Trade Policy Reform, Productivity Growth and Welfare in Korean Agriculture

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Abstract

We examine the effects of multilateral trade reform on Korean agriculture and economy. We first measure agricultural total factor productivity (TFP) and its components, technological and technical efficiency change, by estimating a production function and stochastic frontier using data from 1970 to 2009. Then, we examine the sources of Korean agricultural TFP with emphasis on trade openness, and agricultural research and extension. We find that TFP elasticity with respect to trade openness is significantly larger after 1994 relative to the pre-reform period. Korean farmers have passed on productivity gains from trade reform to consumers in the form of lower prices.

Key words: productivity, Korean agriculture, trade reform

JEL Classification: O13, O24, F13

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Introduction

Korea has transitioned from an underdeveloped to a middle-income economy in just four decades. Its gross domestic product (GDP), in current prices, has increased from $8 billion to $833 billion between 1970 and 2009 with an average growth rate of 19.2 percent per year (Bank of Korea). International trade has been at the core of the remarkable expansion of the Korean economy. Between 1970 and 2009, exports have grown by 17 percent per annum from about $1 billion to $364 billion, and imports by 14 percent from $2 billion to $323 billion (Table A1). Not surprisingly, trade (import plus export) share of GDP has increased from 35 to 82 percent during 1970-2009 (Bank of Korea).

The Korean agricultural sector, however, has become a large and net importer over the past 15 years (Bank of Korea). The surge in imports surprisingly began in mid 1990s when Korean economy was decelerating from double-digit GDP growth rates of the 1980s and coincidental with the conclusion of the Uruguay Round Agreement on Agriculture (URAA) in 1994. For example, import of agricultural products doubled since 1995 with the sectors' trade deficit widening from $5.7 billion in 1995 to $11 billion in 2009 (Table A1). Compared to manufacturing and service sectors, agricultural trade liberalization has been a politically sensitive issue due to a range of consequences. The sensitivity arises, in part, due to claims of worsening sectoral income inequalities, rural unemployment and food security (Anderson and Martin 2005; Anderson and Valenzuela 2007). A closer look at economic indicators on the Korean agricultural sector from the last 15 years presents a mixed picture of its ability to adjust to global competition. For instance, labor productivity has more than doubled from 6, 462 to 14,061 Korean Won per hour during 1995-2009, likely from capital deepening and consolidation of farms (Korean Statistical Information Service).[1] However, real agricultural output, measured as national farm gross revenue, has increased by only 0.48 percent per annum for 1995-2009 compared to 5.2 percent per year during 1980-94. Furthermore, annual growth rates, on average, of real prices of farm products and real net farm business income per farm household are -1.9 and -3.9 percent, respectively, after URAA (1995-2009) relative to -0.13 and 6.7 percent during 1980-1994.[2] Annual income per farm household including its non-farm business income declined from 95 to 66 percent of that of the urban household between 1995 and 2009 (Korean Statistical Information Service).

The objective of this study is to examine how trade liberalization, as part of the Uruguay Round Agreement on Agriculture, has affected Korean agriculture and the broader economy. In particular, we focus on the productivity effects of trade liberalization and its implications for farmers' and consumers' welfare. For this purpose, we first derive measures of total factor productivity (TFP), which include technological and technical efficiency change, from the estimation of an aggregate production function of Korean agriculture with forty year time-series data (1970-2009). Then, we identify the productivity effect of agricultural trade openness during 1980-2009, controlling for other technology-changing variables such as infrastructure, agricultural research and development, and extension (Capalbo and Antle 1988; Fulginiti and Perrin 1993; Gopinath and Roe 1997; Huffman and Evenson 2006; Huffman 2009; Evenson and Fuglie 2010; Rada, Buccola, and Fuglie 2010). Finally, we compare productivity gains from agricultural trade liberalization with changes in real farm products' price and draw implications for Korean consumers' and farmers' welfare (Roe, Somwaru and Diao 2006).

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[1] Labor productivity is the ratio of agricultural value added to agricultural labor hours.

[2] Net farm business income equals farm gross receipts less farm expenses, i.e. net return from selling farm products.

The next section reviews implementation of trade reforms as part of URAA in Korean agriculture. Then, empirical methods and data employed in the analysis of productivity effects of trade reform are described, followed by a discussion of results. Conclusions and policy implication are provided in the final section.

The Setting: Trade Liberalization and Korean Agriculture

The implementation of URAA has brought about significant changes in Korean agricultural policy. Chief among the changes is the conversion of all import restrictions on agricultural products, except rice, into tariffs. Since Korea is treated as a developing country in URAA, it has been required to reduce tariffs on agricultural products except rice by 24 percent, on average, over ten years (1995-2004).[3] In the case of rice, the most important commodity of Korean agriculture, the minimum market access (MMA) provision has been imposed instead of tariffication. Korea has been increasing rice imports via MMA from 1 percent of average domestic consumption during 1988-1990 in 1995 to 4 percent in 2004. Additional negotiations with WTO in 2004 has led Korea to increase the MMA from 4 percent in 2005 to 8 percent in 2014, based again on 1988-1990 consumption. In terms of implementation, MMA acts like an import quota, where an in-quota tariff of 5 percent is applied (Policy materials, Ministry for Food, Agriculture, Forestry and Fisheries. Korea). Moreover, Korea has considerably reduced domestic (price) support through a government purchase program, which accounted for about 90 percent of total Aggregate Measurement of Support (AMS).[4]

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[3] Developed countries are required to reduce the tariffs on agricultural products by 36 percent, on average, for six years from 1995 to 2000 (The Legal Text, Uruguay Round of Multilateral Trade Negotiations, World Trade Organization, 1994).

[4] Total AMS is the sum of all domestic support provided to agricultural producers. Domestic support provisions of the URAA include 20% (13.3%) reduction in the total AMS for developed (developing) countries for 1995-2000 (1995-2004) (The Legal Text, Uruguay Round of Multilateral Trade Negotiations, World Trade Organization, 1994).

