	China
		2,550	Philippines
		840	Japan
		800	Thailand
		800	Singapore
Flash memory		1,200	Korea
		20	China
Other chips	10	140	Taiwan
		25	Various
PCB assembly and test		600	China
Display panels and modules		900	Japan
Other inputs		3,500	China
		100	Japan
		100	Taiwan
Final iPod assembly		3,400	China
		100	Taiwan
Apple engineers	700		
Apple managers/professionals	5,046	75	Singapore
		75	Various
APPLE NONPROFESIONAL	1,554	75	Singapore
		75	Various
Distribution	150	150	Various
Freight	250	250	Various
Apple store	1,785	200	Various
Other retailers	3,675	3,675	Various
Third-party online sales	650	650	Various
Total	13,920	27,250	

Source: Linden, Dedrick, and Kraemer, "Innovation and Job Creation in a Global Economy," May 2011.

COUNTING ALL THE JOBS CREATED IN THE UNITED STATES

The appropriate means to measure the total number of iPod-related jobs in the United States should recognize that the true number is higher than the number of jobs directly involved. For example, the manufacture of flash memory may require, among other things, etching equipment, microlithography equipment, thin layer deposition equipment, nonferrous metals, basic inorganic chemicals, and so on. Only the goods and services manufactured or sold in the United States should be included in this estimation because those acquired in another country create jobs in those locations but not in the United States. Input-Output models quantify interindustry linkages in a way that allows the ripple effects of the initial job creation to be determined. Those effects (on employment, output, tax revenues, or income) are classified as "direct," "indirect," or "induced"—

- Direct effects are generated by the initial exogenous shock.
- Indirect effects result from the expansion of supplier industries whose products are used by those producing the goods and services directly acquired (for example, hard disks; flash memories but also distribution, transportation or retail services).
- Induced effects reflect the expansion of overall economic activity that results from the increased purchases of consumer goods and services by the workers considered in the previous two paragraphs.

It is reasonable to assume that the indirect and induced effects associated with the 27,250 jobs located in the Asia-Pacific region will stay there. It is equally reasonable to assume that the 13,920 iPod-related jobs in the United States will have significant indirect and induced effects in the United States.[5] To estimate these effects, I use a model developed by IMPLAN, which considers 440 industrial sectors, 9 types of households differentiated by income levels, 4 types of government spending, 22 types of taxes and transfers, and 4 types of investment flows.[6]

[5] All leakages caused by imports of inputs or other goods are taken into account in these estimations.

[6] IMPLAN Web site, *http://implan.com/V3/Index.php* (accessed November 15, 2011).

The 13,920 direct jobs in the United States lead to 4,100 indirect jobs in diverse sectors like advertising, warehousing, insurance, telecommunications, or refined petroleum products. In addition, there will be 18,100 jobs to produce the goods and services consumed by the 18,020 (13,920+4,100) previous jobs. Linden, Dedrick, and Kraemer estimate that the wages paid in the United States amount to $745 million ($525 million paid to professional workers and $220 million to nonprofessional ones) but do not take into account the disposition of those earnings. The 18,020 020 jobs are needed to generate the goods and services consumed with those $745 million of income. In one sentence, the iPod value chain does NOT need 13,920 jobs in the United States but 36,120 (13,920+4,100+18,100), which is 2.6 times more—a material difference.

CONCLUSION

Assumptions about the "vanishing middle class" and the destruction of blue-collar jobs underlie many current public policy discussions. Automation, supply chain fragmentation, and delocalization have been made responsible for the loss of many jobs in the United States. U.S. companies continue to design and bring to market innovative products creating well-paid jobs for American workers even if the actual product is manufactured overseas. Research and development and corporate support functions do create indirect jobs, and so do the retail, transportation, and warehousing functions contemplated by the authors.

More structural analysis of the productive sector is needed to determine whether well-paid jobs are evaporating or whether they are not, as a result of innovation. The recent iPod case study is a nice but an incomplete parable of the profound changes that are dislocating the U.S. manufacturing structure. To properly ascertain the magnitude of the effect on employment, it is crucial—particularly in a time of high unemployment—to count all the jobs.

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