The Effects of US/Canada Trade on Production Costs and Productivity

David K. Lambert
Eric C. Schuck
Hyun Jin
and
Won Koo

Paper prepared for presentation at the
American Agricultural Economics Association Annual Meeting
Montreal, Canada, July 27-30, 2003

Authors are Professor and Chair, North Dakota State University, Assistant Professor, Colorado State University, and Assistant Research Professor and Professor, respectively, North Dakota State University. The authors express appreciation to Eldon Ball and Carol Whitten of the Economic Research Service for providing state-level price and quantity indices and historical state-level trade data for the seven states used in the analysis.

The Effects of US/Canada Trade on Production Costs and Productivity

Abstract: Increased international trade can affect production costs by promoting changing input and output prices and by promoting technological innovation. Econometric results suggest increasing state exports of agricultural products and rising US/Canada agricultural trade has shifted production costs from labor and material inputs towards capital and land and that trade-induced technological improvements have driven down production costs in the Great Plains.

Trade between Canada and the United States has increased substantially in the last several decades. The value of trade between the United States and Canada increased from $20.6 billion in 1970 to $409.8 billion in 2000. The value of agricultural trade has grown from $0.9 billion to $16.3 billion over the same period. The increase in agricultural trade volume has been matched by changes in the composition of agricultural goods crossing the border. The value share of bulk commodities fell from 12.3 percent in 1989 to 7.4 percent in 2000. Intermediate agricultural goods fell from 32.2 to 24.5 percent of agricultural trade over the same period. The value of consumer-oriented food products increased from 55.4 to 68.1 percent between 1989 and 2000. Figure 1 illustrates the growth in total bulk agricultural and animal trade over the 1973-1996 period.

Farmers in the Great Plains of the United States claim that they have suffered damage from increases in Canadian agricultural imports. Agricultural production in the Great Plains is concentrated in grains, oilseeds, and livestock, the primary products entering the U.S. from Canadian farms. The distribution of value shares of Canadian imports in 1996 was 41 percent in animals and products, 24 percent in grains and feeds, and 12 percent in oilseeds and products (ERS). U.S. farmers claim increased supplies resulting from Canadian imports negatively impact U.S. commodity prices.

Ameliorating the impacts of agricultural imports is the importance of export markets for farmers of the Great Plains. Table 1 illustrates the increasing importance of state exports. Nebraska exported over $3.3 billion of agricultural bulk commodities and animals in 1996, nearly 27 percent of the value of that year's agricultural production for the state. Exports are even more important in North Dakota, where state exports account for over 40 percent of agricultural production. Not only do exports represent an important market for the farmers of these states, but the importance of exports both in absolute dollar terms as well as the share of the states' agricultural production has been increasing over the last thirty years.

The purpose of this paper is to investigate the effects on agricultural producers in the states of the Great Plains resulting from increasing state agricultural exports and from bulk commodity and animal product trade between the United States and Canada. Concentration on the Great Plains reflects similarities in agricultural production between these states and the Canadian Prairie Provinces and the importance of agricultural exports to the states' agricultural industries.

Trade promotes domestic production efficiency by favoring industries in which a country enjoys a comparative advantage. Domestic prices more closely reflect world prices as trade barriers fall and economies become more open to global markets. Although welfare enhancing, the impacts of changing trade policies vary among sectors of the economy. Consumers gain from lower prices for goods affected by trade liberalization. Recent evidence points to additional consumer gains arising from the availability of increased product variety and improved quality (Romer). Domestic processors who substitute imported for domestically produced intermediate inputs also gain from lower costs and potential improvements in input variety and quality (Feenstra, Markusen, and Zeile). Lower input costs will improve the competitive position of domestic processors in both domestic and export markets. Domestic producers of exported goods also gain as trade barriers fall and foreign earnings from trade increase demand abroad for U.S. products.

On the negative side, short run impacts may adversely affect domestic producers of goods when competing imports capture a greater share of domestic markets. Product prices may fall as imports add to domestic supplies. Lacking comparative advantage, aggregate domestic output will fall in response to lower prices. Factors migrate to other industries. Returns to industry-specific quasi-fixed factors may fall. Total welfare impacts ultimately depend upon the volume of goods traded, demand elasticities, and income effects resulting from changes in factor and product markets.

Agricultural producers in the U.S. facing increasing competition from Canadian imports maintain they have incurred welfare losses as Canadian products crowd out markets for domestic suppliers. In a static world, changing prices may reduce domestic production, the market share of domestic production may decline, and producer welfare falls. In this respect, U.S. producer concerns may be valid.

However, firms respond in a variety of ways to changing conditions. Lower prices for goods competing with foreign imports may force some domestic producers to go out of business. Alternatively, lower prices may induce technological change that lower production costs. Evidence confirms substantial productivity gains occur in countries following trade liberalization (Harrison; Tybout and Westbrook). Of special relevance to the current study, productivity increases in Canadian manufacturing have been substantial since passage of the Canada-U.S. Free Trade Agreement. Trefler documents overall labor productivity increases of 0.6 percent per year in Canadian manufacturing since passage of CUSTA. Industries most affected by reductions in tariffs following passage of the CUSTA (i.e., those industries facing the highest trade barriers prior to CUSTA) experienced even greater labor productivity gains averaging 2.1 percent per annum. In these cases, relaxation of trade barriers resulted in trade expansion which preceded the observed factor productivity gains.