The volume of government purchase has declined from 1.4 million ton in 1995 to 0.7 million ton in 2004, and the program, in operation for over fifty years, was eliminated in 2005 (Policy materials, Ministry for Food, Agriculture, Forestry and Fisheries, Government of Korea). Instead, a mixed policy of target price and direct payment has been introduced to support farmers' income since 2005.[5]

In general, Korean agricultural policy appears to have become more market-oriented following URAA.[6] Following URAA, imports of agricultural products have significantly increased from \$6.9 billion to \$14.2 billion for 1995-2009 at an average rate of 5.3 percent per year (Table A1). Major Korean imports include grains (corn, wheat and soybeans) and meat (beef and pork). Exports of agricultural products have also grown annually by 6.8 percent, on average, but its value increased from \$1.2 billion to \$3.1 billion only during the same period. Leather, seafood, snacks, noodles and beverages constitute major Korean exports. Since imports substantially outweigh exports, the resulting trade deficit in the agricultural sector has widened from \$5.7 billion to \$11 billion during 1995-2009 (Korea Customs Service; Ministry for Food, Agriculture, Forestry and Fisheries, Government of Korea).

Empirical Methodology and Data

In the following, a production function framework relating output to all measured inputs is

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[5] The Korean government pays farmers a fixed (decoupled) direct payment based on 1998-2000 rice-cultivation area regardless of market price changes. If the market price falls below the target price, a variable direct payment is applicable. In the latter case, government subsidizes as much as 85 percent of the difference between market and target prices, after subtracting from the target price the fixed direct payment on a per unit basis. See Goodwin and Mishra (2006) for a definition of decoupled payments and their production effects.

[6] Other policy changes initiated by the Korean government include efforts to strengthen agriculture's competitiveness via farm consolidation, and improved irrigation infrastructure, mechanization and marketing systems (Policy materials, Ministry for Food, Agriculture, Forestry and Fisheries, Government of Korea). Detailed data on such individual efforts are not available, but the computation of farm capital stock by the Korean government includes the above investments.

presented for the computation of agricultural productivity. Then, productivity is related to trade openness controlling for the effect of R&D and infrastructure. Finally, a comparison of trade-reform induced productivity with changes in real farm products' price is made to draw welfare implications for Korean consumers and farmers.

Measurement of Total Factor Productivity

Consider real gross revenue of Korean agriculture (Y_t, $t=1,2,\ldots,T$) as a function of real capital stock (K_t), real farm production materials (M_t), and labor force (L_t) as:.

(1) $$Y_t = A_t \cdot f_t\,(K_t\,,\,M_t\,,\,L_t),$$

where A_t is the Hicks-neutral technology, i.e. TFP index (Capalbo and Antle 1988). Suppose that the function $f_t\,(K_t\,,\,M_t\,,\,L_t)$ takes the Cobb-Douglas form. Then, equation (1) can be expressed in double-log form as follows:

(2) $$\ln\,Y_t = \alpha_{0t} + \alpha_1 \ln K_t + \alpha_2 \ln M_t + \alpha_3 \ln L_t\,,$$

where $\alpha_{0t} = \ln A_t$, that is, the logarithm of TFP. Subtracting $\ln L_t$ from both sides of equation (2) yields:

(3) $$\ln\,(Y_t/L_t) = \alpha_{0t} + \alpha_1 \ln(K_t/L_t) + \alpha_2 \ln(M_t/L_t) + \beta \ln L_t\,,$$

where $\beta = \alpha_1 + \alpha_2 + \alpha_3 - 1$, indicating the extent of deviation from constant returns to scale (Harrigan 1999). If β is greater (or less) than zero, the production function exhibits increasing (or decreasing) returns to scale. We include a time trend in equation (3) to allow technological change over time:

(4) $$\ln\,(Y_t/L_t) = b_0 + b_1 \cdot t + \gamma_1 \ln(K_t/L_t) + \gamma_2 \ln(M_t/L_t) + \rho \ln L_t + \varepsilon_t\,,$$

where $b_0 + b_1 \cdot t$ represents logarithmic index of TFP, i.e. $\ln \widehat{A}_t$, and ε_t is disturbance term.

Productivity growth comprises of two mutually exclusive components, i.e. technological change (TC) and technical efficiency change (TEC). The former entails a shift of the production possibility frontier (PPF) or changes to the potential output. On the other hand, the latter indicates a movement toward or away from the PPF, namely changes in the gap between potential and actual outputs (Aigner, Lovell, and Schmidt 1977; Iyer, Rambaldi, and Tang 2008). Thus, the productivity effects of trade openness on potential and the actual output may vary.

However, the production function in equation (4) explains only TC, because production is assumed efficient over time so that $\ln \widehat{A}_t$ is logarithm of the potential TFP. So, the production function is also estimated using a stochastic frontier model (SFM), introduced by Aigner, Lovell, and Schmidt (1977) and Meeusen and van den Broeck (1977), to measure both TC and TEC (Battese and Coelli 1995; Kumbhakar and Lovell 2000; Greene 2005). For this, disturbance term in (4) is divided into a random error and random variable associated technical inefficiency as:

(5) $\ln (Y_t/L_t) = c_0 + c_1 \cdot t + \delta_1 \ln(K_t/L_t) + \delta_2 \ln(M_t/L_t) + \varphi \ln L_t + v_t - u_t$,

where v_t is time-specific random error assumed to be *iid* and follow normal distribution with mean zero and variance σ^2_v; and u_t is non-negative random variable representing technical inefficiency term ($u_t = -\ln(\xi_t)$, where ξ_t is the level of efficiency).[7] The u_t is assumed to have a half-normal distribution with zero-mean and variance σ^2_u. In equation (5), $c_0 + c_1 \cdot t - u_t$ represents logarithmic index of actual TFP ($\ln\hat{Z}_t$), i.e. actual output change over time given any level of inputs, in the stochastic frontier estimation. In this model, technical efficiency (TE) at time t is given by exp ($-u_t$). If $u_t = 0$, i.e. technical inefficiency does not exist, productivity growth embodies TC only.

The source of data for production function estimation is the Korean Statistical Information Service. Agricultural gross revenue used as output is measured in Korean (million) Won and deflated by index of price received by farmers (2005=100), which includes

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[7] Kumbhakar and Lovell (2000) review stochastic frontier analysis in the context of estimating production and cost functions.

prices of most agricultural products.[8] For inputs, capital stock and farm production materials are measured in Korean (million) Won. Capital includes land, facilities, machines, and animals used for the purpose of farming activities. Capital stock, evaluated annually by the Korean government, is deflated by national Gross Fixed Capital Formation (2005=100). Farm production materials include fertilizers, pesticides, feeds, seeds, oil, and others, whose combined value is deflated by an index of price paid by farmers (2005=100). The labor input is represented by the number of farm workers 15 years and over. All output and input variables are compiled for a forty-year period (1970-2009) from the Korean Statistical Information Service. Table 1 presents summary statistics on output and input variables.

