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Industrialization in hog production: Implications for Midwest agriculture

Gary L. Benjamin

The five states of the Seventh Federal Reserve District have dominated U.S. hog production for decades.\(^1\) Iowa, Illinois, and Indiana rank among the top five states in terms of the number of hogs on farms, and District states have accounted for 48 percent of the roughly $11 billion in annual hog sales over the last five years. In line with this dominance, hogs are a major component of Midwest agriculture. Sales of all farm commodities in District states have approximated $32 billion annually over the last five years. Roughly one of every six of those dollars were generated by hogs. Only two commodities—corn and soybeans—generated more sales than hogs in District states (figure 1).

District states’ dominance in pork production has prevailed through a long history of structural change that parallels most components of U.S. agriculture. That history reflects a steep decline in the number of farms that raise hogs and a corresponding increase in the average size of those farms still in business. The structural change continues and at an accelerated pace. The latest phase of this structural change, labeled the *industrialization* of hog production, has been characterized by the expanding presence of very large, highly integrated pork producers, which now account for a sizable share of the industry. Other regions have proven more attractive to these so-called mega farms, causing a decline in the District states’ share of hog production in recent years. Because of some divisive issues that have surfaced with the large operations, there are fears that the Midwest’s role in hog production will continue to decline in the years ahead. The concern is magnified because a decline in Midwest hog production would likely be accompanied by a decline in the area’s related food processing activities. Moreover, a decline in Midwest hog production would also weaken local markets for the District’s key corn and soybean crops. Countering these concerns, however, others argue that the social and environmental problems associated with mega producers are too great to blindly pursue this economic activity for the Midwest.

Irrespective of these polar views, it is clear that mega producers have ushered in a new era for Midwest agriculture. This new era will likely recast the characteristics of production agriculture in the Midwest. It will also require balancing the growing environmental concerns associated with concentrated animal agriculture (especially in rural areas where the nonfarm population is growing) with the desire to maintain a competitive regional niche for an industry that is of significant economic importance.

The market for U.S. hogs

An overview of the market for U.S. hogs helps to identify the economic forces influencing the industrialization in hog production. Historically, the market was characterized by very slow growth, with the output of U.S. hog farmers—supplemented by modest net imports—going entirely to domestic consumers. But in

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terms of recent and prospective trends, there is considerable optimism about the potential for pork exports. This optimism has been reinforced by the recent trend in pork exports and the North American Free Trade Agreement and General Agreement on Tariffs and Trade signings. Indeed, a portion of the recent growth of mega producers has been geared to the export market. Since the mid-1980s, U.S. pork exports have risen sharply while pork imports have declined. In 1995, for the first time in 40 years, the U.S. became a net exporter of pork (figure 2). However, the net exports absorbed less than 1 percent of U.S. pork production last year. Moreover, the U.S. remains a net importer of live hogs. Net hog imports soared in 1995 and were equivalent to nearly 2 percent of the hogs processed in domestic packing plants, well above the normal share.

The domestic market still absorbs the bulk of all hogs raised in the U.S. The domestic pork market has recorded only nominal growth over the years despite declining real (inflation-adjusted) prices. Per capita consumption of all meats has trended slowly upward, rising about half a percentage point each year. But the mix in domestic meat consumption continues to shift, encompassing strong gains in poultry, a downturn in beef, and a relatively flat trend for pork (figure 3).

While demand for U.S. hogs has grown very slowly over the years, productivity gains have added significantly to supplies. The growing share of production from mega producers has probably accelerated the productivity gains. The continuing gains reflect a combination of technological advances in disease control, genetics, and management practices in the feeding and raising of hogs. The gains have led to more efficient use of the breeding herd, resulting in more litters per sow per year. Moreover, producers now wean more pigs per litter. In 1995, the average number of pigs weaned per litter reached 8.3, up nearly 8.5 percent from the average of ten years earlier. In addition, more efficient feed conversion ratios permit producers to raise pigs to market weight faster than was the case a few years ago. And at the packing plant, live weights and dressing yields have
edged up over time, generating more pork for every hog shipped to market.

Due to the sustained gains in productivity, the ratio of annual pork production per head of breeding stock has trended steadily upward over the years. In 1995, this ratio exceeded 2,500 pounds (carcass weight basis), up nearly 60 percent from the annual average during the late 1970s (figure 4). As a result of the productivity gains, hog farmers today can produce the same amount of pork as in 1980—the peak year for per capita pork production—using less labor, less feed, and an inventory of 20 percent fewer hogs.

Because of limited growth in demand for pork and continuing gains in productivity, the inventory of hogs on farms, irrespective of cyclical swings, has not changed much over the years. The inventory stood at 58.2 million head in December of 1995, up somewhat from the cyclical lows of 10 and 20 years earlier but still short of the cyclical highs of the early 1970s and the early 1980s (figure 5).

With little growth in market demand and with real hog and pork prices trending downward, the highly cyclical returns to assets used in raising hogs have often proved disappointing to farmers, despite the reputation of hogs as the
“mortgage lifter.” Low returns to capital and labor have pushed many farmers out of the hog business and prompted others to expand in order to achieve lower costs per unit of production. These conditions account for the long-prevailing downtrend in the number of hog farms and the simultaneous rise in their average size. As incredible as it may seem, the number of U.S. farms with hogs shrinks by one-third every five years. (Many of these farms continue to operate but are no longer involved in hog production.) Looking at the last 10 years, the decline in the number of hog farms (206,000) exceeds the number of hog farms in operation today (183,000). With the same economic forces driving the industrialization phenomenon, these trends will no doubt continue, and possibly at an accelerated pace. The rate of increase in the average size of hog farms has picked up in recent years with the arrival of the mega producers. And along with this recent trend, the District states’ share of hogs on farms has retreated to levels not experienced since at least the early 1960s. That share stood at 41.6 percent as of December 1995, down from 48.5 just four years earlier (figure 6).

**Other areas attracting the larger farms**

The data available for making regional comparisons of the industrialization in hog production are somewhat limited. Although the industrialization has roots in the 1980s, the most evident changes have occurred in the 1990s. The most current data are provided in quarterly reports by the U.S. Department of Agriculture (USDA). However, these data are highly aggregated and, for the most part, only available for the 16 major hog-raising states. As noted below, several minor states have attracted many of the new mega producers. Moreover, because of the cannibalization that can occur when large producers take over from small producers, these data do not fully capture the regional differences that might be occurring even within the more traditional states. On the other hand, the more detailed Agricultural Census data, which provide more refined farm size comparisons for all states broken down to the county level, are too dated (1992) to be
of much help in portraying the latest developments from the recent industrialization phenomenon. The following discussion is therefore based on the most current USDA data.

Among the major hog-raising states, the industrialization phenomenon has been especially apparent in North Carolina and, to a lesser extent, Missouri. Reflecting this, the average size of hog farms in North Carolina rose sixfold between 1989 and 1995, while the average in Missouri rose two and a half times. Those gains far exceed the 84 percent rise nationwide and the increases, ranging from 49 percent to 58 percent, among the top-ranked District states. Historically, Iowa, Illinois, and Indiana have had the largest hog farms, with averages in 1989 that were substantially above those for North Carolina and Missouri. But the average hog farm in North Carolina now has twice the number of hogs as that in Iowa, while the average in Missouri is comparable to that in Indiana (table 1).

The limited farm-size breakouts that are available in the USDA data also reveal the effect of the industrialization phenomenon in North Carolina and Missouri, as well as the collective effect among minor hog-raising states. Farms with 2,000 or more hogs accounted for 43 percent of all hogs on farms nationwide as of December 1995. In most District states however, these large farms accounted for a much smaller share of the hog inventories. Only 26.5 percent of the hogs in Iowa were on farms with 2,000 head or more. Corresponding shares for the other District states were 36 percent for Illinois, 43 percent for Indiana, 46 percent for Michigan, and 19 percent for Wisconsin. Among the 16 major hog-raising states, those with the biggest share of hogs on large farms were North Carolina (88 percent) and Missouri (51 percent). Surprisingly enough, however, the minor hog-raising states collectively rank even higher than Missouri. Among the minor states, the share of hogs on large farms (2,000 plus head) was 59 percent (table 1).

Further evidence of where the industrialization is occurring surfaces in a comparison of hog inventory changes over the last five years. From December 1, 1990, to December 1, 1995, hog numbers nationwide rose nearly 11 percent. All of that growth came in seven states, which recorded consistent (four out of the five years) growth over that period and which, for the most part, have been identified as attracting the new mega producers. Only two of those growth states, Missouri and North Carolina, are among the 16 major hog-producing states. Hog numbers in those two states more than doubled in the five years to December 1995. In comparison, hog numbers in District states—and in all other major hog states—declined 3 percent over that period (figure 7). The other five states that recorded consistent growth over the five-year period are among the so-called minor hog-raising states. Colorado, Mississippi, Oklahoma, Utah, and Wyoming registered an almost threefold increase in hog numbers from December 1990 to December 1995.

Collectively, the seven growth states identified above account for over 23 percent of all hogs nationwide, up from 11.5 percent in 1990. The growth has been

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**TABLE 1**

Other areas attracting the larger farms

<table>
<thead>
<tr>
<th>Hogs per farm</th>
<th>1989</th>
<th>1995</th>
<th>Percent change</th>
</tr>
</thead>
<tbody>
<tr>
<td>United States</td>
<td>179</td>
<td>329</td>
<td>84</td>
</tr>
<tr>
<td>Top-ranking states</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Iowa</td>
<td>365</td>
<td>576</td>
<td>58</td>
</tr>
<tr>
<td>Illinois</td>
<td>343</td>
<td>510</td>
<td>49</td>
</tr>
<tr>
<td>Indiana</td>
<td>290</td>
<td>432</td>
<td>49</td>
</tr>
<tr>
<td>Missouri</td>
<td>169</td>
<td>423</td>
<td>150</td>
</tr>
<tr>
<td>N. Carolina</td>
<td>206</td>
<td>1,258</td>
<td>511</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Farms with 2,000+ hogs</th>
<th>Percent of farms</th>
<th>Percent of hogs</th>
<th>Hogs/farm</th>
</tr>
</thead>
<tbody>
<tr>
<td>United States</td>
<td>3</td>
<td>43</td>
<td>5,400</td>
</tr>
<tr>
<td>16 major states</td>
<td>3</td>
<td>41</td>
<td>5,200</td>
</tr>
<tr>
<td>Iowa</td>
<td>4</td>
<td>26</td>
<td>4,200</td>
</tr>
<tr>
<td>Other District</td>
<td>3</td>
<td>38</td>
<td>4,200</td>
</tr>
<tr>
<td>Missouri</td>
<td>2</td>
<td>51</td>
<td>10,200</td>
</tr>
<tr>
<td>N. Carolina</td>
<td>17</td>
<td>88</td>
<td>6,600</td>
</tr>
<tr>
<td>Minor states</td>
<td>1</td>
<td>59</td>
<td>9,100</td>
</tr>
</tbody>
</table>

Source: U.S. Department of Agriculture.
especially apparent in North Carolina. In 1990, North Carolina ranked seventh with an inventory of 2.7 million hogs. In 1993, North Carolina moved into second place ahead of Illinois.\textsuperscript{7} The revised estimates show North Carolina had an inventory of 8.2 million hogs at the end of 1995, well above Illinois’s 4.8 million head and closing in on Iowa’s 13.4 million head (figure 7).