Evidence of the importance of technological change in explaining trade patterns has recently been presented by Gustavsson, Hansson, and Lundberg and by Krugman. Gopinath and Kennedy used state-level production and trade data to estimate the relationship between a state's export share and productivity changes. Their model treated productivity changes as exogenous and was used to explain differences in state agricultural exports. In a conclusion relevant to the current research, Gopinath and Kennedy found states with greater rates of productivity growth were more likely to export bulk commodities and gain comparative advantage over other states. Their results support the Ricardian claim that specialization derives from productivity differences.

In addition to productivity gains based on firm entry and exit and neutral technological change, factor price changes predicated upon the Stolper-Samuelson theorem may further induce biased technological change. As domestic price for a product falls when imports increase, the theorem predicts that the prices of factors used intensively in production of the affected good will fall. For example, domestic prices of agricultural products facing increasing import substitution should fall. As a result, prices of factors used intensively in the production of agricultural commodities, such as land, should fall as well.

Innovation induced by changing relative factor prices may alter production possibility sets and lower average costs in the industry. The extent to which factor prices change will depend in part upon the mobility of factors across different industries and the volume of trade (Krugman). Changing relative input prices foster factor substitution in the short run and may induce biased technological change in the longer run. Under the Ricardian model, induced changes in factor productivity can further affect a country's trade and production mix, fueling additional long term impacts on relative prices and further technological change.

A Model of Trade-Induced Technological Change

Measurement of the effects of U.S.-Canadian agricultural trade is premised upon cost minimizing behavior on the part of U.S. farmers. Average costs should decline as the industry become more efficient in order to be competitive. Relative input prices should change from the effects of changing output prices and product mix. Costs are assumed to be a function of input prices $w \in \Re_+^n$, a composite output $y \in \Re_+$, and technology τ, or $C(w, y; \tau)$.

Various assumptions underlie the treatment of technological change and costs. In the past, deterministic trend models were the customary approach to modeling changing cost structures over time. Deterministic trends assume costs change from year to year in a predictable manner often proxied by the simple progression of time. Theoretical discomfort with this assumption, as well as estimation problems identified from an evolving understanding of time series' processes (Nelson and Kang; Durlauf and Phillips), led to treatment of technological change, and resulting changes in costs, as stochastic when the underlying data are trend nonstationary (Slade, Shumway and Lim, Lambert and Shonkwiler).

Several mechanisms have been identified by which cost and share equations are affected by technological change. Disembodied technological change assumes innovation is factor neutral. The marginal productivities of all factors change proportionately, so all improvements resulting from technological change are reflected in increased output. However, empirical evidence supports the embodiment of technological change in factors of production (Ball, Butault, and Nehring, Binswanger, Lambert and Shonkwiler). Factor quality changes do, however, raise measurement problems. A common approach is to posit effective factors, $x_{it}^{*} = \mathrm{A}_{it} x_{it}$, where A_{it} represents a quality adjustment for comparing units of factor x_i across time. A symmetric adaptation to factor prices, w_{it}, adjusts observed prices for quality changes, $w_{it}^{*} = w_{it} / \mathrm{A}_{it}$. An assumption of embodied technological change and the use of effective factor prices results in the effective cost function, $C(w^{*}, y)$. In the effective cost function, the impacts of technological change are incorporated in the augmentation factors A_{it}.

Augmentation factors are not observable. Alternative approaches to measure the augmentation factors include estimation via nonparametric (Chavas and Cox) or parametric techniques (Binswanger, Lambert and Shonkwiler). We adopt the parametric approach. Isolating the differential effects of changes in TFP on inputs was parameterized similar to

Lambert and Shonkwiler, so that $A_{it} = \tau_t^{\gamma_i}$ or $\ln A_{it} = \gamma_i \ln \tau_t$. The time-varying measure τ is the state-level TFP measure reported by Ball, Butault, and Nehring. The coefficient γ_i is the indicator of factor biasedness. In order to identify the γ_i's, we impose the restriction $\sum_i \gamma_i = 0$.

We are interested in the effects of changing trade levels on farm productivity, with subsequent impacts on factor shares and production costs. In addition, it has been well-documented that TFP is influenced by private and public expenditures on agricultural research and development and, ultimately, by farmer adoption of innovations in response to market conditions. Consequently, TFP is considered endogenous. Endogeneity of TFP was also assumed by Yee et al., who explored the relationship between state-level TFP and explanatory variables including the stock of public research and Extension investment, weather conditions, and transportation infrastructure. We add trade activity variables to identify impacts of international trade on state productivity growth, or TFP = *f*(Z), where Z are the explanatory variables.

It is anticipated that the impact of trade *m* on TFP is positive, or $\partial TFP / \partial m > 0$. Productivity is expected to increase as domestic farm performance improves in order to be competitive in world markets. Two mechanisms might explain a positive relationship between trade and TFP. First, inefficient firms might exit the industry, being unable to reduce costs sufficiently to remain profitable under falling output prices resulting from outward shifts in domestic supply. Exit of inefficient firms will improve average productivity levels. Second, remaining firms will face the same reduced output prices, and will thus be encouraged to innovate to reduce production costs to retain previous profit levels achieved under more protectionist domestic trade policies. The combination of the two effects should result in a measurable relationship between TFP and increasing trade volumes.