Measuring Productivity Effects of Agricultural Trade Openness

Following Amiti and Konings (2007), agricultural productivity is a specified as a function of agricultural trade openness (*OPEN*), agricultural research and extension (*RAE*), and other control variables affecting technology (*CONTROLS*). However, previous studies on productivity effects of trade liberalization often suffer from an endogeneity problem. That is, trade liberalization may be initiated in high productivity segments of an economy (Frankel and Romer 1999; Miller and Upadhyay 2000; Alcalá and Ciccone 2004; Trefler 2004; Pavcnik 2002; Goldberg and Pavcnik 2005; Amiti and Konings 2007). Fortunately, the liberalization addressed in this study is multilateral, i.e. URAA, with limited effects from the internal political economy of Korea. Since identifying appropriate instruments for endogenizing trade liberalization has eluded most researchers, the one-period lagged trade openness variable is employed in the productivity model:

$$\ln PROD_t = \beta_0 + \beta_1\, OPEN_{t-1} + \beta_2 \ln RAE_t + \beta_3\, CONTROLS_t + \mu_t. \tag{6}$$

[8] The derivation of agricultural gross revenue includes payments arising from price support policies.

The productivity model in equation (6) is estimated for both the log of potential TFP ($\ln\hat{A}_t$) and actual TFP ($\ln\hat{Z}_t$) obtained in the previous section. With the estimates of equation (6), the productivity effect of trade openness is compared for two fifteen-year periods: before (1980-1994) and after (1995-2009) URAA.

Trade openness is represented by the trade share of GDP, that is, imports plus exports divided by GDP (Coe and Helpman 1995; Miller and Upadhyay 2000). Similar to Ades and Glaeser (1999) and Dinopoulos and Thompson (2000), the trade share is directly employed, i.e. without a natural log transformation, in equation (6). To test the sensitivity of the results to the assumed openness variable, three measures of agricultural trade openness are considered: $TRADE_{t-1}$, $IMPORT_{t-1}$, and $EXPORT_{t-1}$ i.e. agricultural trade (import and export), import, and export share of agricultural GDP, respectively. Import share reflects competition between domestic and foreign agricultural commodities in the Korean market, while export share indicates competition in foreign markets. Thus, trade share is a global competition indicator for Korean agriculture in both domestic and foreign markets. As depicted in figure 1, the agricultural trade share is dominated by the import share, which has dramatically increased after URAA. Agricultural import, export, and GDP are measured in billions of Korean Won and obtained from Korea Customs Service, Korean Statistical Information Service, and Ministry for Food, Agriculture, Forestry and Fisheries of Korea.

The effect of trade openness on productivity cannot be evaluated in isolation since most countries including Korea provide public support for agricultural research, development and extension. Such support not only determines technological progress but also adoption of available technologies by farmers (Capalbo and Antle 1988; Fulginiti and Perrin 1993; Huffman and Evenson 2006; Evenson and Fuglie 2010; Huffman 2009; Rada, Buccola, and Fuglie 2010). A joint research and extension variable ($\ln RAE_t$), whose stock is measured similar to the capital input, is employed in equation (6). For instance, Huffman (2009) discusses alternative measures of research and development stock, which are often highly correlated with each other. In this study, a five-year inverted-V lag structure is used to compute the RAE_t stock (Fulginiti and Perrin 1993). That is, annual expenditure (Exp_t) on agricultural research and extension is weighted to increase until the second lag and then decrease for the remaining lags as follows:

(7) $$RAE_t = \frac{1}{9}\ \text{Exp}_t + \frac{2}{9}\ \text{Exp}_{t-1} + \frac{1}{3}\ \text{Exp}_{t-2} + \frac{2}{9}\ \text{Exp}_{t-3} + \frac{1}{9}\ \text{Exp}_{t-4}.$$

The Exp_t in equation (7) is the annual budget for agricultural research and extension from the Rural Development Administration. The data are obtained from the National Assembly of Korea and converted to real term by using the GDP deflator (2005=100). The RAE_t stock based on a trapezoidal lag structure is highly correlated with that from the inverted V lag structure (correlation coefficient of 0.98).

For control variables ($CONTROLS_t$) in equation (6), measures of crop disaster incidents ($DISAS_t$) and infrastructure ($INFRA_t$), and the log of exchange rate ($\ln EXC_t$) are included. The $DISAS_t$, measured as the ratio of land area damaged by crop diseases and unfavorable weather conditions to total cultivation area, is expected to negatively affect productivity. Data on the $DISAS_t$ variable are taken from the Ministry for Food, Agriculture, Forestry and Fisheries of Korea. County-level road density, i.e. road length divided by county area, (*km/km2*) is used to denote $INFRA_t$, data for which are obtained from the Ministry of Land, Transport and Maritime Affairs of Korea. Higher road density would improve agricultural productivity, possibly through increased technical efficiency, because improved access to markets lowers farming cost (Rada, Buccola, and Fuglie 2010). While fertilizers, pesticides, agricultural machines, and other farm supplies are produced in Korea, imported intermediates account for a large share of output in these input industries. For example, almost all petroleum and related products used in fertilizers and pesticides are imported. The revenue-cost gap in real terms is sensitive to exchange rate variation, which is included in the productivity model. Thus, the log of the exchange rate, EXC_t, (Korean Won per US Dollar) is anticipated to negatively affect agricultural productivity. Data on EXC_t, measured as the annual average exchange rate, are obtained from the Bank of Korea. Table 1 presents summary statistics on independent variables used in the productivity model.

Trade Openness and Farmers' Welfare Before and After URAA

The objective here is to evaluate the productivity effect of openness before and after multilateral reforms. For this purpose, productivity elasticity with respect to trade openness ($\varepsilon_{PROD,\ OPEN}$) is computed for two periods: 1980-1994 and 1995-2009, pre- and post-URAA, respectively. The productivity elasticity with respect to openness is:

(8) $$(\varepsilon_{PROD,\ OPEN})_t = \hat{\beta}_1 \text{ x } OPEN_{t-1},$$

where $\hat{\beta}_1 = \partial \ln PROD_t \,/\, \partial\, OPEN_{t-1}$, and $OPEN_{t-1}$ is represented by $TRADE_{t-1}$, $IMPORT_{t-1}$, and $EXPORT_{t-1}$ in equation (6). Then, the mean of equation (8) and its standard deviation for the two periods are computed. A *t*-test of the difference between the two means is conducted under the null hypothesis of no difference. The alternative hypothesis is that mean elasticity after URAA is greater or less than that before URAA.