A more dramatic portrayal of the extent and location of the industrialization in hog production comes from surveys conducted by Successful Farming magazine to identify all producers owning 10,000 or more sows,\textsuperscript{8,9} The most recent survey (October 1996) found some 43 such producers (table 2). Collectively, those 43 producers owned 1.74 million sows or, on average, 40,500 each. Compared to similar surveys the previous two years, the latest results mark a 23 percent increase in the average number of sows owned by mega producers during the last year. The latest results also mark two large, consecutive annual gains in the total number of sows owned by producers with 10,000 sows or more. In contrast, USDA reports indicate that the inventory of hogs held for breeding purposes by all producers has declined the last two years. Assuming that sows represent about 90 percent of that inventory, it appears the 43 mega producers identified in the most recent survey own 29 percent of all sows. Adjusted for their more efficient use of sows and their ability to wean more pigs per litter, those 43 mega producers probably account for nearly 40 percent of all pigs born and raised nationwide.

Table 3 provides a closer look at the 12 largest producers as identified by Successful Farming in October 1996. Those 12 producers owned 1.22 million sows, accounting for about 20 percent of all sows in the U.S. The table shows the state where the firms are headquartered and the states where they have production facilities. Two District states are referenced in the table, but not very frequently. From the
perspective of Midwest agriculture, there are several ironies in the listings. For instance, there is the reference to family farms in the name of the largest producer. Also, several of the companies listed are more typically associated with other agricultural commodities, for example, Tyson (poultry) and Continental Grain, Cargill, and DeKalb (grain).

Two firms in particular merit mention as a means of illustrating how mega producers are dramatically changing the structure of pork production. Fifth-ranked Premium Standard Farms (PSF) was organized in the late 1980s. Initially, PSF wanted to locate in Iowa but was unable to do so because regulations in the state precluded the organizational structure the company was proposing. Instead, it located initially in a three-county area of north central Missouri and subsequently acquired additional facilities in Texas. After building all new facilities, PSF started production in 1992. Following a comparatively modest rise of 8 percent last year, its inventory of sows reached about 105,000 head as of late 1996. In 1995, PSF opened its own packing plant in Missouri with intentions to eventually process all the hogs it raises on that site.10

Smithfield Foods recorded another large increase in sow inventories last year to become the second largest hog producer. It is also the second largest pork packer. Its state-of-the-art packing plant in North Carolina has two operating lines, each capable of processing 8,000 hogs per eight-hour shift. When fully operational and running two shifts on each line—as it has requested in pending applications—the plant will process some 32,000 hogs daily. At that level, that one plant would account for one-twelfth of all hogs shipped to packing plants.

| TABLE 2 | Producers with 10,000+ sows |
|---|---|---|---|---|---|
| Number of producers | 31 | 44 | 43 | –2 |
| Sows owned (000) | | | | |
| Total | 1,131 | 1,517 | 1,741 | 15 |
| Per producer | 36.5 | 34.5 | 40.5 | 23 |
| % of U.S. sow inventoryb | 17 | 24 | 29 | |
| Hogs held for breeding purposes by all producers (000) | | | | |
| Total | 7,415 | 6,898 | 6,770 | –2 |
| Sowsb | 6,674 | 6,208 | 6,093 | –2 |

*From previous year.

bBased on author’s approximation (90 percent) of the share of all hogs held for breeding purposes that are sows.

Sources: Successful Farming, various issues, and U.S. Department of Agriculture.

| TABLE 3 | The top 12 producers |
|---|---|---|---|
| Headquarters | Production sites | Sows owned | Percent change* |
| Murphy Family Farms | NC | NC, MO | 260,300 | 14 |
| Smithfield Foods | VA | NC, VA | 112,000 | 18 |
| Carroll Foods | NC | NC, VA, SC, IA | 111,400 | 1 |
| Tyson Foods | AR | AR, NC, MO, OK, AL | 110,000 | 3 |
| Premium Standard Farms | MO | MO, TX | 105,000 | 8 |
| Prestage Farms | NC | NC, MS | 102,200 | 6 |
| Cargill | MN | NC, AR, MO, IL, OK | 90,000 | 13 |
| Seaboard Corporation | KS | KS, CO, OK | 90,000 | 80 |
| DeKalb Swine Breeders | IL | KS, OK, IL, TX, IA, CO | 72,000 | 0 |
| Iowa Select Farms | IA | IA | 62,000 | 48 |
| Goldsboro Milling Co. | NC | NC | 54,000 | 4 |
| Continental Grain | NY | MO, NC, AR, IA, | 52,000 | 49 |

*From previous year.

Source: Freese, Successful Farming, October 1996.
Characteristics of the mega producers

Various studies have shown that mega producers are more successful in capturing technological advances that lower production costs and/or improve the quality of the final product (pork) to consumers. Those technological advances are apparent in the genetics; the feeding, breeding, and handling practices; the disease-control procedures; and the buildings, structures, and facilities used to raise hogs. Reflecting the differences among producers, some observers have suggested the range in production costs between the most efficient one-third of all producers and the least efficient one-third is as much as $10 to $12 per hundredweight. Compared to the $43 per hundredweight average in hog prices the last three years, the wide range in production costs gives the more efficient producers much more staying power during cyclical downturns in hog prices. The need to remain competitive has long been a major factor in the restructuring in hog production; it continues to be the driving force behind the recent industrialization phenomenon.

Another characteristic of mega producers is they tend to operate with multiple production sites that are geared to coordinate large batch flows of hogs. These sites separate by location the three key stages of production and are designed to minimize or eliminate the intermingling of pigs from different batches. One site is used for breeding, gestation, and farrowing (giving birth). Following an early weaning, the young pigs are moved en masse to a separate nursery facility. Later, they are moved en masse to another site to be finished out to market weight. This practice helps guard against the spread of diseases. It also permits better utilization and specialization in the labor and facilities and in the feeding and breeding practices that are used for raising hogs.

Mega producers also operate with a highly refined form of integration that contrasts with the structure of the typical Midwest hog farm. This integration often begins with the genetic lines developed specifically for the producer’s own breeding herd. As suggested above, it is also reflected in specialized labor and management for each stage of production and in state-of-the-art feed mixing and handling facilities. In many cases, these producer-owned modern facilities have led to the demise of commercial feed businesses located in rural areas. Moreover, the modern facilities have eroded much of the Midwest hog producers’ traditional advantage of being in close proximity to the feed (corn and soybeans) grown in the Midwest. With such facilities and scale economies, mega producers located considerable distances from the Midwest can be competitive by relying on frequent deliveries of corn via unit grain trains shipped out of the Midwest.

The highly refined form of integration is also evident in the on-site veterinarian facilities, services, and employees maintained by many of the mega producers. Also, as suggested earlier, the integration increasingly extends all the way to the packer. In some cases, mega producers own packing plants that process only their own hogs. In other cases, mega producers’ plants process their own hogs along with hogs from other producers.

A final characteristic worth noting is the increased use of contracting arrangements that have surfaced with mega producers and the industrialization in hog production. In some cases, these contracts are between the producer and a grower. Such arrangements permit the producer to leverage his/her capital by contracting with a grower to feed out the producer’s hogs to market weight. With parallels to the contracting common in broiler production, these arrangements increasingly find the Midwest farmer becoming the grower. The producer furnishes the pigs, the feed, and the veterinarian services. The grower provides the facilities and labor in exchange for a fixed fee and, in all likelihood, an incentive clause to produce top-quality carcasses in a stipulated time period with minimal death losses.

Other contracting arrangements are between producers and packers. In some cases, these contracts are designed primarily to assure an integrator (mega producer) access to a packing plant when the integrator’s hogs are ready to be marketed. Such arrangements were a key factor behind the phenomenal growth in North Carolina’s hog production at a time of very limited capacity at close-by packing plants. Fortified by these contracts, it was much easier to coordinate the construction of new packing facilities simultaneously with the rapid expansion in that state’s hog production. In addition, many of the contracts between producers and packers include pricing arrangements. Some
are simple formula-pricing arrangements that peg the price to the producer to some base market price. Others provide for the sharing of price risks between the producer and packer. Many contracts also offer premiums to producers that consistently deliver large quantities of hogs and/or hogs that consistently yield high-quality carcasses.

**Key issues for the Midwest**

The industrialization that has swept the hog industry has raised a number of issues that will be critical to whether the Midwest will be able to maintain its historical share of hog production. For instance, many Midwest states, including Iowa (but not Illinois and Indiana), have restrictions that curtail or limit the involvement of large, nonfamily corporations in farming activities. In some cases, the restrictions prohibit packers from processing their own hogs. In many cases, these restrictions were originally imposed to protect the smaller, family-sized farms prevalent in the Midwest from the market power that corporate farms might exert. Although still considered worthwhile by some observers, these restrictions often preclude the organizational structures that have sprung up with the mega hog farms.

The environmental concerns that have surfaced with large-scale livestock production facilities are probably the biggest issue confronting the Midwest and its dominance in hog production. The handling of livestock wastes from any size operation can, at times, cause odors that are strongly obnoxious to those located nearby. But the problems are often magnified with large, high-density hog operations. In addition, the animal waste-handling and storage practices of large operations often lead to concerns that the nutrients from the wastes—which have value as a natural fertilizer but are harmful in concentrated form—and/or the pathogens will leach into groundwater supplies, contaminate rivers, lakes, and streams through surface run-off, or vaporize into the air. These problems sometimes arise because of flooding and other extreme weather conditions. Poorly constructed facilities for holding livestock wastes and ill-advised practices in spreading the wastes over fields (to capture the soil-enhancing benefits of the nutrients and organic matter) also contribute to the problems. However, even with the best practices and management, the odor and waste concerns associated with large livestock operations seem to be under constant agitation, much like similar quality-of-life concerns that exist in communities adjacent to major airports or industrial centers.

These concerns have led to a very contentious debate in the Midwest and elsewhere, pitting agricultural and nonagricultural interests against large hog production facilities. Strong NIMBY (not in my backyard) sentiments have surfaced in many areas. These sentiments may often be formed without a clear understanding as to what extent these facilities pose a significant environmental hazard as opposed to simply a nuisance. Moreover, there is probably little understanding of the rights and obligations of producers and residents in states with right-to-farm statutes or in areas where land has been zoned for agricultural use, or granted an exemption from other zoning restrictions. Nevertheless, these sentiments increasingly serve as the catalyst for regulations to restrict the location and size of hog production facilities and their manure storage and handling practices. Implementing such regulations, however, has often been difficult. This is partly due to legal issues that can arise when the regulations treat different-sized producers in a non-uniform manner. In addition, there can be problems of inequitable treatment between new producers and *grandfathered* producers and problems of *first-claim* rights between established producers and new residents (or established residents and new producers). At any rate, observers have suggested the recent success of states on the western fringe of the Corn Belt in attracting mega producers is due largely to the less intense environmental concerns in those areas as compared to the more populous rural areas of the Midwest. Lower land costs and lower population densities in those areas make it easier to site a large hog production facility a safe distance from neighbors. Moreover, the more sparsely populated western fringe areas have probably been more inclined to view the start-up of a large hog operation as needed economic development for the local area. Indeed, some reports have touted the substantial economic growth—in terms of jobs, local infrastructure, and amenities—that can accrue in remote areas that do attract a mega producer.
Another critical issue regarding the expanding presence of mega producers pertains to changing markets and pricing arrangements. It has been suggested that one-third of all hogs now move to market through either fully integrated ties with packers or some form of contracting arrangements with packers. For the independent Midwest farmer that markets hogs through traditional practices, there are numerous concerns about the long-run implications of these direct ties to packers. Will independent producers continue to have access to competitive markets as packer ownership and contracting of hogs continues to expand? Is the important marketing function of price discovery compromised by the growing ties between production and packers? How valid are reported market prices when a growing share of the production also receives premium payments for quantity and/or quality preferences? This issue is especially important in terms of the efficiency of the market’s pricing signals in conveying consumer’s preferences for pork into the allocation of resources to produce pork. Moreover, there is the question of whether prices to independent producers will become more volatile as more of the overall production is shielded by direct ties to packers. And if that is the case, will independent producers shoulder a disproportionate share of the production adjustments needed from time to time to balance supplies with demand?