The volume of trade is exogenous to the individual producer. However, price and technological change affect the minimization problem faced by the individual farmer.

$$1) \qquad C(w^*, y) = \min_x \{ w^{*\prime} x : y \le f(x) \}$$

Employing Shepherd's Lemma,

$$2) \qquad \frac{\partial\, C(w^*, y)}{\partial\, w^*} = x$$

This is the basic result of duality theory. Expression (2) indicates that increases in the effective factor price w* will increase costs. Reductions in w*, such as might occur when the quality of the input improves due to technological innovation, will lower the effective cost of production. How effective prices and, subsequently, effective input demands, change with increasing trade can be derived from the factors influencing effective prices. Trade is hypothesized to positively affect TFP. The impact of TFP on individual inputs is determined by the biasedness of technological change. Recalling *w* = w/A*,

$$3) \qquad \frac{\partial\, C(w_t^*, y)}{\partial\, A_{it}} = \frac{\partial\, C(w_{1t}^*, \ldots, w_{it}^*, \ldots, w_{nt}^*, y)}{\partial\, A_{it}} = \frac{\partial\, C(w_{1t}^*, \ldots, w_{it}^*, \ldots, w_{nt}^*, y)}{\partial\, w_{it}^*} \, \frac{\partial\, w_{it}^*}{\partial\, A_{it}}$$

The first term on the right hand side is positive, as seen in expression (2). The second term is negative given the definition of effective prices. Improvements in the augmentation factors affecting effective inputs will therefore reduce effective production costs.

Recalling $\mathrm{A}_{it} = \tau_t^{\gamma_i}$ and $\tau_t = f(\mathrm{Z}_t) = f(\{z_{jt}\})$, expression (3) can be further defined to indicate the cost impacts of the different factors affecting TFP:

4) $$\frac{\partial C\left(w_t^*, y\right)}{\partial z_{jt}} = \frac{\partial C\left(w_{1t}^*, \ldots, w_{it}^*, \ldots, w_{nt}^*, y\right)}{\partial w_{it}^*} \frac{\partial w_{it}^*}{\partial A_{it}} \frac{\partial A_{it}}{\partial \tau_t} \frac{\partial \tau_t}{\partial z_{jt}}$$

As before, costs will change with changes in effective input prices. In addition, the effects of changes in a single z_{jt} will depend upon the impact of z_{jt} on τ_t, the differential impacts of τ_t on the effective prices of the various inputs, and changes in costs as effective input prices change. The signs of the latter two effects are to be determined empirically. We expect that trade, as well as research stock, will positively impact τ_t. The direction of factor biasedness, or $\partial A_{it} / \partial \tau_t$, is not known *a priori*.

Empirical Application

The focus of this research is on production cost changes, technological change, and factor shares over time for seven states of the Great Plains (Colorado, Kansas, Nebraska, North Dakota, Oklahoma, Montana, and South Dakota). Panel procedures were employed to estimate production cost changes between 1973 and 1996 for the seven states. Data included agricultural output quantity indices for combined livestock and crop production (y) and input price indices for labor (w_l), materials (w_m), capital (w_k), and land (w_d).

Technology was proxied using state-level total factor productivity (TFP) indices calculated by Ball, Butault, and Nehring. Instrumental variables for TFP included the total volume of bulk commodity and animal product exports and imports between the United States and Canada constructed from the Production, Supply and Distribution data compiled by FAS, state level agricultural exports for each of the seven states (Whitten), and a measure of agricultural private and public research capital (National Research Council). Research capital is derived using the spline function approach described in Yee et al. State dummy variables were created to capture local differences in effective prices, shares, and production costs.

Summary statistics for trade and total factor productivity are reported in Table 1. All seven states increased the real value of agricultural exports over the 1973-1996 period. Rates of average annual growth in export value ranged from a low of 1.21 percent for Oklahoma to a high of 7.98 percent for Nebraska. In addition to the increases in the real value of exports, the share of each state's agricultural production that is exported has also increased. Nebraska again leads the other six states with exports growing as a percentage of agricultural production by 6.15 percent per year. Oklahoma has the lowest rate of annual growth of exports as a share of total production value. Even thought the value of exports has been growing as a proportion of state production, the annual growth has been a modest 1.36 percent. Rates of growth in total factor productivity are also seen to vary by state. North Dakota, South Dakota, and Nebraska experienced the greatest increases in TFP over the period, averaging growth rates of around 1.9 percent. The two southern-most states, Kansas and Oklahoma, experienced TFP gains of less than one percent per year over the period.

Parameter estimates for the cost function were estimated using the translog cost function. The translog is a flexible functional form in which symmetry and homogeneity with respect to input prices was imposed by construction.

The general cost function is:

5)

$$\ln C\left(w^*,y\right)=\beta_0+\beta_k\ln w_k^*+\beta_l\ln w_l^*+\beta_m\ln w_m^*\ +\beta_d\ln w_d^*$$

$$+\ \sum\nolimits_{s=1}^{6}\sum\nolimits_{i=k,l,m,d}\delta_{is}\,D_{s}\left(\ln w_i^*\right)\ +\beta_Y\ln y\ +\ \ \beta_{YY}\left(\ln y\right)^2$$

$$+\frac{1}{2}\left(\beta_{kk}\left(\ln w^*_k\right)^2+\beta_{ll}\left(\ln w_l^*\right)^2\ \ +\beta_{mm}\left(\ln w_m^*\right)^2+\beta_{dd}\left(\ln w_d^*\right)^2\right)$$