Productivity growth implies an increase in output given an input level. Thus, as agricultural productivity improves, domestic supply of agricultural commodity increases, which causes prices to fall given demand. Thus, to gain insights on farmers' welfare, a comparison is made between the magnitude of productivity growth induced by openness and changes in real farm products' price in pre- and post-URAA periods (Fulginiti and Perrin 1993). For this purpose, productivity arising from openness in equation (6), holding other variables constant, is derived as follows:

(9) $$\ln \widehat{PROD}_t = \hat{\beta}_o + \hat{\beta}_1 \text{ x } OPEN_{t-1},$$

where $OPEN_{t-1}$ is represented by $TRADE_{t-1}$, $IMPORT_{t-1}$, and $EXPORT_{t-1}$ in equation (6). Then, the annual growth rate of the openness-induced productivity, computed based on $\widehat{PROD}_t = \exp(\ln\widehat{PROD}_t)$, and rate of change in farm products' price is compared for each period, i.e. before and after URAA, respectively. The index of price received by farmers deflated by CPI (2005=100) is used to measure the rate of change in real farm products' price.

Results and Discussion

Productivity Growth of Korean agriculture

Prior to the estimation of the production function, a unit root test of each time-series in the production function, equation (4), is carried out. The Augmented Dickey-Fuller test results showed that both dependent and independent variables in the production function are non-stationary, i.e. integrated of order 1, I(1). However, the ordinary least squares (OLS) residual of the production function is found to be stationary. That is, the null of unit root of the OLS residual is rejected at the five percent level by the Engle-Granger test, implying that the variables in the production function are co-integrated (Table 2). Moreover, the Johansen and Juselius' (1994) rank test for multivariate cointegration showed that there is only one cointegration vector in the production relationship specified in equation (4). Hence, the linear combination of inputs and outputs in equation (4), i.e. the cointegration vector, is indeed a stable, long-run relationship. For the purposes of this study (productivity), the long-run coefficients are needed and the short-run error correction or adjustment to the long-run equilibrium is less relevant. Thus, Table 2 reports estimates of the production function using level variables. Moreover, in the estimation of equation (4), autocorrelation of OLS residuals is detected ($\rho = 0.59$ and Durbin-Watson (D-W) statistic = 0.89), which is corrected by using the Prais-Winsten AR(1) estimator. Results from using the Prais-Winsten estimator are reported in Table 2 and the corrected D-W statistic is 1.78. Heteroskedasticity of OLS residuals is not detected based on the Breusch-Pagan/Cook-Weisberg test.

In the second column of Table 2, the coefficient on the log of capital-labor ratio, ln(K/L), is significant at the one percent level and the output elasticity with respect to capital is 0.304. Normalized materials', ln(M/L), coefficient is also statistically significant at the five percent level and the implied elasticity of output with respect to farm production materials is 0.223. A F test fails to reject constant returns to scale (CRS) in Korean agricultural production because the coefficient on ln$L$ is not significant. Technological progress is evident from the positive and significant coefficient on time trend (t).

Similar results are obtained from estimation of the stochastic frontier model (third column of Table 2). Coefficients on both inputs (logs of capital-labor and materials-labor ratio) are significant at the one percent level. Time trend takes a positive and significant coefficient at the five percent level. The coefficient on ln$L$ is not significant and thus, the CRS technology assumption is not rejected for Korean agriculture. However, results from SFM estimation provide little statistical evidence of technical inefficiency. If σ_u, standard deviation of u_t in equation (5), equals zero, then technical inefficiency does not exist. As reported in table 2, σ_u (0.002) is close to zero and from the one-sided generalized likelihood ratio (LR) test, the null hypothesis ($\sigma^2_u = 0$) is not rejected (Gutierrez, Carter, and Drukker 2001).[9] Technical efficiency is estimated to be nearly one over the sample period, ranging from 0.998 (minimum) to 0.999 (maximum) with mean of 0.999. Thus, in the 1970-2009 sample, productivity growth of Korean agriculture has been led by technological progress rather than technical efficiency change. Potential and the actual TFP, i.e. ln$\hat{A}_t$ and ln$\hat{Z}_t$, are computed for each year based on the estimation of AR(1) and the SFM models, respectively. As shown in figure 2, the difference between the growth rate of two TFP indexes is negligible.

[9] Technical inefficiency term, u_t, is an one-sided error from the production frontier in equation (5). Since the LR test statistic in the model lies on the boundary of the parameter space of σ^2_u, the standard LR test is not valid. Instead, an one-sided generalized LR test is conducted, based on the asymptotic distribution.

For 1970-2009, the average growth rate of potential and actual TFP is 1.45 and 1.47 percent per year, respectively.

Productivity Effects of Trade Openness and Other Technology-Changing Variables

Table 3 reports productivity effects of agricultural trade openness, research and extension, and other control variables. Recall that equation (6) is estimated using three alternative measures of openness: agricultural trade (import + export), import, and export share of agricultural GDP. Again, to avoid possible endogeneity of trade reforms with TFP, the one-period lagged trade openness variable is used in the estimation of the productivity model.

Similar to the production function estimation, the time-series in the productivity model are found to be non-stationary, I(1). However, OLS residuals in all three specifications of the productivity model are I(0). That is, the null of unit root of OLS residuals is rejected by the Engle-Granger test at the one percent level (Table 3). Moreover, the Johansen and Juselius (1994) rank test identified only one cointegration vector in each of the three specifications of the productivity model. Hence, equation (6) is estimated using level variables since long-run coefficients are needed for assessing the impact of trade reform on productivity. The null hypothesis of no autocorrelation ($\rho = 0$) is not rejected in all specifications. Autocorrelation coefficients, D-W statistics, and Durbin's alternative test results (F-statistic) are reported at the bottom of Table 3. Again, heteroskedasticity of OLS residuals is not detected based on the Breusch-Pagan/Cook-Weisberg test. In the following, productivity effects of openness using potential and actual TFP are also compared (six specifications).