Another key issue for the Midwest is the likelihood that the economic activity of pork packing and processing will follow any geographical shift in hog production. This is important for the Midwest, since it has an even larger share in hog processing than in hog raising. In terms of the number of hogs on farms, Iowa is by far the largest hog producing state. Yet Iowa’s home-grown hogs are not sufficient to sustain the volume of hogs processed in that state. At least one of every five hogs processed in Iowa in recent years had to be shipped in from some other state. There is little doubt that in time the geographic distribution of packing plant activity will parallel that of hog production. In 1990, for instance, North Carolina ranked seventh in hog production and tenth in hog slaughter. By 1993, it had moved ahead of Illinois into second place in hog production, and in 1996, it probably bumped Illinois from the number two position in hogs processed at packing plants.

Although packing plants add considerable economic value, they do not offer the type of jobs or economic activities that are typically in high demand for economic development purposes. A job in a packing plant is tedious, repetitive, fast-paced, and carries a relatively high probability of injury. In contrast to the high wages and strong unionization that characterized meat packing in the past, wages offered in the industry today are relatively low. Moreover, packing plants today tend to be located more in regional or rural areas—as opposed to major urban centers in the past—and the jobs increasingly tend to be filled by people who have relocated from other areas, or in many cases, from other countries. This inflow of laborers and their families can result in social, educational, and housing problems that some local communities may wish to avoid. Nevertheless, the U.S. pork market is a $30 billion industry. The Midwest has long enjoyed a large slice of this market, based on its dominance in both hog production and hog processing. The possible loss of this economic activity due to the developments emerging with the industrialization phenomenon should not be viewed lightly.

A concluding observation

The hog production and processing models and standards that have come about with the industrialization of recent years present a rather foreboding picture for the typical family farm concept of Midwest hog production. The standards set by the largest hog producers now suggest that some 50 producers could account for all the hogs needed in the U.S. Moreover, the standards set by new, state-of-the-art packing plants suggest that fewer than 12 plants could process all of the country’s hogs. If the restructuring process goes that far, many rural communities will be affected. Even if the Midwest were to maintain its share, the structure of hog production would differ markedly from the family-farm-dominated structure of the recent past.
ECONOMIC PERSPECTIVES

1 The five states that comprise the Seventh Federal Reserve District are Illinois, Indiana, Iowa, Michigan, and Wisconsin. In this article, “the District,” “District states,” and “the Midwest” are used interchangeably.

2 Larger producers have higher weaning rates. The weaning rate among producers with 2,000 or more hogs was 8.7 head per litter in 1995.

3 The 16 major hog-raising states are those for which the USDA provides quarterly inventory estimates and which collectively account for over 90 percent of all hogs on farms nationwide.

4 These are referred to as large farms here only because this is the largest size category reported annually by the U.S. Department of Agriculture. As noted below, mega farms tend to be much larger.

5 Subsequent revisions to the December 1995 data lowered the increase to 7 percent. Revisions were made for both the major and the minor states. There was also a change in the states classified as major. So far, only the revised estimates for the newly defined major states have been published. Therefore, the following discussion uses the original estimates rather than the revised estimates. Where possible, the effects of the revisions on the five-year inventory changes will be shown.

6 The revised estimates still show hog numbers in the two major growth states doubled over the five-year period. For District states, the revised estimates show inventories declined 8 percent over the five years. The partial revisions currently available for the other major states show a five-year decline of 5 percent.

7 Last year, Illinois dropped behind Minnesota into fourth place.

8 The estimates from these surveys may lack the statistical rigor usually associated with official government estimates. However, industry observers closely attuned to these developments consider the numbers to be fairly accurate.

9 The inventory classification used here refers to sows only, not the entire inventory of hogs held by these producers. To put this in better perspective, the U.S. inventory of hogs held for breeding purposes—comprising sows, boars, and gilts (immature sows)—accounts for less than 12 percent of all hogs.

10 On July 2, 1996, PSF filed for protection under Chapter 11 of the federal bankruptcy laws. The highly leveraged entity was crippled by very low hog prices in late 1994 and by very high feed costs in 1995/96. The company continued to operate during the filing and observers note that an extensive reorganization plan has apparently been worked out and that the firm, under new ownership and management, will likely continue to operate.

11 A common example is the risk-sharing window pricing arrangement. Under such an arrangement, the packer and producer might agree to split the difference if prices rise above or fall below a specified window price. If the specified price window was $42 to $47 per hundredweight and the market price fell to $36, the producer would be paid a price of $39 per hundredweight. Alternatively, if the market price rose to $53, the price paid to the producer would be $50 per hundredweight.

12 These types of restrictions led PSF to give up its initial plans for locating in Iowa and move to north central Missouri.

13 The restrictions on location are usually expressed in terms of distances separating the production facilities from neighboring residences, schools, churches, etc. These so-called set-back restrictions can translate into costly land requirements for siting a large hog production facility, especially in the Midwest where both land values and rural population densities tend to be higher. Other efforts have tried to use zoning regulations to ban the construction of large hog production facilities.

14 Some attempts at such regulation have tried to protect the preferred family-sized producers from the costly requirements imposed on mega producers.

15 Due to confidentiality issues, the number of hogs shipped to packing plants in Michigan has not been published since 1990. At that time, the five District states accounted for 50 percent of all hogs processed in packing plants.

16 On a monthly basis, packing plants in North Carolina processed more hogs than those in Illinois for the first time in May 1996.

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________, Concentration in the red meat packing industry, Washington, DC, February 1996.

A dynamic macroeconomic analysis of NAFTA

Michael A. Kouparitsas

On December 8, 1993, President Clinton signed into law the North American Free Trade Agreement Implementation Act. The United States’ action was soon followed by Canada and Mexico and the North American Free Trade Agreement (NAFTA) came into force on January 1, 1994. NAFTA represents the first far-reaching free trade agreement between major industrial countries and a developing country. Throughout the development of NAFTA, there was intense domestic debate about the desirability of pursuing expanded trade ties within North America.

From the U.S. perspective, one of the foremost objectives of NAFTA was to ensure that Mexico would lock in the economic and political reforms it has instituted since 1985. These reforms have created a more predictable business environment for U.S. exporters and investors. The U.S. negotiators believed that the agreement would also benefit the U.S. economy by accelerating Mexico’s trade liberalization process and give U.S. exporters and investors increased access to Mexico’s growing marketplace.

Canada hopes NAFTA will improve its access to the Mexican market. NAFTA avoids separate U.S. agreements with Canada and Mexico. Canadian negotiators realized that trade reforms between the U.S. and Mexico (along the lines of the U.S.–Canada Free Trade agreement [CFTA] signed in 1989) would affect Canada’s share of the North American market whether Canada participated in NAFTA or not. Canadian officials believed that by joining NAFTA, Canada would be better positioned to keep what it achieved through the CFTA and to take advantage of closer economic ties with the growing Mexican marketplace.

For Mexico, NAFTA offered an opportunity to lock in the extensive market-oriented policy reforms of the late 1980s. Mexico hoped to gain credibility for its reform process and encourage foreign investment in Mexican industry and trade. At the same time, Mexico viewed NAFTA as a means of reducing the threat of U.S. protectionism and further enhancing export opportunities in the U.S. and Canadian markets. Mexico also anticipated greater access to U.S. and Canadian technology and capital.

In its most basic form, the trilateral agreement will eliminate all tariffs and significantly reduce nontariff barriers (NTBs), such as quotas and import licenses, between the U.S., Canada, and Mexico. Tariff duties will be phased out in stages over a period of 15 years, with the majority of tariff reductions taking place within ten years. In addition to tariff reform, there are three broad agreements on NTBs. First, all countries will eliminate prohibitions and quantitative restrictions applied at the border, such as quotas and import licenses. Second, the three countries have agreed not to impose new user fees and to phase out existing prohibitions and quantitative restrictions applied at the border, such as quotas and import licenses.
user fees by June 1999. Third, NAFTA will permit eligible businesspeople to bring in the tools of their trade, such as professional samples and other goods, on a duty free basis. NAFTA also includes investment provisions that reduce the barriers to capital flows between the parties.

One of the costs of a limited-participation free trade area is that agreements like NAFTA must develop rules of origin that define which goods are entitled to preferential tariff treatment. As such, goods that are wholly produced in the U.S., Canada, or Mexico will qualify for NAFTA treatment. Most goods containing nonagricultural components will qualify, if those goods are sufficiently transformed in the NAFTA region that the ultimate article undergoes a specified change in tariff classification. In some cases, NAFTA establishes set percentages of North American content in addition to the tariff classification requirement.

NAFTA adds to the worldwide trend toward regional trade agreements, which is no doubt related to the General Agreement on Tariffs and Trade (GATT). Over its long history, GATT has fostered and achieved a lowering of trade barriers across most countries/regions. These gains have largely been achieved through the efforts of a small number of influential participants that actively sought free trade. In recent years, the number of players has increased, which has made it harder to achieve the type of consensus of the early GATT days. Regional preferential trading arrangements are seen by many as a natural outgrowth of the GATT process. In contrast to GATT, regional trading groups are typically smaller and better able to deal with a narrow, but very difficult trade liberalization agenda. Moreover, limited participation in a free trade group makes monitoring less costly for all participants. The architects of regional trade agreements argue that the long-term objective of regional free trade is a union of these regions that would ultimately lead to global free trade.

Although NAFTA has been in place for more than two years, it is too early to gauge the long-run impact of its far-reaching trade liberalization program. The short-run impact of NAFTA is also difficult to gauge, since accurate measurement of its short-run effects would require disentangling cyclical features not directly related to NAFTA from those that are driven by NAFTA. At this time the only guide to the short- and long-run impact of NAFTA is analysis involving quantitative models of international trade. In this article, I study the impact of NAFTA on the three North American economies and a composite of their trading partners. My results suggest NAFTA will lead to welfare gains for all North American participants, with the greatest gains accruing to Mexico.

My analysis differs from earlier trade liberalization analysis along one important dimension. In contrast to earlier research which works exclusively with static trade models, I work within the framework of a dynamic model of North American trade. The dynamic approach overcomes three weaknesses of traditional static analyses. First, static models limit the world supply of capital to that available in the pre-liberalization steady state. Therefore, welfare and output gains associated with free trade come from a reallocation of capital across sectors and countries in a static model. Static models ignore the fact that capital accumulation is more efficient under free trade and, therefore, understate the potential welfare and output gains that accrue from trade liberalization. In a dynamic model, production gains flow from greater investment in capital and a reallocation of these factors across sectors and countries. Through simulations of the dynamic model developed in this article, I show that removing trade barriers does indeed lead to greater North American capital accumulation, which in turn leads to output gains that are roughly twice as large as those predicted by static models.