$$+\beta_{kl}\left(\ln w^*_k\right)\left(\ln w^*_l\right)+\beta_{km}\left(\ln w^*_k\right)\left(\ln w^*_m\right)+\beta_{kd}\left(\ln w^*_k\right)\left(\ln w^*_d\right)$$

$$+\beta_{lm}\left(\ln w^*_l\right)\left(\ln w^*_m\right)+\beta_{ld}\left(\ln w^*_l\right)\left(\ln w^*_d\right)$$

$$+\beta_{md}\left(\ln w^*_m\right)\left(\ln w^*_d\right)$$

$$+\beta_{Yk}\left(\ln w^*_k\right)\left(\ln y\right)+\beta_{Yl}\left(\ln w_l^*\right)\left(\ln y\right)+\beta_{Ym}\left(\ln w_m^*\right)\left(\ln y\right)+\beta_{Yd}\left(\ln w_d^*\right)\left(\ln y\right)$$

where all explanatory variables are as previously defined. Share equations for capital s_k, labor s_l, material inputs s_m , and land formed the estimating equations for the model:

6a) $s_k\ =\ \beta_k+\sum_{s=1}^{6}\delta_{ks}\,D_s+\ \beta_{kk}\left(\ln w^*_k\right)+\beta_{kl}\left(\ln w^*_l\right)+\beta_{km}\left(\ln w^*_m\right)+\beta_{kd}\left(\ln w^*_d\right)+\beta_{Yk}\ln y$

6b) $s_l\ =\ \beta_l+\sum_{s=1}^{6}\delta_{ls}D_s+\beta_{kl}\left(\ln w^*_k\right)+\beta_{ll}\left(\ln w^*_l\right)+\beta_{lm}\left(\ln w^*_m\right)\ +\beta_{ld}\left(\ln w^*_d\right)\ +\beta_{Yl}\ln y$

6c) $s_m\ =\ \beta_m+\sum_{s=1}^{6}\delta_{ms}\,D_s+\beta_{km}\left(\ln w^*_k\right)\ +\beta_{lm}\left(\ln w^*_l\right)+\beta_{mm}\left(\ln w^*_m\right)+\beta_{md}\left(\ln w^*_d\right)+\beta_{Ym}\ln y$

6d) $s_d\ =\ \beta_d+\sum_{s=1}^{6}\delta_{ds}\,D_s+\ \beta_{kd}\left(\ln w^*_k\right)+\beta_{ld}\left(\ln w^*_l\right)+\beta_{md}\left(\ln w^*_m\right)+\beta_{dd}\left(\ln w^*_d\right)+\beta_{Yd}\ln y$

Adding up was imposed by setting $\sum_{i=k,l,m,d}\beta_i\ =1$ and homogeneity by requiring $\sum_j\beta_{ij}\ =0$ for all *i*. Symmetry was imposed by construction. Note that while all four equations are listed here, homogeneity and symmetry requirements result in an over-identified system, allowing us to drop (6d). Parameter estimates for this land share equation were recovered from the other parameters. Effective prices *w** were parameterized $\ln w_{it}^{*} = \ln w_{it} - \ln A_{it}$, with $\ln A_{it} = \gamma_i \ln \tau_t$ and *TFP* serving as the proxy for τ_t. Finally, identification of the system required the biasedness parameters γ_i sum to zero.

The derivative of each factor share with respect to TFP indicates the effects of biasedness on factor shares:

$$7) \qquad \frac{\partial s_i}{\partial \tau_t} = -\sum_j \beta_{ij} \gamma_j \big/ \tau_t$$

In addition to the four share equations, an instrumental equation was estimated for the technology proxy, TFP. The instrumental variable equation for TFP is:

$$8) \ \ln TFP = \alpha + \sum_{s=1}^{6} \eta_s D_s + \theta_{sx} \ln\left(StateExports\right)_{t-1} + \theta_{CFT} \ln\left(CanadianForeignTrade\right)_{t-1} + \theta_R \ln\left(Research\right)$$

The hypothesis of this research is that increasing trade, both state level exports and increasing trade with Canada, has forced changes in agricultural practices in the Great Plains. Increasing trade openness requires U.S. producers to adopt technological innovations in order to remain competitive as domestic markets adjust to increasing globalization. Given similar resource endowments, Canadian exports tend to parallel products produced in the Plains. Therefore, total factor productivity is assumed endogenous to the agricultural sector, and adjusts in part to increasing competition resulting from increasing trade.

Results

Prior to estimation, unit root tests were conducted to assure proper accounting for the time series properties of the data series in estimation. Unit root processes can underlie cross-sectional as well as univariate time series. Nonstationarity arising from unit-root process has the potential to lead to serious errors in inferences arising from econometric estimation. However, traditional unit-root tests such as the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests lack power in distinguishing the unit-root null from the stationary alternative in panel data. Panel data unit root tests have recently been developed to increase the power of the traditional tests (Levin and Lin; Wu; Frankel and Rose; Im, Pesaran, and Shin; Harris and Tzavalis; Maddala and Wu). The test developed by Maddala and Wu (MW) has several advantages among the alternative approaches. In particular, the MW can be applied to any type of univariate unit root test, it allows specification of different lag lengths in the unit-root regression, and it can be used for unbalanced panel data. We adopt the MW to perform unit root tests for the current study. Test results are presented in Table 2.