Since Korean agriculture has experienced substantial trade openness in recent decades, this study hypothesized that liberalization has a positive effect on productivity. Thus, as expected, coefficients on the trade openness variable in all six specifications reported in Table 3 are positive and statistically significant at least at the five percent level. The microeconomic foundations for the positive effect of trade openness on productivity can be found in Melitz (2003). Suppose Korean agriculture is characterized by heterogeneous farmers with productivity as the key source of difference. Then, trade openness forces the exit of least-productive farms (extensive margin) and reallocation of resources to high productivity farmers (intensive margin). The resulting churning of resources leads to higher average industry productivity in an open trade regime relative to autarky. Other channels through which liberalization can affect productivity are improved intermediate input quality and innovation incentives, and lower price-cost margins (Helpman 2006).

Government expenditure on agricultural research and extension has increased on average by about 12 percent per year during 1980-2009 (National Assembly, Korea). Previous studies have found a dominant role for public research and extension in raising agricultural productivity (Huffman and Evenson 2006; Huffman 2009; Evenson and Fuglie 2010). In Korean agriculture as well, research and extension ($\ln RAE_t$) has a positive effect on productivity with statistical significance at least at the five percent level in all specifications (Table 3). Note that the relationship between productivity and RAE_t is specified in log-log form, and hence, the coefficient on $\ln RAE_t$ indicates productivity elasticity with respect to research and extension. Every one percent increase in the research and extension stock raises Korean agricultural productivity by about 0.1 percent in all specifications. The coefficient estimate on road density ($INFRA_t$) is positive and significant at the one percent level in all specifications (Table 3). This implies that higher road density makes access to both output and input markets easier, which should increase farm productivity. Other control variables, crop disaster ($DISAS_t$) and log of exchange rate ($\ln EXC_t$), also take the expected negative signs. Both variables show significantly negative effects on the productivity. Fuels and raw materials of farm supplies such as fertilizers, pesticides, and machinery are mostly imported and so, a depreciation of the Korean Won should raise prices of these intermediates and lower farm productivity.[10]

Trade-Induced Productivity Growth and Farmers' Welfare Before and After URAA

Having identified productivity growth and its sources in Korean agriculture, some insights into farmer's welfare before and after URAA are offered in the following. For this purpose, the productivity elasticity with respect to the openness ($\varepsilon_{PROD,\ OPEN}$) is computed by using equation (8). As noted earlier, technical inefficiency in Korean agriculture is limited during the sample period based on the estimated stochastic frontier model in equation (5). Moreover, the estimation results for the productivity effect of trade openness do not differ between potential and actual TFP (Table 3). Hence, the following assessment considers potential TFP only.

Table 4 shows that productivity elasticities with respect to trade share are 0.080, 0.056, and 0.103 for the entire period (1980-2009), before (1980-1994), and after URAA (1995-2009), respectively. Similarly, the corresponding elasticities with respect to import (export) share are 0.092 (0.084), 0.068 (0.059), and 0.117 (0.108) for each period, respectively. Thus, the contribution of trade openness to productivity appears to be larger after than before URAA. Further confirmation of this claim comes from testing the difference between mean elasticities before and after URAA. Recall that the null hypothesis is no difference between the two means, and the alternative hypothesis is that the mean elasticity after URAA is bigger or less than before URAA. As Table 4 shows, in all specifications, the null hypothesis is rejected at the one percent significance level by an upper-tail test (t-statistic of 4.51, 4.30, and 4.52, respectively). Thus, the productivity effect of trade openness has increased following URAA.

However, the gain from openness in the form of agricultural productivity growth

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[10] During the Korean financial crisis for 1997-1998, Korean currency depreciated from 951 Won to 1,399 Won per US dollar (Bank of Korea). For that year, farm supplies component of index of price paid by farmers increased by approximately 20 percent (Korean Statistical Information Service).

should be contrasted with other key factors, e.g. price received, to draw inferences on farmers' welfare. For this purpose, openness-induced productivity growth is computed using equation (9), holding other variables fixed. The second and third columns of Table 5 report the annual average growth rate of openness-induced productivity for each specification. Before URAA, the productivity fitted by trade, import, and export share of agricultural GDP has increased at an average rate of 0.09, 0.01, and 0.08 percent per year, respectively. In comparison, productivity increased by 1.14, 1.05, and 1.15 percent per annum, respectively, after URAA. However, the real price of farm products, which declined on average by 0.13 percent per year until 1994, dramatically fell by an average 1.88 percent per year. The larger decrease in real price of farm products after URAA is partly offset by productivity gains from increased openness. Nevertheless, Korean consumers have greatly benefitted from trade openness relative to farmers. In the United States, the fall in agricultural prices is often associated with R&D induced productivity growth (Huffman and Evenson 2006; Gopinath and Roe 1997; Huffman 2009). Likewise in Korea, even when comparing entire TFP growth (1.45 percent per year) against the fall in prices, consumers have significantly gained from productivity growth in agriculture relative to farmers. However, the caveat here is that the TFP-price association is not necessarily a causal analysis. Along with productivity growth, increase in agricultural imports expands total supply of agricultural products in domestic markets and affects prices. Moreover, the decrease in consumption of domestic farm products, e.g. a shift away from staples, could be another possible reason of the price fall.[11] As mentioned earlier (footnote 6), the Korean government has supported agriculture with investments in consolidation, irrigation and other farm infrastructure since 1992. Whether or not farmers have benefitted in the net, productivity growth induced by

[11] For example, per capita rice consumption has decreased from 107 kg in 1995 to 74 kg in 2009 (Korean Statistical Information Service).

trade openness and R&D plus other investments less the effects of falling prices, remains an interesting question for future research.

Summary and Conclusions

This study examined how trade openness affected productivity and welfare in Korean agriculture. The focus was on the effects of multilateral reform from the Uruguay Round Agreement of Agriculture on agricultural productivity growth, farmers' welfare, and gains to the broader economy.

An aggregate production function for Korean agriculture was estimated with forty years of time series data (1970-2009). Results from the estimates of the production function suggested that Korean agriculture exhibited constant returns to scale during the past forty years. Moreover, productivity growth of Korean agriculture has been led by technological progress rather than technical efficiency change. Agricultural productivity has grown at an average rate of 1.45 percent per year during 1970-2009.

Then, agricultural productivity was specified a function of trade openness, research, development and extension, and other control variables. Due to limited data availability on research and development, productivity effects of trade liberalization are assessed during 1980-2009 only. Agricultural trade openness was represented by three alternative indicators: agricultural trade (import and export), import, and export share of agricultural GDP. The finding that trade openness significantly improved productivity in Korean agriculture is robust across alternative specifications. More importantly, the productivity elasticity with respect to openness was significantly larger after than before URAA.