Second, traditional static trade models rule out trade in financial assets by restricting current account balances to zero. International capital flows serve three basic purposes: 1) by trading international assets, agents can achieve a higher level of welfare by maintaining smooth consumption paths, while undertaking major capital investment and sectoral reallocation of factors following trade liberalization; 2) international capital flows allow for more rapid adjustment to the new policy environment; and 3) by trading international assets, agents can achieve a more efficient allocation of resources across countries. I depart from static analyses by allowing countries/regions to trade financial assets internationally. Simulation results suggest that in the long run, there is a sizeable inflow of capital to the Mexican economy, largely from countries outside North America.
Finally, static models limit the analysis of free trade agreements to a comparison of long-run equilibria (or steady states)—specifically, a comparison of the pre-liberalized economy with the liberalized economy after it settles to its new long-run equilibrium. These models offer no estimate of the length of time it takes to get to the new steady state or the path of adjustment. Dynamic models provide this information. Simulations of my dynamic trade model suggest that the adjustment to NAFTA will be virtually completed by the free trade date of 2004. Moreover, the model suggests that the transition to the NAFTA steady state will be characterized by smooth output, trade, and expenditure paths.

Quantifying NAFTA

There is an extensive quantitative literature on regional free trade agreements and NAFTA. Typically, authors use computable general equilibrium (CGE) models. It is difficult to incorporate NTBs in these models, so researchers use so-called tariff-equivalent measures of NTBs in their quantitative analysis (that is, the level of tariff protection that yields the same levels of output and trade as the NTB). Table 1 provides an overview of Roland-Holst, Reinert, and Shiells’ (1992) estimates of the levels of tariff and tariff-equivalent NTB protection that existed in 1988 prior to the signing of the CFTA and NAFTA. Tariff-equivalent NTBs greatly exceed explicit tariff levels, which suggests that NTBs represent the highest barrier to free trade. NAFTA calls for the removal of all North American trade barriers. My results show that the gains from the removal of NTBs under NAFTA far outweigh the gains from removing explicit tariffs.

NAFTA followed the signing of a far-reaching CFTA in 1989, which was designed to eliminate all trade barriers between Canada and the U.S., described in table 1. Therefore, I model NAFTA as the joint free trade agreement between Canada and Mexico and between the U.S. and Mexico. In practical terms, NAFTA involves the removal of barriers to 1) Mexican exports to Canada and the U.S. and 2) Canadian and U.S. exports to Mexico. As the majority of tariff reductions will take place within ten years,

| TABLE 1
Levels of protection in North America prior to implementation of CFTA and NAFTA

<p>| Tariff rates | Composite protection rates (tariffs and NTBs) |
| Primary products | Primary products |
| Importer | Exporter | Exporter |</p>
<table>
<thead>
<tr>
<th>Canada</th>
<th>Mexico</th>
<th>U.S.</th>
<th>ROW</th>
<th>Canada</th>
<th>Mexico</th>
<th>U.S.</th>
<th>ROW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canada</td>
<td>0.01</td>
<td>0.01</td>
<td>0.00</td>
<td>Mexico</td>
<td>0.80</td>
<td>0.81</td>
<td>0.72</td>
</tr>
<tr>
<td>Mexico</td>
<td>0.00</td>
<td>0.02</td>
<td>0.00</td>
<td>U.S.</td>
<td>0.61</td>
<td>0.88</td>
<td>0.77</td>
</tr>
<tr>
<td>U.S.</td>
<td>0.01</td>
<td>0.01</td>
<td>0.01</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Nondurable manufactured goods

<table>
<thead>
<tr>
<th>Exporter</th>
<th>Importer</th>
<th>Canada</th>
<th>Mexico</th>
<th>U.S.</th>
<th>ROW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canada</td>
<td>0.18</td>
<td>0.07</td>
<td>0.14</td>
<td>Mexico</td>
<td>0.78</td>
</tr>
<tr>
<td>Mexico</td>
<td>0.04</td>
<td>0.05</td>
<td>0.10</td>
<td>U.S.</td>
<td>0.16</td>
</tr>
<tr>
<td>U.S.</td>
<td>0.04</td>
<td>0.05</td>
<td>0.10</td>
<td></td>
<td></td>
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</table>

Durable manufactured goods

<table>
<thead>
<tr>
<th>Exporter</th>
<th>Importer</th>
<th>Canada</th>
<th>Mexico</th>
<th>U.S.</th>
<th>ROW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canada</td>
<td>0.04</td>
<td>0.02</td>
<td>0.04</td>
<td>Mexico</td>
<td>0.25</td>
</tr>
<tr>
<td>Mexico</td>
<td>0.01</td>
<td>0.03</td>
<td>0.02</td>
<td>U.S.</td>
<td>0.39</td>
</tr>
<tr>
<td>U.S.</td>
<td>0.01</td>
<td>0.03</td>
<td>0.03</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Notes: Roland-Holst et al. (1994) report estimates for 26 sectors. Sectoral aggregates reported in this article are weighted by 1988 import shares. ROW is rest of the world.

I model NAFTA as the uniform reduction of protection levels over a ten-year period (that is, protection levels are reduced by 10 percent each year), starting in the first quarter of 1994.

Model simulations begin in the period following the signing of the initial NAFTA agreement, first quarter of 1993. I conduct the NAFTA simulations as if agents in the world economy fully anticipated the path of trade liberalization described above. This assumes that agents knew at the date of the initial signing, December 17, 1992, that NAFTA would be ratified in late 1993, implemented in the first quarter of 1994, and phased in slowly over ten years.

**North American trade flows**

Figure 1 describes North American trade flows prior to the signing of NAFTA in 1992. There are three things to note. First, Canada–Mexico trade is quite small. Their bilateral trade accounts for 1 percent to 2 percent of their export and import baskets. Second, trade with the U.S. represents a large share of Canadian and Mexican trade (in the order of 70 percent of their import and export baskets). Finally, trade with Canada and Mexico is less important to the U.S.; more than 70 percent of U.S. trade is with countries outside North America. This primarily reflects the U.S.’s considerably larger size relative to its North American counterparts.

Based on these statistics, NAFTA was expected to have a small impact on the U.S. and Canadian economies and a large impact on the Mexican economy, because of Mexico’s strong dependence on North American trade. Simulation results reported in this article support this conjecture.

**A dynamic model of North American and world trade**

The model developed in this article combines the multisector characteristics of static CGE models with the dynamic characteristics of one-sector, international real business cycle (IRBC) models. Countries in the world economy are sorted into two groups. The North American countries (Canada, Mexico, and the U.S.) are modeled individually, while the

---

**FIGURE 1**

**Direction of North American trade prior to NAFTA (1992)**

**Exports by destination**

- **Canada**:
  - U.S. 77.8%
  - Rest of World 21.7%
  - Mexico 0.5%

- **Mexico**:
  - U.S. 68.7%
  - Rest of World 28.4%
  - Canada 2.9%

- **U.S.**:
  - Canada 20.2%
  - Mexico 9.1%
  - Rest of World 70.8%

**Imports by origin**

- **Canada**:
  - U.S. 72.0%
  - Rest of World 25.8%
  - Mexico 2.2%

- **Mexico**:
  - U.S. 62.8%
  - Rest of World 35.0%
  - Canada 2.2%

- **U.S.**:
  - Canada 22.0%
  - Mexico 7.8%
  - Rest of World 70.2%

remaining countries are consigned to a residual rest of the world (ROW) aggregate. All countries, including the ROW, are fully specified, in the sense that production, consumption, work effort, and trade decisions are the result of well-defined optimization problems. The inclusion of a fully specified ROW avoids the need for ad hoc residual ROW supply and demand equations and ensures endogenous determination of all prices and quantities.

Figure 2 provides a summary of the domestic and international goods and factor flows in the model (a detailed description of the model is provided in the appendix). Each country/region has five production industries: primary raw materials, nondurable manufactures, durable manufactures, construction, and services. Output in all sectors is described by a production function that has two basic inputs. The first factor of production is the value-added component, which reflects that part of output attributable to primary factors of production, such as capital, labor, and land. The other factor of production is an aggregate intermediate component, which represents the volume of goods consumed in the production of other goods. For example, nondurable manufacturing goods, such as food, require the input of primary raw materials, such as grains.

The model assumes households in the world economy have a fixed endowment of time, which they can consume as leisure or supply to the market in the form of labor services in return for a wage. Labor is mobile between sectors within in a country, subject to small adjustment costs, but immobile internationally.
Households are also assumed to have an endowment of land. Land only enters the model as an important factor of production in the primary sector. The supply of land is held fixed throughout the policy experiments.

There are two types of investment goods in the model. The first is durable capital goods that gradually depreciate over time. Capital goods are either used as inputs in the production of goods or household durable services. Production capital and household durable investment is a composite of equipment and structures. Equipment is produced in the durable-manufacturing sector, while structures are produced in the construction sector. Capital is mobile between sectors within a country and across countries, subject to small adjustment costs.

The second investment goods category is intermediate goods, which are held as inventories and completely consumed in the production of future goods. Empirical evidence (see Ramey [1989] for details) suggests intermediate goods require one quarter to put in place. The time period in the model is quarterly, so I assume that period $t + 1$ intermediate inputs are produced in period $t$. All sectors produce intermediate goods, so the aggregate intermediate goods component that appears in the production function is a composite of goods from all five sectors.

The model allows for trade between all three North American countries and the ROW. Construction is the only nontraded good. Private final expenditure on a given good is an aggregate of all imports of that good and domestically produced levels of that good. These aggregates are then broken up into four final expenditure components: consumption, investment, government spending, and intermediate goods. Using this aggregation procedure, I limit the number of expenditure goods to five and the number of output goods to five. The difference is that the output good is country specific, while the expenditure aggregate is a composite of output from all four trading areas.

Each country/region has a government that imposes explicit tariffs on imported goods in proportion to their value. I take the standard approach of imposing tariff-equivalent NTBs. Therefore, all barriers to trade are in the form of tariffs. The tax revenue from the tariff and the quota rents from the NTBs are rebated by lump-sum payments to households. For simplicity, I assume the government levies a lump-sum tax to finance its current spending on goods. Real government spending is held constant throughout the policy simulations.

Each country/region is assumed to have a single infinitely lived representative household, whose objective is to maximize its expected lifetime utility. Households in all countries/regions derive utility from consuming a composite consumption good and leisure. The composite consumption good is an aggregate of nondurable consumption goods, such as food and the flow of services from household durables like transportation services. In particular, nondurable consumption is an aggregate of goods from the primary, nondurable manufacturing, and service sectors.

The representative households in all four countries/regions own all productive inputs, labor, capital, and land. Each period, the households rent these productive inputs to the various firms in the same economy. Firms produce all five goods and sell the output to the households. For simplicity, I assume that the only financial assets available to the households are noncontingent one-period bonds. The competitive world equilibrium is described by the processes for capital, labor, consumption, and investment and their associated prices, which satisfy the representative households' optimization problems and the world resource constraints. I follow Baxter and Crucini's (1995) approach to solving dynamic trade models, in which foreign assets are restricted to one-period bonds. In general, it is not possible to generate an analytical solution for this class of model, so their methodology uses numerical techniques to solve for the model's dynamic equilibria. Specifically, the log-linear approximation technique advanced in the real business cycle literature by King, Plosser, and Rebelo (1988, 1990).

Model calibration

The model's parameters must be defined before I can apply numerical solution methods. Direct estimation of all the model's parameters is ruled out because there is insufficient international data to estimate all preference, production, and trade parameters. Researchers working with static multisector, multicountry CGE models have overcome this problem using so-called model calibration (see, for example, Shoven and Whalley, 1992). More
recently, this approach has been extended to dynamic models of international trade. Calibration essentially involves two steps. First, the researcher chooses a set of elasticities that describe the degree of substitution in consumption, production, and trade. Second, given this set of elasticities, the researcher chooses weighting terms in preference, production, and trade aggregation functions, so that the model’s steady state corresponds to a specific point in time. In this case, the model’s base year or pre-liberalization steady state is assumed to be 1992, when the three countries signed the initial NAFTA proposal.