We could not reject the null of unit roots under the drift model for any of the variables (TFP, state exports, Canadian-U.S. trade, and research stock) for the TFP regression, equation (8). Subsequent testing of trends in the TFP equation led to the rejection of the null hypothesis for all of the four variables at the 5 percent level.

For the variables of the share equations (equations 6a through 6d), we could reject the null of unit-root for only three variables at the 5 percent level for the model with drift. When we include a trend in unit-root tests for the levels data, the null hypothesis is that the observations follow a random walk with drift and the alternative hypothesis is that the deviation from a linear trend is stationary. Table 2 indicates that we reject the null for all but two of the panel series. Detrending removes the unit root in seven of the series. We could not reject the null of a unit root in labor price and capital share. However, their p-values are 0.129 and 0.166, respectively, which are relatively closer to the 10 percent significance level.

We therefore detrended the models to achieve stationarity. One can detrend for each series individually, or one can simply include a trend in the empirical regression. We followed the latter approach by including a linear time trend in equations (6a) through (6d) and (8) to reduce any errors arising from existence of time trends in the panel variables.

Parameters of the share equations were estimated using three stage least squares-seemingly unrelated regression in TSP. As mentioned previously, the share equation for land was omitted. Expression (8) was embedded in the share system prior to estimation. Efficiency gains resulted from simultaneously estimating the share equations and the TFP equation.

Table 3 summarizes the econometric results. In general, the model performed well and nearly all parameter estimates are significant at the $\alpha = 0.01$ level. The four parameters representing factor biasedness indicate technological change has changed effective prices over time. Three coefficients are significant (for capital (γ_k), labor (γ_l), and land (γ_d)) and one, manufactured inputs (γ_m) is insignificant. The χ^2 statistic to test embodied technological change is 85.652, thus leading to the rejection of $H_o : \gamma_k = \gamma_l = \gamma_m = 0$. The derivatives of the shares with respect to TFP, as derived in expression 7, are $0.1035/\hat{\tau}_t$ (capital), $-0.0830/\hat{\tau}_t$ (labor), $-0.0884/\hat{\tau}_t$ (materials), and $0.0679/\hat{\tau}_t$ (land).

Results for these seven states indicate that the effects of technological innovation over time are to shift production costs away from labor and material inputs and toward capital and land. The labor saving results are consistent with other studies of agricultural productivity in the U.S. (Lambert and Shonkwiler). Howevre, other studies often find technological change to be materials using (Lambert and Shonkwiler), with results mixed for capital and land inputs. Lambert and Shonkwiler found neutrality in a combined measure of capital and land, whereas Ball, Butault, and Nehring, using the same data set we used expanded to all 48 U.S. states, found a positive relationship between the capital/labor ratio and total factor productivity. Our results suggest regional (and perhaps temporal) differences may exist in the factor bias of technological change. The capital and land intensive nature of Great Plains agriculture may suggest capitalization of cost reductions resulting from technological change into land values, thus increasing the share of land in costs, as well as an increasing cost of the machinery complement necessary to farm the increasingly large farms in the region.

The primary purpose of this research is to evaluate how state level agricultural trade and overall Canadian-U.S. agricultural trade has affected production costs in the Great Plains. These effects are seen through the impacts of the trade variables on the technology proxy, TFP. As the parameter estimates for the TFP instrumental equation show (table 3), state level agricultural exports are positively and significantly associated with increasing TFP. A one percent increase in (lagged) state trade value increases TFP by 0.021 percent. Canadian trade similarly exerts a positive and significant effect on technological change. A one percent increase in (lagged) Canadian-U.S. trade value increases TFP by 0.121 percent. Both measures of trade positively impact TFP. This finding is consistent with our initial hypothesis that increasing competition associated with increasing trade must result in improved efficiency for U.S. farmers.

Unlike many other studies measuring factors important in agricultural productivity (Yee et al., Huffman et al.), private and public research stock did not exert a significant impact on state TFP. A one percent increase in research stock did result in a 1.249 percent increase in state TFP. However, we could not reject the hypothesis that the effect of research stock on TFP was no different than zero.

The effects of TFP, trade and research stock were next extended to their marginal effects on production costs. Elasticities are calculated for each observation and state means are reported in table 4. The elasticity of production costs with respect to changes in TFP are negative (i.e., production costs fall with improvements in TFP). The impacts range from a low of a 0.216 percent drop in costs with a one percent increase in TFP in Montana to a high of 0.661 in Colorado. Production cost effects can be further disaggregated by investigating the effects of research stock, state exports, and Canadian-U.S. trade on TFP and, consequently, on costs. The results are proportional to the impacts of each factor on TFP itself. The range of elasticities in production costs for changes in research stock range from –0.270 (Montana) to –0.826 (Colorado). These values are slightly smaller than the elasticities reported in Huffman et al. in their analysis of five Midwestern states for the 1960-1996 period. In their study, research stock entered directly into their cost function rather than through the intermediary TFP variable. They reported a mean variable cost elasticity of –0.866 looking just at each state's publicly funded research stock for the five states. One shortcoming of our results may arise from the lack of state level research stock (as well as the important spill-in effects measured in Huffman et al.). Some of the state specific benefits of research stock may be masked by our reliance on aggregate U.S. public and private research stock.