The growth in productivity attributable to trade openness was computed holding all other influences constant. This exercise shows that increased agricultural openness after URAA has brought about significant productivity growth in Korean agriculture. However, the real price of farm products has declined after URAA, while it remained almost constant before the multilateral reform. A similar pattern was observed for real net farm business income per farm household.

Put together, productivity growth from agricultural trade liberalization and farm product's real price decline has greatly benefitted Korean consumers. However, the net impact of agricultural trade liberalization on farmers' welfare depended on weighing gains from productivity growth against the real price decline in the presence of other interventions in Korean agriculture. Such an evaluation in the aggregate and for individual agricultural commodities should be a topic for future research. In the mean time, options to revitalize losers from trade include investments in agricultural technology, infrastructure and marketing systems, and farmers' income support.

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Table 1. Descriptive statistics on variables used in the estimation of the production function and productivity models

Variable	Unit	Mean	Standard deviation
Output (*Y*/1,000,000)	Constant Won	24,445, 619	6,285,980
Capital (*K*/1,000,000)	Constant Won	40,112,209	15,045,879
Labor (*L/1,000*)	Number	5,572.89	2,089.12
Material (*M*/1,000,000)	Constant Won	6,898,111	3,317,606
Trade share (*TRADE*)	Index (0-1)	0.375	0.189
Import share (*IMPORT*)	Index (0-1)	0.312	0.159
Export share (*EXPORT*)	Index (0-1)	0.063	0.031
Research and extension (*RAE*/1,000,000)	Constant Won	170,421	113,878
Infrastructure (*INFRA*)	Index (0-1)	0.501	0.181
Crop disaster (*DISAS*)	Index (0-1)	0.082	0.083
Exchange rate (*EXC*)	Constant Won	927.33	218.68

Source: Korean Statistical Information Service, Ministry of Food, Agriculture, Forestry and Fishery of Korea, Bank of Korea, and Ministry of Land, Transport and Maritime Affairs of Korea

Note: The sample period for the production function estimation is 1970-2009, while that for productivity is 1980-2009.

Table 2. Parameter estimates of the agricultural production function

Variable	Prais-Winsten AR(1)	Stochastic Frontier
ln(*K/L*)	0.3041 (0.1102) ***	0.3779 (0.0830) ***
ln(*M/L*)	0.2232 (0.0843) **	0.2131 (0.0572) ***
ln*L*	-0.1003 (0.1620)	0.0357 (0.1815)
t (time trend)	0.0140 (0.0069) **	0.0144 (0.0061) **
Constant	5.4135 (2.6830) *	2.7207 (3.1725)
R^2	0.9917	
D-F statistic[1)]	-3.087**	
D-W (5, 40) statistic [2)]	1.778	
σ_v		0.0512 (0.0063)
σ_u		0.0019 (0.2024)
$\lambda = \sigma_u / \sigma_v$		0.037
LR test statistic		0.00

Note: *, **, and *** indicate statistical significance at 10%, 5%, and 1%, respectively; number in the parenthesis is standard error; σ_v and σ_u are standard deviations of the two error components, i.e. v_t and u_t, in equation (5). The null hypothesis of the LR test in the stochastic frontier model is no technical inefficiency ($\sigma^2_u = 0$) against the alternative hypothesis, $\sigma^2_u > 0$. The technical inefficiency term, u_t, is an one-sided error from the production frontier in equation (5). Since the LR test statistic in this model lies on the boundary of the parameter space of σ^2_u , the standard LR test is not valid. Instead, an one-sided generalized LR test is conducted, based on the asymptotic distribution (Gutierrez, Carter, and Drukker 2001); 1) represents Dickey-Fuller test statistic (Engle-Granger test) for the null of unit root of residual and ** indicates rejection of the null at the 5% (critical value : -2.961); 2) indicates Durbin-Watson statistic. Dependent variable is log of output per labor.

Table 3. Productivity effects of openness and other technology-changing variables

Variable	Specification 1 (Trade share)		Specification 2 (Import share)		Specification 3 (Export share)	
	Potential TFP	Actual TFP	Potential TFP	Actual TFP	Potential TFP	Actual TFP
$TRADE_{t-1}$	0.2727*** (0.0935)	0.3374*** (0.0924)				
$IMPORT_{t-1}$			1.5721** (0.5998)	1.9643*** (0.5988)		
$EXPORT_{t-1}$					0.2391*** (0.0816)	0.2962*** (0.0806)
$\ln RAE_t$	0.0961*** (0.0291)	0.0961*** (0.0287)	0.0890*** (0.0317)	0.0868** (0.0311)	0.0939*** (0.0293)	0.0934*** (0.0290)
$INFRA_t$	0.2788*** (0.0811)	0.2725*** (0.0802)	0.3061*** (0.0887)	0.3077*** (0.0886)	0.2854*** (0.0818)	0.2808*** (0.0808)
$DISAS_t$	-0.2941*** (0.1049)	-0.2698** (0.1038)	-0.3127*** (0.1067)	-0.2923** (0.1066)	-0.2951*** (0.1047)	-0.2709** (0.1034)
$\ln EXC_t$	-0.1883*** (0.0662)	-0.1940*** (0.0655)	-0.1834** (0.0678)	-0.1884*** (0.0677)	-0.1886*** (0.0661)	-0.1944*** (0.0653)
Constant	5.7279*** (0.3346)	3.0652*** (0.3308)	5.7528*** (0.3589)	3.1031*** (0.3583)	5.7478*** (0.3378)	3.0908*** (0.3335)
R^2	0.9064	0.9126	0.9014	0.9061	0.9066	0.9130
D-F statistic[1)]	-4.308***	-4.476***	-4.554***	-4.806***	-4.365***	-4.559***
ρ [2)]	0.2469	0.1913	0.2147	0.1262	0.2354	0.1729
D-W (6,30) statistic [3)]	1.6101	1.6895	1.7358	1.8443	1.6376	1.7272
F (1, 23)-statistic[4)]	0.970	0.597	0.410	0.137	0.830	0.456

Note: **, and *** indicate statistical significance at 5%, and 1%, respectively; number in the parenthesis is the standard error; 1) represents Dickey-Fuller test statistic (Engle-Granger test) for the null of unit root of residual and *** indicates rejection of the null at the 1% (critical value : -3.723); 2) and 3) indicate autocorrelation coefficient and Durbin-Watson statistic, respectively; 4) represents Durbin’s alternative test under the null hypothesis of no serial correlation.