Household preference parameters are based on national accounts data from each country/region and parameters widely used in the IRBC literature (see Backus, Kehoe, and Kydland [1995] and Baxter [1995] for surveys of this literature). I set the parameters of the model’s production functions using U.S. manufacturing sector cost function estimates from Ramey (1989) and the most recent input–output tables for Canada, Mexico, and the U.S. Because the ROW is dominated by major industrial countries, such as Japan and Germany, which have similar input–output tables to the U.S., the ROW production function is calibrated to U.S. input–output data.

Following Baxter and Crucini (1993), I set the parameters defining the capital adjustment cost function so that: its steady state value is equal to the steady state ratio of investment to capital; in the steady state, Tobin’s \( q \) (the ratio of the price of existing capital to the price of new capital) is one; and the elasticity of sectoral investment–capital ratios with respect to their sectoral Tobin’s \( q \) is consistent with relative sectoral and aggregate investment volatility levels. I measure relative investment volatility using sectoral investment data (see Kouparitsas, 1996, for details). The sectoral labor adjustment cost functions are calibrated in a similar fashion. The primary sector has the highest adjustment costs, which is consistent with the view that primary capital and labor tend to be industry specific.

The trade aggregation parameters are calibrated to match the trade flow statistics described in figure 1. For comparability with earlier static analyses, I set the level of pre-liberalization protection in my model to match Roland-Holst et al.’s estimates reported in table 1. These estimates were constructed using trade aggregation functions calibrated to match estimates from Shiells and Reinert (1993) for Canada and the U.S. and Sobarzo (1994) for Mexico. I maintain consistency between the protection rates and trade aggregation functions by adopting Canadian, Mexican, and U.S. elasticities of substitution between home and imported goods to match Shiells-Reinert’s and Sobarzo’s estimates. There is a wide range of estimates used in the literature, so the sensitivity analysis section addresses the model’s sensitivity to this parameter choice.

**Measuring the impact of trade liberalization**

Below, I report the results of simulations of the quantitative North American trade model under three trade liberalization scenarios. The first experiment looks at a limited North American free trade agreement (LNAFTA), in which I remove only the explicit tariffs between Canada, Mexico, and the U.S. The second experiment examines the removal of all North American tariffs and NTBs (NAFTA). The third scenario focuses on another limited trade liberalization agreement, which involves only Mexico and the U.S., a hub and spoke arrangement (HASP). The U.S. is the hub, having free trade agreements with Canada and Mexico, while Canada and Mexico are the spokes, each having a free trade agreement only with the U.S. The HASP is implemented by lowering barriers to Mexican imports in the U.S. and to U.S. imports in Mexico.

**Welfare analysis**

Table 2 describes the long-run effects of the LNAFTA, NAFTA, and the HASP. I calculate the welfare implications of the free trade agreements using the compensating variation measure from tax analyses of Cooley and Hansen (1989) and McGrattan (1994). Following McGrattan, I define \( \delta_{ck} \) as the solution to the following problem:

1) \[ u(\bar{c}_c(1 + \delta_{ck}), \bar{h}_k) = u(\bar{c}_c, \bar{h}_k) \]

where \( u \) is the representative household’s momentary utility function, and \( (\bar{c}_c, \bar{h}_k) \) and \( (\bar{c}_c, \bar{h}_k) \) are country \( k \)’s representative household’s respective steady state levels of consumption and leisure in the pre-liberalization and liberalized environments. By calculating \( \delta_{ck} \), I can determine the percentage change in pre-liberalization steady state consumption \( (\bar{c}_c, \bar{h}_k) \), that would make households in country \( k \) indifferent to the
In other words, $\zeta_k$, measures the amount of additional consumption you would have to give the household in the pre-liberalized environment to make it as well off as under the liberalized environment.

The compensating variation in consumption required to leave households indifferent between the initial steady state and the LNAFTA steady state is $0.15$ percent for Mexico, $0.03$ percent for the U.S., and small and negative for Canada and the ROW. This suggests that removing explicit tariffs slightly raises Mexican and U.S. households' welfare, but leads to a negligible loss of welfare in Canada and the ROW.

In the middle panel, I calculate the welfare implications of NAFTA. The compensating variation in consumption required to leave households indifferent between the initial steady state and the NAFTA steady state is $0.96$ percent for Mexico, $0.12$ percent for the U.S., and small and negative for Canada and the ROW. Based on these results, NAFTA leads to welfare improvements for all participants.

Finally, the right panel describes the effects of a HASP arrangement, in which the U.S. and Mexico negotiate a bilateral trade agreement that excludes Canada. Mexico's welfare gain under the HASP is lower than under NAFTA, while the U.S.'s is roughly unchanged. In contrast, Canada's gain under the HASP is larger than under NAFTA, reflecting NAFTA's liberalized steady state.

### Table 2: Long-run effects of competing North American trade liberalization schemes

<table>
<thead>
<tr>
<th>Variable</th>
<th>LNAFTA</th>
<th>NAFTA</th>
<th>HASP</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Canada</td>
<td>Mexico</td>
<td>U.S.</td>
</tr>
<tr>
<td>Welfare (CV)</td>
<td>-0.02</td>
<td>0.15</td>
<td>0.03</td>
</tr>
<tr>
<td>Real GDP</td>
<td>0.02</td>
<td>0.52</td>
<td>0.03</td>
</tr>
<tr>
<td>Real consumption</td>
<td>0.00</td>
<td>0.38</td>
<td>0.04</td>
</tr>
<tr>
<td>Labor hours</td>
<td>0.02</td>
<td>0.29</td>
<td>0.01</td>
</tr>
<tr>
<td>Real wage</td>
<td>0.00</td>
<td>0.37</td>
<td>0.03</td>
</tr>
<tr>
<td>Capital investment</td>
<td>0.01</td>
<td>0.90</td>
<td>0.06</td>
</tr>
<tr>
<td>Real rental rate</td>
<td>0.00</td>
<td>-0.32</td>
<td>-0.02</td>
</tr>
<tr>
<td>Total imports</td>
<td>0.04</td>
<td>1.45</td>
<td>0.17</td>
</tr>
<tr>
<td>Exports to world</td>
<td>0.04</td>
<td>1.79</td>
<td>0.14</td>
</tr>
<tr>
<td>to Canada</td>
<td>0.00</td>
<td>4.76</td>
<td>-0.05</td>
</tr>
<tr>
<td>to Mexico</td>
<td>1.31</td>
<td>2.16</td>
<td>0.29</td>
</tr>
<tr>
<td>to U.S.</td>
<td>0.08</td>
<td>2.20</td>
<td>0.02</td>
</tr>
<tr>
<td>to ROW</td>
<td>0.06</td>
<td>0.13</td>
<td>-0.01</td>
</tr>
<tr>
<td>Terms of trade</td>
<td>-0.07</td>
<td>-0.24</td>
<td>0.04</td>
</tr>
<tr>
<td>Net foreign assets/GDP</td>
<td>0.35</td>
<td>-1.26</td>
<td>-0.04</td>
</tr>
</tbody>
</table>

Notes: LNAFTA is a limited North American free trade agreement. HASP is a hub and spoke arrangement.
negative impact on Canada’s terms of trade. Under NAFTA, Canada’s terms of trade deteriorate by 0.15 percent, while under the HASP, Canada’s terms of trade improve by 0.15 percent. This result highlights the important role of relative price movements in determining the individual country gains from trade liberalization.\(^5\) I elaborate on this point in my discussion of unilateral trade liberalization.

The welfare analysis in this article is not directly comparable to the welfare calculations from static trade models. In general, static analyses do not include leisure as a component of household utility. However, these models typically allow for variable labor effort or endogenous labor supply responses. This explicitly ignores the loss of welfare a household suffers from additional labor effort (less leisure time) and implicitly raises the level of the welfare gain associated with trade liberalization. For example, static models surveyed here typically report welfare improvements that are roughly twice as large as those reported for the dynamic model. This is despite the fact that the dynamic model generates output and consumption increases that are roughly twice as large as those of static analyses.

**Aggregate effects of trade liberalization**

Table 2 shows that the three liberalization scenarios lead to an expansion of output, investment, consumption, labor hours, and trade in all three North American economies. NAFTA generates the largest expansion of the North American region, with Mexico enjoying the largest expansion within the region. Under NAFTA, Mexico’s steady state gross domestic product (GDP) is predicted to rise by 3.26 percent. Underlying this increased output is greater capital accumulation and increased labor effort. This expanded output is also reflected in increased steady state consumption of 2.52 percent and double-digit increases in export and import volumes. The model predicts NAFTA will also lead to capital inflows to Mexico. Over the simulation period, Mexico’s ratio of net foreign assets to GDP falls by 8 percentage points. It is clear from table 2 that the Mexican capital inflows are largely driven by capital flows from the ROW. NAFTA has a smaller impact on the U.S., with U.S. steady state GDP rising by 0.24 percent. U.S. trade is predicted to rise by about 1.5 percent over the steady state level. Given the small volume of Mexican–Canadian trade, it is not surprising that NAFTA has a negligible impact on the Canadian economy, with steady state output expected to rise by 0.11 percent. According to the model, NAFTA will have a negligible impact on the ROW.

Although there is a wealth of quantitative research on NAFTA, studies are not directly comparable because they generally consider different policy experiments. My model’s calibration draws on the parameters used in Roland-Holst et al. (1992, 1994), which makes their study a logical static benchmark for my dynamic analysis. However, Roland-Holst et al. take a somewhat broader view by allowing NAFTA to include the CFTA. Brown, Dardorff, and Stern (1992), Cox and Harris (1992), Cox (1994), and Sobarzo (1992, 1994) define NAFTA in roughly the same way as this article. Brown et al. is a static CGE analysis, in which North America is fully modeled as in this article. Cox-Harris and Sobarzo use partial equilibrium models, fully modeling Canada and Mexico, respectively, but closing the model by employing rest-of-the-world demand and supply equations.

Brown et al. (1992) find, as I do, that NAFTA has a large impact on the Mexican economy, but a negligible impact on the Canadian, U.S., and ROW economies. Their static model predicts that Mexican steady state GDP will rise by 2.2 percent and that Canadian and U.S. steady state GDP will be 0.1 percent higher following NAFTA. All three estimates are below those predicted by my dynamic trade model. Cox and Harris (1992) and Cox (1994) focus on the effects of NAFTA and a HASP on the Canadian economy. Cox-Harris find that NAFTA and the HASP have a negligible impact. Their results are similar to mine, in that NAFTA stimulates greater real activity than the HASP. Under the assumption of fixed capital stocks and a zero current account, Sobarzo’s (1992, 1994) model predicts NAFTA will raise Mexican steady state GDP by 1.7 percent. This is roughly half the change predicted by my dynamic model. Overall, the direction of change predicted by the static and dynamic models following NAFTA is the same. However, the predicted size of the impact is roughly twice as large in the dynamic model. This is because the static models limit the world capital stock to its pre-NAFTA level and rule out international capital flows. Greater capital accumulation in the dynamic model explains roughly two-thirds
of the change in North American steady state output. For example, Mexico’s steady state GDP is predicted to rise by roughly 3 percent of its pre-NAFTA level. Changes in Mexico’s capital stock alone explain roughly 2 percent of this change, while increased labor effort accounts for the remaining 1 percent.