Cost elasticities relative to state agricultural exports are small, ranging from –0.006 (North Dakota) to –0.014 (Colorado and Nebraska). Similar elasticities for overall

Canadian-U.S. agricultural trade range from –0.026 (Montana) to -0.080 (Colorado). It is interesting that our results indicate a greater impact on TFP and, consequently, production costs arises from increasing Canadian-U.S. trade than from the overall levels of state exports for the seven states. It appears that the perhaps greater direct competition due to increasing imports of Canadian bulk commodity and animal product trade, as well as U.S. exports to Canada, has greater impacts on the production costs of the states of the Great Plains than the level of each state's overall agricultural exports.

In general, trade reduces U.S. production costs through positive impacts on total factor productivity. These findings are consistent with the studies reported in Irwin, in which increasing trade positively contributes to a country's level of productivity.

Conclusions

Results indicate that increases in total factor productivity reduce agricultural production costs. The major factor influencing TFP improvements in the states analyzed are private and public agricultural research stock. Although not statistically significant, the point estimate of the impacts of research stock on TFP indicated a one percent increase in aggregate U.S. research stock increases TFP by about 1.25 percent. As a result, the one percent increase in research stock reduces production costs by about 0.6 percent averaged over the seven states. The magnitude of the trade impacts are less pronounced on both TFP and production costs, though the results indicate a positive contribution from increasing trade on TFP, with subsequent reductions in costs. Interestingly, although both total state export values and the overall value of Canadian-U.S. agricultural trade are significant factors in determining TFP, the latter effect is larger in magnitude for these seven states. Evidence does therefore support a significant impact on farmers of the Great

Plains of increasing Canadian-U.S. trade. The effect, however, has been positive in terms of increasing competition leading to improvements in TFP, with resulting reductions in aggregate production costs within each of the seven states.

The twin hypotheses that increasing trade increases state-level total factor productivity with subsequent impacts on reducing production costs could not be rejected. Increasing trade increases the level of competition domestic producers face in their local markets as well as the competition encountered in foreign markets. Douglas Irwin describes one way in which international trade contributes to productivity growth: International trade promotes competition that stimulates industries to increase efficiency and productivity. Our results indicate that, despite concerns to the contrary, increasing trade has contributed to increasing productivity and lower production costs for those states of the Great Plains feared to be most adversely affected by increasing trade effectuated by the relaxation of agricultural trade barriers between Canada and the United States.

References

Ball, V. Eldon, J. P. Butault, and R. Nehring. 2002. “United States Agriculture, 1960-1996: A Multilateral Comparison of Total Factor Productivity,” in *Agricultural Productivity: Measurement and Sources of Growth*. edited by V. Eldon Ball and George W. Norton. Kluwer Academic Publishers. Boston, pp11-36.

Binswanger, Hans P. 1974. “The Measurement of Technical Change Biases with Many Factors of Production. *American Economic Review.* 64:964-976.

Chavas, Jean-Paul, and Thomas Cox. 1988. “A Nonparametric Analysis of Agricultural Technology.” *American Journal of Agricultural Economics.* 70:303-310.

Durlauf, S. N., and P. C. B. Phillips. 1988.“Trends Versus Random Walks in Time Series Analysis.” *Econometrica*. 56:1333-1354.

ERS. 1997. “Foreign Agricultural Trade of the United States,” Economic Research Service, U.S. Department of Agriculture. Washington D.C.

FAS. 2003. Production, Supply, and Distribution Data Product. Foreign Agricultural Service. U.S. Department of Agriculture. http://www.fas.usda.gov/psd/intro.asp

Feenstra, R.S., J. R. Markusen, and W. Zeile. 1992. “Accounting for Growth with New Inputs.” *American Economic Review.* 82:415-421.

Fisher, R. A. *Statistical Methods for Research Workers*. 4th ed., Edinburgh: Oliver & Boyd, 1932.

Frankel, J. A. and A. K. Rose. “A Panel Project on Purchasing Power Parity: Mean Reversion Within and Between Countries.” *Journal of International Economics* 40(1996):209-24.

Gopinath, Munisamy, and P. Lynn Kennedy. 2000. “Agricultural Trade and Productivity Growth: A State-Level Analysis.” *American Journal of Agricultural Economics.* 82:1213-1218.

Gustavsson, Patrik, Pär Hansson, and Lars Lundberg. 1999. “Technology, resource Endowments, and International Competititveness.” *European Economic Review.* 43:1501-1530.

Harris, Richard D. F. and E. Tzavalis. “Inference for Unit Roots in Dynamic Panels Where the Time Dimension is Fixed.” *Journal of Econometrics* 91(1999):201-226.

Harrison, A.E. “Productivity, Imperfect Competition, and Trade Reform.” 1994. *Journal of International Economics.* 36:53-73.

Huffman, Wallace E., V. Eldon Ball, Muniswamy Gopinath, amd Agapi Somwaru. 2002. “Public R&D and Infrastructure Policies: Effects on Cost of Midwestern Agriculture,” in *Agricultural Productivity: Measurement and Sources of Growth.* edited by V. Eldon Ball and George W. Norton. Kluwer Academic Publishers. Boston.

Im, K. S., M. H. Pesaran, and Y. Shin. “Testing for Unit Roots In Heterogeneous Panels.” Working Paper, Department of Applied Economics, University of Cambridge, 1997.

Irwin, Douglas. 2002. *Free Trade under Fire*. Princeton University Press. Princeton, NJ.

Krugman, Paul. 2000. “Technology, Trade, and Factor Prices.” *Journal of International. Economics.* 50:51-71.