Table 4. Productivity elasticities with respect to trade openness

Variable	Whole Period (1980-2009)	Before URAA (1980-1994)	After URAA (1995-2009)	Difference Test (t-statistic)
Specification 1 (Trade share)	0.0795 (0.0367)	0.0557 (0.0120)	0.1033 (0.0378)	4.51***
Specification 2 (Import share)	0.0923 (0.0366)	0.0678 (0.0132)	0.1168 (0.0361)	4.30***
Specification 3 (Export share)	0.0838 (0.0375)	0.0591 (0.0121)	0.1084 (0.0383)	4.52***

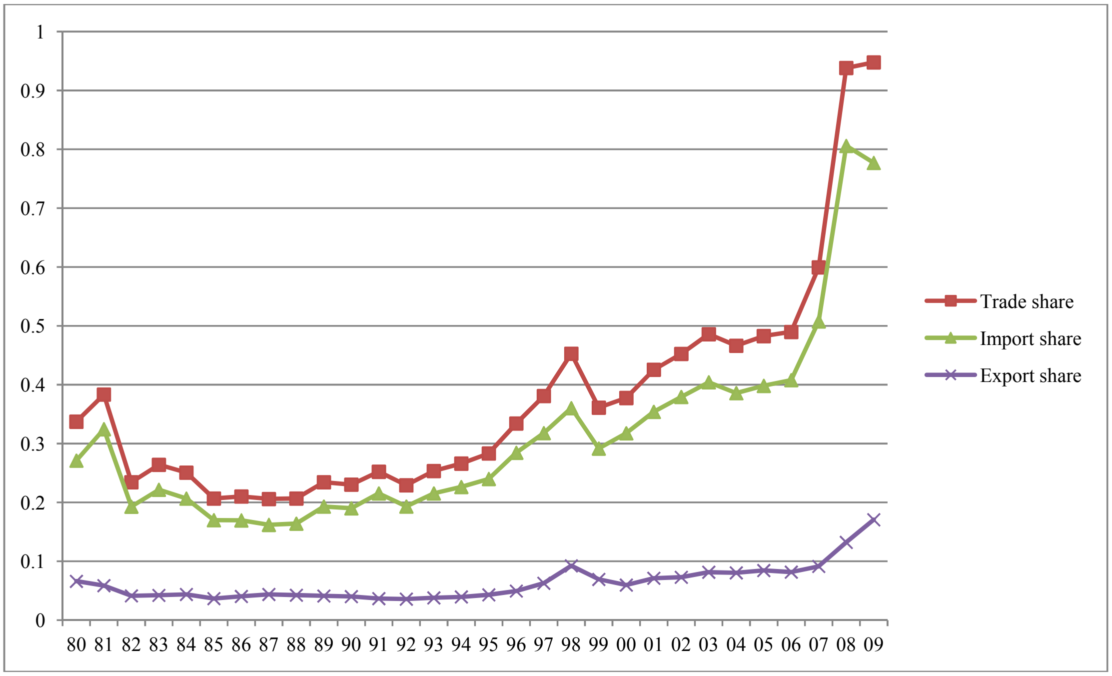
Note: Elasticity is the mean value and number in parenthesis is standard deviation; *** indicates that elasticity is larger after than before URAA at the 1% significance level.

Table 5. Openness-induced productivity growth and farm products' price

	Annual growth rate of openness-induced productivity [1)]		Annual growth rate of real farm products' price [2)]	
	Before URAA	After URAA	Before URAA	After URAA
Specification 1 (Trade share)	0.09	1.14	-0.13	-1.88
Specification 2 (Import share)	0.01	1.05	-0.13	-1.88
Specification 3 (Export share)	0.08	1.15	-0.13	-1.88

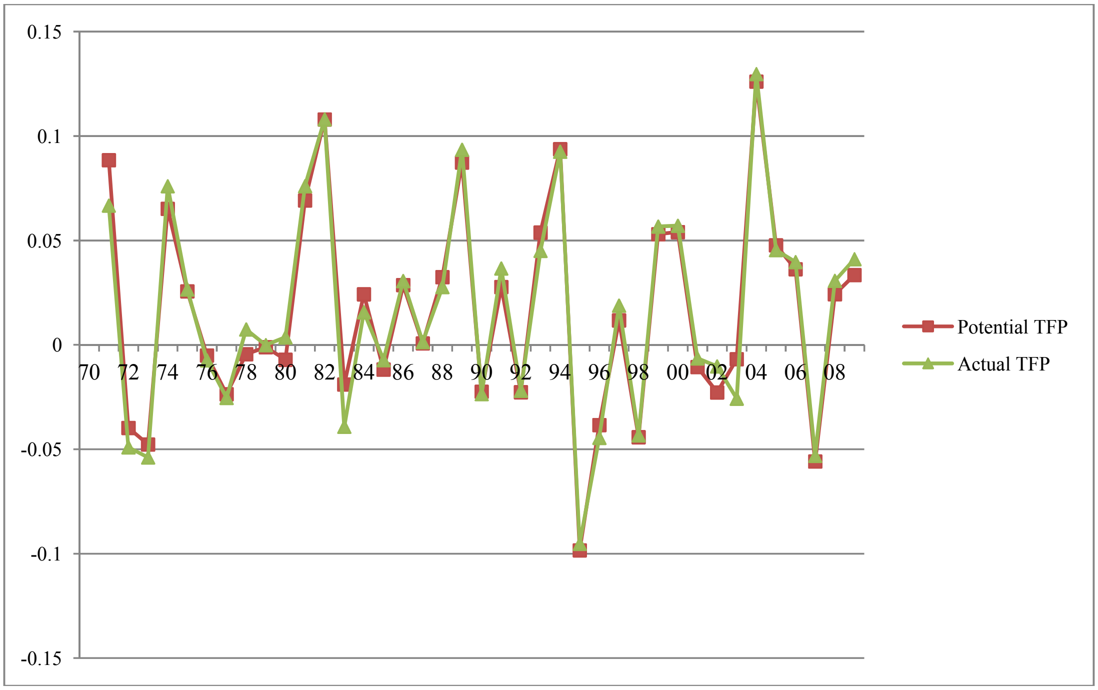
Note: 1) indicates total factor productivity fitted by openness indicator only, holding other variables constant;

2) represents the real index of price received by farmers, deflated by the consumer price index (2005=100).