Sectional effects of NAFTA

Figures 3–5 describe in much greater detail the paths of adjustment of each of the North American economies under NAFTA. One striking feature of these figures is that the adjustment to NAFTA is virtually complete by the free trade date, 2004. Agents in this model know the exact path of the NAFTA program one year before its implementation in 1994. Households in all countries/regions desire smooth consumption paths and this is achieved by responding to the anticipated changes in NAFTA before its implementation date. All nonprimary sectors (nondurable manufacturing, durable manufacturing, construction, and services) are predicted to expand in Canada and the U.S. in the long run. Canada’s response to NAFTA is to temporarily shift factors from nontraded to traded sectors in the early years and boost traded goods production. U.S. sectors respond more smoothly, with all nonprimary sectors expanding over the period. In

---

**FIGURE 3**

**Effects of NAFTA on Canadian economy**

Gross domestic product

- Total
- Primary
- Nondurable mfg.
- Durable mfg.
- Construction
- Services

Exports by destination

- Total
- U.S.
- Mexico
- Rest of world

Capital investment

- Total
- Durable mfg.
- Primary
- Nondurable mfg.
- Construction
- Services

Labor hours

- Total
- Durable mfg.
- Primary
- Nondurable mfg.
- Construction
- Services

Source: Model simulation.
contrast to its northern partners, Mexico’s primary sector is expected to expand under NAFTA. Mexico’s response is much like that of the U.S., in that all sectors expand over the course of the adjustment to free trade. Sectoral changes in labor hours and capital investment tend to mimic changes in sectoral GDP.

NAFTA greatly expands the flow of all goods from Canada and the U.S. to Mexico and from Mexico to the U.S. and Canada. In general, bilateral Mexican–North American trade is predicted to increase by about 20 percent. In contrast, the model predicts NAFTA will have a negligible impact on bilateral trade flows between the U.S. and Canada and between North America and the ROW. The expansion of North American trade is distributed across all traded goods sectors. Primary goods flows expand by roughly twice as much as manufactured goods flows. For example, Mexican primary goods exports rise by roughly 20 percent of their pre-NAFTA level, while Mexican manufactured goods exports rise by roughly 10 percent of their pre-NAFTA level.

Sectoral comparisons between my work and the static studies cited above are complicated by the fact that my model is highly aggregated in comparison to these static analyses. Specifically, Brown et al.’s (1992) model has 29 sectors, while the models of Cox and Harris...
(1992), Cox (1994), and Sobarzo (1992, 1994) have 19 sectors. The Cox-Harris and Sobarzo models predict an expansion of all Canadian and Mexican sectors under NAFTA. In contrast, Brown et al. find that all Canadian and U.S. sectors expand under NAFTA, but only a few major industries expand in Mexico. Aggregating their results to the level of the dynamic model, I find similar directions of change, but the changes are typically larger than in the static models.

Static models hold the stock of world capital fixed, so production gains flow in part from the reallocation of capital across sectors and countries. In a dynamic model, production gains flow from greater investment in capital and a reallocation of these factors across sectors and countries. Static models make different assumptions about the supply of labor, ranging from perfectly inelastic supply to perfectly elastic supply. Brown et al. and Cox-Harris assume the former, while Sobarzo assumes the latter. Sobarzo’s model appears to generate its increased output in large part through greater supply of effort and a minor reallocation of capital. The dynamic model displays some sectoral reallocation of labor and capital in the short run, although it is negligible compared with the long-run sectoral reallocations in the static models.

Source: Model simulation.
The economics of trade liberalization

This section addresses a number of policy experiments that are designed to shed light on the mechanisms at work in the North American trade model.

Basic tools of analysis

Classic trade theory provides some insight into the economics behind the results of the previous section. Figure 6 develops the basic tools of analysis. The analysis is simplified by assuming that there are two countries, home and the foreign country. Each country produces two goods, denoted goods 1 and 2. The home and foreign varieties of goods 1 and 2 are assumed to be perfect substitutes. Without loss of generality, the home country is assumed to be an exporter of good 1 and an importer of good 2 (vice versa for the foreign country).

Panel A of figure 6 displays the home country’s production, consumption, and trade decisions for goods 1 and 2, given world terms of trade of \( p_1 / p_2 \) (where \( p_1 \) denotes the price of good 1 and \( p_2 \) denotes the price of good 2), in the free trade and tariff-ridden cases. In free trade, the home country faces a relative price of \( p_1 / p_2 \). At these prices, production occurs at point A, where the home country’s production frontier, \( TT' \), is tangent to a line of slope \( p_1 / p_2 \) (line 1). Free trade consumption is at point C, where the home country’s indifference curve,
At these terms of trade, the home country exports $AB$ of good 1 and imports $BC$ of good 2. Panel B of figure 6 describes trade patterns using an offer curve, which essentially summarizes the home country’s optimal trade bundles for given terms of trade. For example, in free trade the home country’s offer curve is $OR$. At the given world terms of trade $p1/p2$, the home country exports $OG$ ($=AB$ in panel A of figure 6) and imports $OI$ ($=BC$ in panel A of figure 6).

Consider what happens to the offer curve when the home country imposes a tariff at rate $\tau$ on imports of good 2. The home country’s effective relative price of good 1 falls to $p1/(1+\tau)p2$. Home production shifts from $A$ to point $D$ (in panel A of figure 6), where the home country’s production frontier, $TT'$, is tangent to a line of slope $p1/(1+\tau)p2$ (line 2). This encourages greater domestic production of good 2. Line 4 is parallel to line 1, and shows combinations of goods 1 and 2 that have the same value at world prices as the production point, $D$. The home country’s consumption bundle must lie along line 4; specifically it must lie at $F$ where indifference curve $u$, has slope equal to the domestic price ratio (line 3 is parallel to line 2). The volume of trade falls under the tariff. Exports of good 1 fall from $AB$ to $DE$, while imports of good 2 fall from $BC$ to $EF$. The tariff has also lowered domestic welfare from the $u$, curve to $u''$. This is a well-known result in trade theory. A country that has influence over the price of its traded goods can be made better off when it imposes a tariff on its importable goods, but a small economy that faces given world prices for its traded goods is unambiguously made worse off when it imposes a tariff on its importable goods. In panel B of figure 6, this new trade curve is represented by a point like $F$ on the tariff-ridden offer curve $OR'$. At given terms of trade, the home country exports $OH$ ($=DE$ in panel A of figure 6) and imports $OI$ ($=EF$ in panel A of figure 6).

It is important to note that the home country’s tariff-ridden offer curve always lies to the right of its free trade offer curve.

**The effect of imposing a tariff in the home country**

Panel C of figure 6 displays the solution to a simple, static two-good, two-country model, where the home and foreign countries have some influence over the world price of their traded goods. I consider this case because Mexico and Canada are small countries in the dynamic model but the product differentiation assumption allows them to influence the world price of their traded goods. $OR$ and $OR'$ describe the home and foreign country’s offer curves before they impose tariffs on the exports of the foreign and home goods. The free trade equilibrium occurs at the point where the offer curves intersect, $Q$. The home country’s free trade terms of trade are shown by the slope of line 1. Assume that the home country imposes a tariff on the foreign country’s exports. The home country tariff shifts its offer curve to $OR'$, with the new equilibrium at $Q'$, where the home country’s tariff-ridden offer curve intersects the foreign country’s free trade offer curve. This improves the home country’s terms of trade, which are shown by the slope of line 2. The home country is better off at the new equilibrium since it has moved from indifference curve $u''$ to $u_0$. The foreign country is made worse off by the home country’s tariff.

**Foreign country retaliation**

Panel D of figure 6 describes the case where the foreign country retaliates to the home country’s imposition of a tariff by imposing a tariff on home-country exports. The underlying economic environment is the same as in panel C. The home country initially imposes a tariff on foreign exports that shifts its offer curve from $OR$ to $OR'$ and the equilibrium from $Q$ to $Q'$. The foreign country retaliates by imposing a tariff on home exports that shifts its offer curve from $OR'$ to $OR''$ and the world equilibrium from $Q'$ to $Q''$. At the new equilibrium, $Q''$, both countries are worse off than they were under free trade, $Q$, but the removal of their own tariff would leave them worse off relative to $Q''$. Given that the foreign country will maintain its tariff, it is optimal for the home country to maintain its tariff (and vice versa).

**Unilateral trade liberalization in the dynamic model**

Table 3 shows the results of various unilateral trade liberalizations in the dynamic trade model (note, I solve the model using a log-linear technique, so the sum of the three unilateral trade liberalizations equals the total effect of the trilateral NAFTA). In the left panel, I report the model’s response to a reduction in the level of protection on imports of Mexican goods in Canada. The middle panel considers
<table>
<thead>
<tr>
<th>Variable</th>
<th>Canada</th>
<th>Mexico</th>
<th>U.S.</th>
<th>ROW</th>
<th>Canada</th>
<th>Mexico</th>
<th>U.S.</th>
<th>ROW</th>
<th>Canada</th>
<th>Mexico</th>
<th>U.S.</th>
<th>ROW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Welfare (CV)</td>
<td>-0.16</td>
<td>0.19</td>
<td>0.01</td>
<td>0.00</td>
<td>0.13</td>
<td>-2.74</td>
<td>0.35</td>
<td>-0.05</td>
<td>0.04</td>
<td>3.50</td>
<td>-0.24</td>
<td>0.06</td>
</tr>
<tr>
<td>Real GDP</td>
<td>0.06</td>
<td>0.16</td>
<td>0.00</td>
<td>0.00</td>
<td>0.05</td>
<td>0.69</td>
<td>0.13</td>
<td>-0.01</td>
<td>-0.00</td>
<td>2.41</td>
<td>0.11</td>
<td>0.01</td>
</tr>
<tr>
<td>Real consumption</td>
<td>-0.07</td>
<td>0.23</td>
<td>0.01</td>
<td>0.00</td>
<td>0.12</td>
<td>-1.50</td>
<td>0.32</td>
<td>-0.04</td>
<td>0.03</td>
<td>3.79</td>
<td>-0.07</td>
<td>0.05</td>
</tr>
<tr>
<td>Labor hours</td>
<td>0.09</td>
<td>0.04</td>
<td>-0.00</td>
<td>-0.00</td>
<td>-0.01</td>
<td>1.58</td>
<td>-0.03</td>
<td>0.02</td>
<td>-0.01</td>
<td>0.36</td>
<td>0.17</td>
<td>-0.01</td>
</tr>
<tr>
<td>Real wage</td>
<td>-0.05</td>
<td>0.20</td>
<td>0.00</td>
<td>0.00</td>
<td>0.11</td>
<td>-1.18</td>
<td>0.27</td>
<td>-0.03</td>
<td>0.02</td>
<td>3.11</td>
<td>-0.02</td>
<td>0.04</td>
</tr>
<tr>
<td>Capital investment</td>
<td>-0.03</td>
<td>0.37</td>
<td>0.01</td>
<td>0.00</td>
<td>0.17</td>
<td>-1.43</td>
<td>0.44</td>
<td>-0.06</td>
<td>0.02</td>
<td>6.11</td>
<td>-0.08</td>
<td>0.07</td>
</tr>
<tr>
<td>Real rental rate</td>
<td>0.04</td>
<td>-0.14</td>
<td>-0.01</td>
<td>-0.00</td>
<td>-0.07</td>
<td>1.21</td>
<td>-0.17</td>
<td>0.04</td>
<td>-0.01</td>
<td>-2.51</td>
<td>0.15</td>
<td>-0.04</td>
</tr>
<tr>
<td>Total imports</td>
<td>0.03</td>
<td>0.67</td>
<td>0.02</td>
<td>0.03</td>
<td>0.23</td>
<td>1.28</td>
<td>1.21</td>
<td>-0.39</td>
<td>0.03</td>
<td>10.52</td>
<td>0.16</td>
<td>0.50</td>
</tr>
<tr>
<td>Exports to world</td>
<td>0.39</td>
<td>0.28</td>
<td>0.00</td>
<td>-0.01</td>
<td>0.03</td>
<td>10.72</td>
<td>-0.05</td>
<td>0.17</td>
<td>-0.05</td>
<td>2.87</td>
<td>1.51</td>
<td>-0.14</td>
</tr>
<tr>
<td>to Canada</td>
<td>18.64</td>
<td>-0.28</td>
<td>-0.30</td>
<td></td>
<td>11.36</td>
<td>-0.20</td>
<td>0.62</td>
<td></td>
<td>-9.52</td>
<td>0.46</td>
<td>-0.45</td>
<td></td>
</tr>
<tr>
<td>to Mexico</td>
<td>1.04</td>
<td>0.66</td>
<td>0.67</td>
<td></td>
<td>7.20</td>
<td>7.76</td>
<td>-9.71</td>
<td></td>
<td>10.39</td>
<td>10.67</td>
<td>10.27</td>
<td></td>
</tr>
<tr>
<td>to U.S.</td>
<td>0.38</td>
<td>-0.52</td>
<td>-0.02</td>
<td></td>
<td>0.13</td>
<td>11.00</td>
<td>0.74</td>
<td></td>
<td>-0.30</td>
<td>7.80</td>
<td>-0.76</td>
<td></td>
</tr>
<tr>
<td>to ROW</td>
<td>0.40</td>
<td>-0.50</td>
<td>0.02</td>
<td></td>
<td>-0.60</td>
<td>9.80</td>
<td>-0.79</td>
<td></td>
<td>0.43</td>
<td>-9.08</td>
<td>0.90</td>
<td></td>
</tr>
<tr>
<td>Terms of trade</td>
<td>-0.45</td>
<td>0.63</td>
<td>0.02</td>
<td>0.03</td>
<td>0.25</td>
<td>-12.69</td>
<td>1.65</td>
<td>-0.41</td>
<td>0.05</td>
<td>11.35</td>
<td>-1.71</td>
<td>0.55</td>
</tr>
<tr>
<td>Net foreign assets/GDP</td>
<td>1.56</td>
<td>-2.75</td>
<td>0.00</td>
<td>0.00</td>
<td>-0.88</td>
<td>35.27</td>
<td>-2.34</td>
<td>0.05</td>
<td>0.62</td>
<td>-44.60</td>
<td>2.20</td>
<td>0.21</td>
</tr>
</tbody>
</table>