Lambert, David K. and J. S. Shonkwiler. 1995. “Factor Bias Under Stochastic Technical Change.” *American Journal of Agricultural Economics*. 77: 578 – 590.

Levin, A. and C. F. Lin. “Unit Root Test in Panel Data: Asymptotic and Finite Sample Properties.” Discussion Paper No. 92-93, University of California at San Diego, 1992.

Maddala, G. S. and Shaowen Wu. “A Comparative Study of Unit Root Tests with Panel Data and A New Simple Test.” *Oxford Bulletin of Economics and Statistics* Special Issue(1999):631-52.

National Research Council. 2003. *Frontiers in Agricultural Research: Fod, Health, Environment, and Communities.* Committee on Opportunities in Agriculture. National Academies Press: Washington, D.C.

Nelson, C. R. and H. Kang. 1984. “Pitfalls in the Use of Time as an Explanatory Variable in Regression.” *Journal of Business and Economic Statistics*. 2:73-82.

Romer, Paul. 1994. “New Goods, Old Theory, and the Welfare Costs of Trade Restrictions.” *Journal of Development Economics*. 43:5-38.

Slade, Margaret. 1989. “Modeling Stochastic and Cycilical Components of Technical Change: An Application of the Kalman Filter.” *Journal of Econometrics.* 41:363-383.

Trefler, D. 2001. “The Long and the Short of the Canada-U.S. Free Trade Agreement.” National Bureau of Economic Research Working Paper No. 8293.

Tybout, J.R., and M.D. Westbrook. 1995. “Trade Liberalization and the Dimensions of Efficiency Change in Mexican Manufacturing Industries.” *Journal of International Economics.* 39:53-78.

Whitton, Carol. 2003. State Export History Data Product. Trade Data Analysis Section, Economic Research Service, U.S. Department of Agriculture.

Wu, Yangru “Are Real Exchange Rates Nonstationary? Evidence from a Panel-Data Test,” *Journal of Money, Credit, and Banking* 28-1 (1996): 54-63.

Yee, Jet, Wallace E. Huffman, Mary Ahearn and Doris Newton. 2002. “Sources of Agricultural Productivity Growth at the State Level, 1960-1993,” in *Agricultural Productivity: Measurement and Sources of Growth*. edited by V. Eldon Ball and George W. Norton. Kluwer Academic Publishers. Boston. pp185-210.

Table 1. State Productivity and Trade Data – State export value reported in millions of constant 1996 dollars

	Value of State Exports - 1973	Value of State Exports - 1996	Average Annual Percent Growth	Exports as Share of State Production (Average)	Average Annual Percent Growth of Share	Average Annual Growth of TFP
Kansas	$1,290	$3,160	3.89%	30.93%	3.06%	0.90%
Colorado	$251	$1,039	6.18%	15.81%	5.04%	1.34%
Montana	$344	$876	4.07%	25.91%	4.09%	1.05%
North Dakota	$758	$1,702	3.52%	41.29%	3.61%	1.92%
Nebraska	$535	$3,353	7.98%	26.90%	6.15%	1.88%
South Dakota	$365	$1,130	4.92%	21.86%	4.11%	1.87%
Oklahoma	$398	$525	1.21%	15.83%	1.36%	0.77%

Table 2. Results of the Panel Unit-Root Test (p-values in parentheses)

Variables	Drift[a]	Trend[b]
Output	20.433 (0.117)	41.193^{**} (0.000)
$\text{Price}_{\text{Capital}}$	56.472^{**} (0.000)	58.291^{**} (0.000)
$\text{Price}_{\text{Labor}}$	1.885 (0.999)	20.025 (0.129)
$\text{Price}_{\text{Material}}$	34.525^{**} (0.002)	58.310^{**} (0.000)
$\text{Price}_{\text{Land}}$	54.304^{**} (0.000)	66.716^{**} (0.000)
TFP	4.407 (0.992)	24.863^{*} (0.036)
State Exports	20.031 (0.129)	36.054^{**} (0.001)
Canadian-US Trade	0.102 (0.999)	30.575^{**} (0.006)
Research Stock	0.012 (0.999)	24.956^{*} (0.035)
$\text{Share}_{\text{Capital}}$	17.810 (0.216)	18.960 (0.166)
$\text{Share}_{\text{Land}}$	14.713 (0.398)	48.813^{**} (0.000)
$\text{Share}_{\text{Labor}}$	18.736 (0.175)	43.870^{**} (0.000)
$\text{Share}_{\text{Material}}$	11.732 (0.628)	30.596^{**} (0.006)

Note: The values in parentheses represent *p*-values. ** and * denote rejection of the null hypothesis of unit-root at the 1 and 5 percent significance level, respectively.