Using the tools developed in the previous section, I can shed some light on the mechanisms at work in the more complicated dynamic model. Using panel D of figure 6.1, I analyze the effects of the liberalization. In figure 6.1, the foreign country removes its tariff on its exports. The new equilibrium, in which the foreign country's trade offer curve, OR*, is no longer the equilibrium. This creates excess demand for the home exportable and excess supply for the foreign exportable. The new equilibrium, in which the foreign country's trade offer curve, OR*, is no longer the equilibrium, creates excess demand for the home exportable and excess supply for the foreign exportable. The new equilibrium, in which the foreign country's trade offer curve, OR*, is no longer the equilibrium, creates excess demand for the home exportable and excess supply for the foreign exportable.

Second, the liberalizing country's trading partners are made better off by its liberalization program. Finally, the liberalizing country's trading partners maintain their trade barriers. It is optimal for the liberalizing country to maintain its trade barriers.
terms of trade (shown by the shift from line 3 to line 2) but increases the volume of trade. However, the deterioration in the terms of trade outweighs the increase in trade volumes and the foreign country’s real income/wealth falls, so it is worse off at $Q'$, while the home country’s wealth rises, so it is better off at $Q''$.

The loss of liberalizing country wealth is clearly reflected in the statistics in table 3. Lower wealth leads households in the liberalizing country to consume less and raise their supply of labor effort. Increased effort leads to higher domestic output. The liberalizing country responds to the wider trade gap by raising its output and lowering its levels of investment and consumption to increase exports of its traded goods. The increase in labor effort also increases the demand for capital inputs. The increased supply of labor leads to a fall in the liberalizing country’s real wage, while the increased demand for capital inputs leads to a rise in the real rental rate of capital.

On the other side of the coin, the unilateral tariff reduction has the reverse implication for the liberalizing country’s trading partners. The tariff reduction improves the terms of trade of the liberalizing country’s trading partners and raises their wealth. Again, the statistics in table 3 support this intuition. For example, a tariff reduction in Mexico raises the wealth of Canada and the U.S., which leads to greater consumption and less labor effort. A decrease in the supply of effort raises real wages in these countries. The decreased labor effort also lowers the demand for capital inputs, while cheaper imports raise the supply of capital, which results in a fall in the real rental price of capital.

Sensitivity analysis

To what extent are the results sensitive to the parameters of the model? For the trade liberalization experiments, a key parameter is the elasticity of substitution between home and imported goods. In table 4, I report results from simulations of the model using different elasticities of substitution between home and foreign goods. In the left panel, I report the benchmark model’s results (scaling coefficient is 1.0), which are the values estimated by Roland-Host and Reinert (1993) and Sobarzo (1992). In the middle panel, I double the elasticities of substitution between home and foreign goods (scaling coefficient 2.0). In the right panel, I multiply the benchmark elasticity by 3.0, which brings the model’s elasticities closer to those of Brown et al.’s (1992) uniform elasticity of 3.

Table 4 shows that many of the aggregate features of the model are not sensitive to this parameter choice. The most sensitive area of the model is trade flows. The percentage increase in post-NAFTA steady state trade volumes rises dramatically with the elasticity of substitution. Specifically, in the high-elasticity case, North American trade volumes are predicted to rise by roughly twice as much as in the benchmark model following NAFTA.
### Table 4
Long-run effects of NAFTA under different parameters (percentage deviation from pre-NAFTA steady state)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Benchmark model (x 1.0)</th>
<th>Low elasticity of substitution (x 2.0)</th>
<th>High elasticity of substitution (x 3.0)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Canada</td>
<td>Mexico</td>
<td>U.S.</td>
</tr>
<tr>
<td>Welfare (CV)</td>
<td>0.11</td>
<td>1.06</td>
<td>0.12</td>
</tr>
<tr>
<td>Real GDP</td>
<td>0.11</td>
<td>3.71</td>
<td>0.24</td>
</tr>
<tr>
<td>Real consumption</td>
<td>0.08</td>
<td>2.81</td>
<td>0.26</td>
</tr>
<tr>
<td>Labor hours</td>
<td>0.07</td>
<td>2.22</td>
<td>0.14</td>
</tr>
<tr>
<td>Real wage</td>
<td>0.09</td>
<td>2.36</td>
<td>0.26</td>
</tr>
<tr>
<td>Capital investment</td>
<td>0.16</td>
<td>5.85</td>
<td>0.39</td>
</tr>
<tr>
<td>Real rental rate</td>
<td>0.03</td>
<td>−1.77</td>
<td>0.00</td>
</tr>
<tr>
<td>Total imports</td>
<td>0.29</td>
<td>23.18</td>
<td>2.47</td>
</tr>
<tr>
<td>Exports to world</td>
<td>0.37</td>
<td>24.97</td>
<td>2.60</td>
</tr>
<tr>
<td>to Canada</td>
<td>18.63</td>
<td>48.49</td>
<td>1.24</td>
</tr>
<tr>
<td>to Mexico</td>
<td>18.28</td>
<td>38.49</td>
<td>1.24</td>
</tr>
<tr>
<td>to ROW</td>
<td>0.23</td>
<td>−2.40</td>
<td>0.06</td>
</tr>
<tr>
<td>Terms of trade</td>
<td>−0.15</td>
<td>−0.24</td>
<td>0.17</td>
</tr>
<tr>
<td>Net foreign assets/GDP</td>
<td>1.30</td>
<td>−8.09</td>
<td>−0.14</td>
</tr>
</tbody>
</table>

Conclusion:

NAFTA is a landmark commercial trade policy because it represents the first far-reaching free trade agreement between major industrial countries and a developing country. My results suggest that NAFTA will generate welfare gains for all North American participants, with the greatest gains accruing to Mexico. The dynamic analysis also suggests NAFTA will lead to an expansion of non-primary sectors in Canada, Mexico, and the U.S. in contrast to the negligible impact on real output of Canadian and U.S. primary sectors but to lead to sizable expansion of primary activity in Mexico. This article has taken the study of multilateral trade liberalization one step further by building a dynamic model of North American trade, which overcomes some of the weaknesses of traditional static analysis, such as fixed capital stocks and zero current accounts.
There are two significant limitations to the current analysis that future work must address. First, the underlying growth rate of the dynamic model economy is exogenous and cannot be influenced by policy. Second, NTBs are incorporated into the numerical analysis by way of tariff-equivalent NTBs. Future work must remove these limitations by developing dynamic trade models that allow for endogenous growth and explicit quantity constraints. Only then will we be in a position to measure the true gains from multilateral free trade agreements.

NOTES

1 See, for example, the recent conference volumes on NAFTA by Greenway and Whalley (1992), Lustig, Bosworth, and Lawrence (1992), Francois and Shiells (1994), and survey by Kehoe and Kehoe (1994).

2 See references in footnote 1 for examples of static computable general equilibrium models.

3 See the surveys of Backus, Kehoe, and Kydland (1995) and Baxter (1995) for examples of one-sector, international real business cycle models.

4 See Wonnacott (1996) for a more general discussion of hub and spoke systems.

5 See Whalley (1984) for a thorough discussion of the terms of trade effects associated with the abolition of tariff and NTBs, in a model of North–South trade (that is, a model describing trade between industrial and developing regions of the world economy).

6 This section draws heavily on the discussion presented in Caves, Frankel, and Jones (1990), chapters 11–15.

7 See Kehoe (1994) for a thorough discussion of the limitations to current static analyses and the steps needed to develop a state of the art dynamic model suitable for analyzing free trade agreements.

REFERENCES


APPENDIX: Detailed description of North American trade model

There are four countries/regions in the model: Canada (c), Mexico (m), the United States (u), and the rest of the world (r). Each country/region has five production industries: primary raw materials (1), nondurable manufactures (2), durable manufactures (3), construction (4), and services (5). Note, countries are indexed by k and l, while industries are indexed by i and j.

Preferences

Each country k has a single infinitely lived representative household that maximizes its expected lifetime utility, $U_k$, from consuming a composite consumption good ($c_{ikt}$) and leisure ($h_{ikt}$):

$$U_k = E_0 \sum_{t=0}^{\infty} \beta^t \left( \frac{c_{ikt}}{1-\sigma} \right)^{1-\sigma} \sum_{j=0}^{\infty} \beta^j (\theta_k^j \ln(c_{ikt}) + (1 - \theta_k^j) \ln(h_{ikt}))$$

for $\sigma > 0$ and $\sigma \neq 1$, and $\beta > 0$ and $0 < \beta < 1$, $0 < \theta_k \leq 1$ for $\forall k$.

Note, $\beta$ denotes the household’s subject rate of time discount. Consumption is an aggregate of nondurable consumption goods ($c_{ikt}$) and the flow of services from consumer durables ($d_{ikt}$). Nondurable goods and the durable service flow are aggregated according to a constant elasticity of substitution (CES) function:

A.1) $U_k = E_0 \sum_{t=0}^{\infty} \beta^t (\theta_k^t \ln(c_{ikt}) + (1 - \theta_k^t) \ln(h_{ikt}))$

for $\sigma = 1$ and $0 < \beta < 1$, $0 < \theta_k \leq 1$ for $\forall k$. The elasticity of substitution between nondurable consumption goods and durable services is $1/\eta$, while $\omega_k$ reflects the bias toward nondurables. Nondurable consumption goods are also aggregated by a CES function:

A.2) $c_{ikt} = \left( \omega_k c_{ikt}^{1-\eta} + (1 - \omega_k) d_{ikt}^{1-\eta} \right)^{1/(1-\eta)}$

for $0 \leq \omega_k \leq 1$ and $\eta > 0$ for $\forall k$. The elasticity of substitution between nondurable consumption goods and durable services is $1/\kappa$, while $\omega_k^{ik}$ reflects the bias toward nondurable good i.

A.3) $c_{ikt} = \left( \sum_i \omega_k c_{ik}^{1-\kappa} \right)^{1/\kappa}$

for $0 \leq \omega_k \leq 1$, $\Sigma \omega_k = 1$ and $\kappa > 0$ for $\forall k$.

The elasticity of substitution between individual nondurable consumption goods ($c_{ik}$) is $1/\kappa$, while $\omega_k^{ik}$ reflects the bias toward nondurable good i.

Production technology

I make the standard multisector assumption that gross production in sector i ($y_{ikt}$) is described by a two-level CES function (see, for example, Shoven and Whalley, 1992):

A.4) $y_{ikt} = A_{ikt} \left( \omega_{ikt} y_{ikt}^{1-\epsilon} + (1 - \omega_{ikt}) m_{ikt}^{1-\epsilon} \right)^{1/\epsilon}$

for $0 \leq \omega_{ikt} \leq 1$, and $\epsilon > 0$ for $\forall i, k$. The first level of production involves a value-added index ($y_{ikt}$) and an aggregate intermediate goods component ($m_{ikt}$). The value-added production index is described by Cobb-Douglas technology, which uses capital ($k_{ikt}$), labor ($n_{ikt}$), and land ($l_{ikt}$) as inputs:

A.5) $y_{ikt} = k_{ikt}^{\alpha_k} n_{ikt}^{\alpha_l} l_{ikt}^{1-\alpha_k-\alpha_l}$

for $\alpha_k, \theta_k \geq 0$ and $\alpha_k + \theta_k \leq 1$ for $\forall i, k$.

The other factor of production is the aggregate intermediate input, which is a composite of intermediate inputs from all sectors. Specifically, these factors are aggregated according to the following CES function:

A.6) $m_{ikt} = \left( \sum_j \alpha_{ikt} m_{jkt}^{1-\epsilon} \right)^{1/\epsilon}$

for $0 < \alpha_{ikt} < 1$, $\Sigma \alpha_{ikt} = 1$, and $\epsilon > 0$ for $\forall i, k$. The variable $m_{ikt}$ denotes the flow of intermediate goods from sector j to sector i. The elasticity of substitution between value-added and all intermediate inputs in sector i is $1/\epsilon$. $A_{ikt}$ is an exogenous productivity shift parameter in sector i.

Investment behavior

Capital goods

There are two types of investment goods in this model. The first type is durable capital goods that depreciate at rate $0 < \delta \leq 1$. Capital goods are either used as inputs in the production of sector j goods ($k_{jkt}$) or as household durables ($d_{ikt}$). Production capital ($k_{ikt}$) and household durable ($l_{ikt}$) investment is a composite of equipment ($s_{ikt}$) and structures ($s_{ikt}$). Equipment is produced in the durable-manufacturing sector and structures are produced in the construction sector. Equipment and structures are aggregated according to a constant elasticity of substitution (CES) function:
A.7) $\sum_{j} i_{akt} + i_{akt} = \left( \omega_{ik} s_{ikt}^{1/\gamma} + (1-\omega_{ik}) s_{ikt}^{1/\gamma} \right)^{1/1-\gamma}$

for $0 < \omega_{ik} < 1$ and $\gamma > 0$ for $\forall j, k$. The elasticity of substitution between equipment and structures is $1/\gamma$, while $\omega_{ik}$ reflects the bias toward equipment. Note, $i_{akt}$ denotes investment in sector $j$ capital.

I assume there are costs of adjusting sectoral capital stocks in all regions. Following Baxter and Crucini (1993), I employ a concave adjustment cost of function where $\phi_{l_j} (x) > 0$, $\phi_{l_j}{''} (x) > 0$, and $\phi_{l_j}{'''} (x) < 0$. Using this notation, I describe accumulation of sector $j$ capital and household durables by the following:

A.8) $k_{jkt+1} = (1 - \delta) k_{jkt} + \phi_{l_j} \left( \frac{i_{akt}}{k_{jkt}} \right) k_{jkt}$ for $\forall j, k$.

A.9) $d_{kt+1} = (1 - \delta) d_{kt} + \phi_{l_d} \left( \frac{i_{akt}}{d_{kt}} \right) d_{kt}$ for $\forall k$.

Intermediate goods

The second investment goods category is intermediate goods ($m_{ijkl}$), which are held as inventories and completely consumed in the production of future goods. The tax period in the model is quarterly. Empirical evidence (see Ramey [1989] for details) suggests intermediate goods require one period to put in place. Based on this I assume period $t + 1$ intermediate inputs are produced in period $t$.

Trade flows

The model allows for trade between the North American countries and the rest of the world, ROW, where the ROW is a composite of Canadian, Mexican, and U.S. trading partners. Specifically, let $x_{iab}$ denote country $k$’s private consumption/use of good $i$ produced in country $l$. In other words, $x_{iab}$ denotes country $k$’s imports of good $i$ from country $l$. The private final expenditure aggregation function for good $i$ is a CES function given by the following:

A.10) $c_{ikt} + s_{ikt} + \sum_{j} m_{ijkl+1} = \left( \sum_{l,u,c,m,r} \omega_{ikt} s_{ijkl+1}^{1/\gamma} \right)^{1/1-\gamma}$

for $0 \leq \omega_{ikt} \leq 1$, $\Sigma_{k} \omega_{ikt} = 1$ and $\mu_{i} > 0$ for $\forall i, k$. Recall $c_{ikt}$ describes nondurable consumption of good $i$, $s_{ikt}$ capital investment, and $m_{ijkl}$ the flow of intermediate goods from sector $i$ to sector $j$. The elasticity of substitution between home-produced and all imported goods is $1/\mu_{i}$, while $\omega_{ikt}$ reflects bias toward country $l$’s good $i$.

Government

Each country has a government that imposes tariffs on imported goods. The explicit tariff rate in country $k$ for good $i$ imported from country $l$ is $\tau_{ikt}$. It is difficult to model nontariff barriers (NTBs) directly, so I take the standard approach of imposing tariff-equivalent NTBs. The tariff-equivalent NTB for good $i$ imported from country $l$ is $\rho_{ilt}$. The government also levies a lump-sum tax, $T_{kt}$, to finance its current spending. By allowing $p_{ilt}$ to denote the price of country $l$’s good $i$ in terms of the numeraire good, I can describe country $k$’s government budget constraint:

A.11) $\sum_{l,u,c,m,r} \Sigma_{l} p_{ilt} g_{ilt} + TR_{ikt} + QR_{ikt} = \sum_{l,u,c,m,r} \Sigma_{l} (\tau_{ikt} + \rho_{ilt}) p_{ilt} x_{ilt} + T_{kt}$

A.12) $TR_{ikt} = \sum_{l,u,c,m,r} \Sigma_{l} \tau_{ikt} p_{ilt} x_{ilt}$, and

A.13) $QR_{ikt} = \sum_{l,u,c,m,r} \Sigma_{l} \rho_{ilt} p_{ilt} x_{ilt}$.

The last element of final expenditure is government spending. For simplicity I assume that the public sector has the same aggregation function as the private sector.

A.14) $g_{ikt} = \left( \sum_{l,u,c,m,r} \omega_{ikt} s_{ijkl+1}^{1/\gamma} \right)^{1/1-\gamma}$ for $\forall i, k$

where $g_{ikt}$ is the country $k$ government’s consumption of good $i$ from country $l$. Combining these results implies $T_{kt} = \Sigma_{l,u,c,m,r} \Sigma_{l} p_{ilt} g_{ilt}$.

Resource constraints

The model contains two non-reproducible factors, labor ($n_{ikt}$) and land ($l_{ikt}$). Labor is mobile between sectors within a country, subject to small adjustment costs. In particular, labor services ($n_{ikt}^{s}$) are described by the following dynamic relationship:

A.15) $n_{ikt}^{s} = \phi_{n} \left( \frac{n_{ikt}^{s}}{n_{ikt}} \right) n_{ikt}^{s}$ for $\forall i, k$. 
I assume $\phi_{n_i}$ has properties similar to the capital adjustment cost functions (that is, $\phi_{n_i}(x) > 0$, $\phi'_{n_i}(x) > 0$, and $\phi''_{n_i}(x) < 0$), although the actual cost of adjusting labor and capital will be different. Total hours are normalized to unity so that agents face the following labor constraints:

\[ A.16 \quad 1 - h_{kt} - \sum_j n_{jt} = 0 \quad \forall k. \]

Land is an important factor of production in the primary sector. The supply of land is assumed to be exogenous. The supply of land is fixed in the NAFTA experiments.

The only financial assets available to agents in country $k$ are noncontingent one-period bonds $b_{kt}$. The price of these assets in terms of the numeraire good is $p_{nt}$ (note, throughout the article I maintain ROW nondurable manufactured goods as the numeraire, $p_{2rt} = 1$). With this notation, I can describe country $k$’s representative household’s intertemporal budget constraint as:

\[ A.17 \quad \sum_i p_{it} y_{it} + b_{it} + QR_{it} + TR_{it} = \sum_{l=u,c,m,r} \sum_j \left(1 + \tau_{ikt} + \rho_{ikt}\right) p_{ilt} x_{ikt} + \sum_i p_{ikt} x_{ikt} + p_{bt} b_{kt} + T_{kt} \quad \forall k. \]

Each regional economy is also subject to the following sectoral resource constraints:

\[ A.18 \quad y_{ikt} = \sum_{l=u,c,m,r} x_{ikt} + g_{ikt} \quad \forall i, k. \]

**Equilibrium and model solution**

I follow Baxter and Crucini’s (1995) approach to solving dynamic trade models, in which foreign assets are restricted to one-period bonds. In each country, the representative household owns all productive inputs. Each period, the household rents these productive inputs to the various firms in the same economy. Firms produce all five goods and sell the output to households in all four countries/regions. In each country/region, the representative household’s dynamic optimization problem is to maximize the expected lifetime utility described by A.1, subject to the constraints given by equations A.2 to A.17. The competitive equilibrium is described by the processes for capital, labor, consumption, and investment and their associated prices, which satisfy the regional representative households’ optimization problems and the resource constraints given by A.18. I use numerical techniques to solve for the models dynamic equilibria. Specifically, the log-linear approximation technique advanced in the real business cycle literature by King, Plosser, and Rebelo (1988, 1990).

\(^1\) Differentiating goods by location is necessary to rule out complete specialization. See Baxter (1992) for a discussion of how complete specialization, along the lines of Ricardian comparative advantage, emerges in a dynamic Heckscher-Ohlin-Samuleson model where goods are not differentiated by production location.

\(^2\) Backus, Kehoe, and Kydland (1995) make a similar assumption in a dynamic one-sector model of international trade.