Table 3: Three Stage-SUR Estimates for Share Equations (t-statistics in parentheses)

	Coefficient Estimate		Coefficient Estimate		Coefficient Estimate
β_{K}	0.4202 (3.0900)	β_{LM}	-0.0455 (-7.3749)	β_{YK}	-0.0166 (-1.7177)
β_{L}	0.3999 (2.2679)	β_{LD}	0.1242 (29.0021)	β_{YL}	-0.0076 (-0.6132)
β_{M}	0.8906 (3.3337)	β_{MM}	0.1359 (11.4087)	β_{YM}	-0.0484 (-2.5485)
β_{D}	-0.7107 (-1.9031)	β_{MD}	-0.0295 (-4.3796	β_{YD}	0.0726 (2.7387)
β_{KK}	0.1059 (8.0486)	β_{DD}	-0.0805 (-9.3802)	θ_{StateX}	0.0208 (1.9350)
β_{KL}	-0.0309 (-7.7908)	γ_{K}	0.4397 (0.8441)	θ_{CUS}	0.1205 (2.3379)
β_{KM}	-0.0608 (-5.9712)	γ_{L}	1.8190 (1.5514)	$\theta_{Research}$	1.2492 (1.0264)
β_{KD}	-0.0142 (-2.6259)	γ_{M}	-0.8423 (-1.1897)		
β_{LL}	-0.0478 (-10.2160)	γ_{D}	-1.4164 (-2.0680)		
β_{DD}	-0.0805 (-9.3802)				

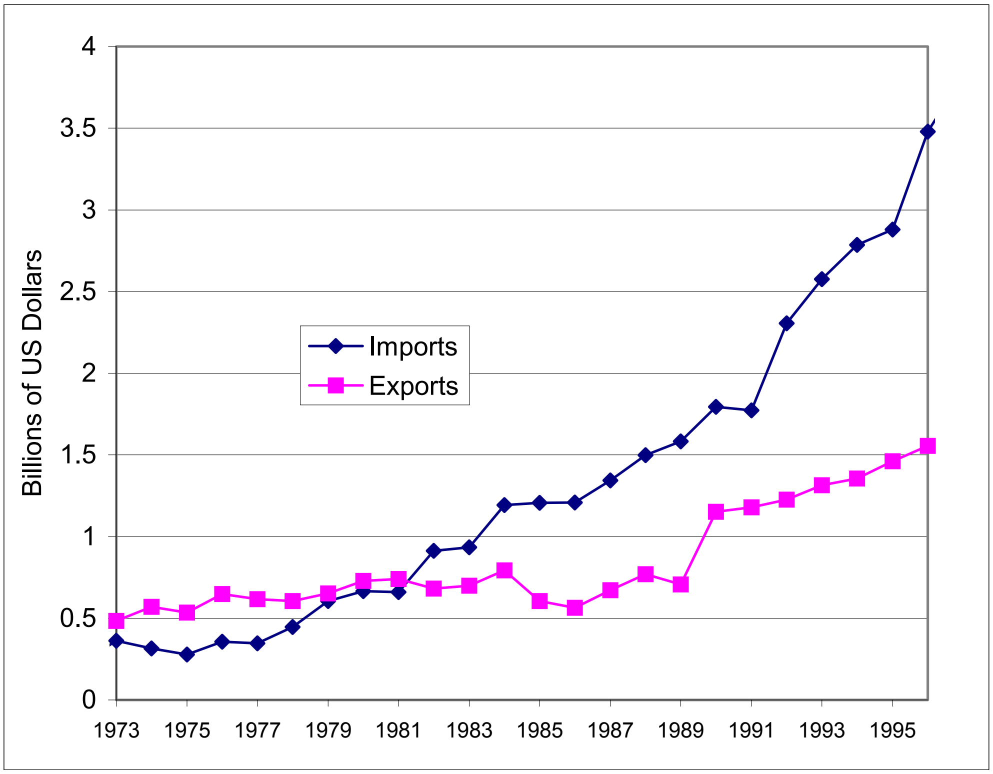
$R^2_{Capital} = 0.8974$ $R^2_{Labor} = 0.9383$ $R^2_{Material} = 0.5418$ $R^2_{TFP} = 0.6113$

NOTE: Constants and coefficient estimates for the state dummy variables are available from the principal author.

Table 4: Marginal Effects on Production Costs of TFP, Research, State Agricultural Exports, and Canadian-U.S. Agricultural Trade

	$\frac{\partial \ln Costs}{\partial \ln TFP}$	$\frac{\partial \ln Costs}{\partial \ln Research}$	$\frac{\partial \ln Costs}{\partial \ln StateExports}$	$\frac{\partial \ln Costs}{\partial \ln Can-US}$
Colorado	-0.6611	-0.8259	-0.0137	-0.0797
Kansas	-0.6108	-0.7630	-0.0127	-0.0736
Montana	-0.2159	-0.2697	-0.0045	-0.0260
Nebraska	-0.6547	-0.8179	-0.0136	-0.0789
NoDak	-0.2801	-0.3499	-0.0058	-0.0338
SoDak	-0.4675	-0.5840	-0.0097	-0.0563
Oklahoma	-0.4420	-0.5521	-0.0092	-0.0533

Figure 1: US/Canada Trade in Bulk Agricultural Products and Animal Products from 1968-1996 (in Billions of Dollars)



Filename: AAEA-DL.doc
Directory: C:\MyFiles\Reports
Template: C:\WINDOWS\Application Data\Microsoft\Templates\Normal.dot
Title: The Effects of CUSTA on US Input Productivity and Production Costs
Subject:
Author: College of Ag Sciences
Keywords:
Comments:
Creation Date: 5/8/03 10:51 AM
Change Number: 2
Last Saved On: 5/8/03 10:51 AM
Last Saved By: Agricultural Economics Morrill Hall
Total Editing Time: 6 Minutes
Last Printed On: 5/8/03 10:55 AM
As of Last Complete Printing
  Number of Pages: 28
  Number of Words: 5,786 (approx.)
  Number of Characters: 32,985 (approx.)