Source: Bank of Korea, Korea Customs Service, and Ministry for Food, Agriculture, Forestry and Fisheries of Korea

Figure 1. Trade, import and export share of agricultural GDP, 1980-2009



Source: Authors' computation

Figure 2. Growth rates of potential and actual total factor productivity

Appendix

Table A1. International trade in Korea (Selected years)

Unit: billion US$

Year	Total			Agricultural sector		
	Export (A)	Import (B)	Balance (A-B)	Export (C)	Import (D)	Balance (C-D)
1970	0.8	2	-1.2	0.03	0.34	-0.31
1975	5.1	7.3	-2.2	0.26	1.02	-0.76
1980	17.5	22.3	-4.8	0.54	2.22	-1.68
1985	30.3	31.1	-0.8	0.39	1.79	-1.40
1990	65.0	69.8	-4.8	0.80	3.75	-2.95
1994	96.0	102.3	-6.3	0.95	5.43	-4.48
1995	125.1	135.1	-10.0	1.24	6.89	-5.65
2000	172.3	160.5	11.8	1.28	6.78	-5.50
2005	284.4	261.2	23.2	2.10	9.80	-7.70
2009	363.5	323.1	40.4	3.10	14.2	-11.1

Source: Korea Customs Service and Ministry of Food, Agriculture, Forestry and Fishery of Korea

Note: Export and import values are on the basis of fob and cif, respectively.

Table A2. Number of farm households by cultivation area (Selected years)

Year	Number of farm households (thousand)					Cultivation area per farm household (ha)
	Below 1.0ha	1.0-2.0ha	2.0-3.0ha	Over 3.0ha	Total [1)]	
1992	965 (58.8)	477 (29.1)	124 (7.6)	53 (3.2)	1,641	1.26
1995	865 (57.6)	418 (27.8)	123 (8.2)	69 (4.6)	1,501	1.32
2000	819 (59.2)	352 (25.5)	114 (8.2)	85 (6.1)	1,383	1.37
2005	788 (61.9)	281 (22.1)	93 (7.3)	94 (7.4)	1,273	1.43
2009	770 (64.4)	239 (20.0)	82 (6.9)	90 (7.5)	1,195	1.45
Annual Growth rate (%)	-0.83	-3.91	-2.85	1.92	-1.62	0.67

Source: Korean Statistical Information Service

Note: Number in parenthesis is proportion (%) of farm households by cultivation area out of total farm households in each year; 1) includes farm households who do not own farm land.

Table A3. Rural price index and farm price parity (Selected years)

	Index of price received by farmers (A)		Index of price paid by farmers (B)		Farm Price Parity (A / B) X 100
	Nominal	Real 1)	Nominal	Real 2)	
1980	32.1	113.9	25.0	88.7	128.4
1985	44.6	112.3	36.6	92.2	121.9
1990	60.3	116.6	47.4	91.7	127.2
1994	74.8	111.8	59.3	88.7	126.1
1995	81.6	116.8	62.8	89.9	129.9
2000	89.5	105.5	80.1	94.4	111.7
2005	100.0	100.0	100.0	100.0	100.0
2009	101.0	89.5	120.4	106.7	83.9
Annual Growth rate (1980-1994)	6.23	-0.13	6.36	-0.01	-0.13
Annual Growth rate (1995-2009)	1.54	-1.88	4.76	1.24	-3.08

Source: Korean Statistical Information Service

Note: 1) and 2) are deflated by the consumer price index (2005=100)

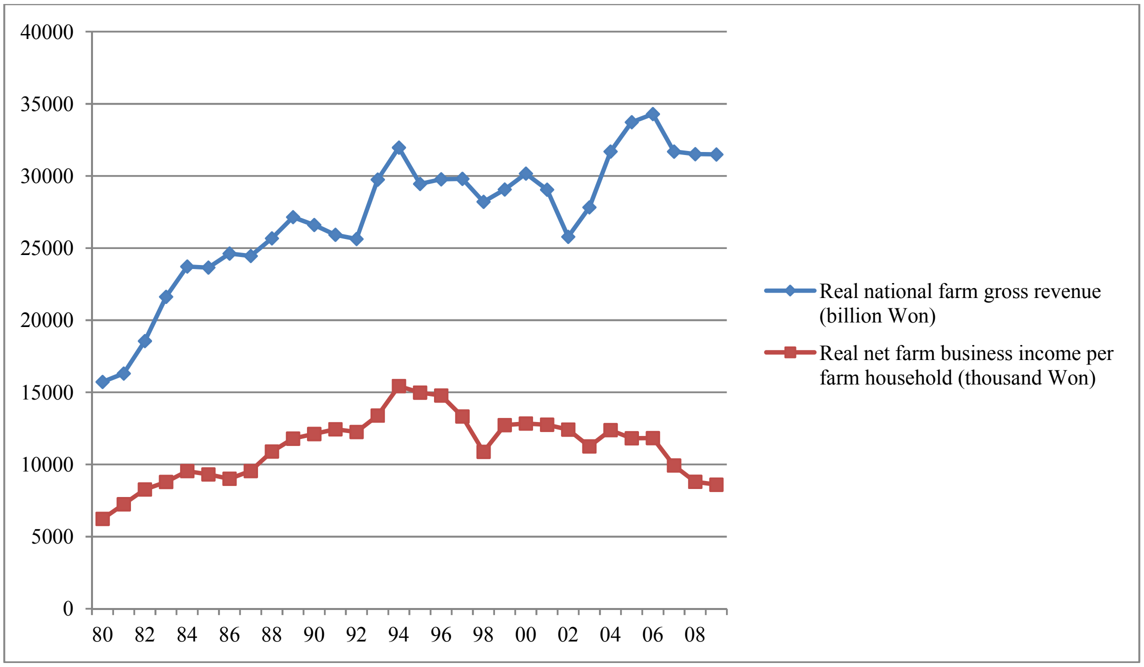
Table A4. Income per farm household (Selected years)

(Unit: thousand Korean Won)

	Net farm business income (A)		Non-farm business income (B)		Income per farm household (C=A+B)	
	Nominal	Real 1)	Nominal	Real 2)	Nominal	Real 3)
1980	1,755	6,228	938	3,330	2,693	9,559
1985	3,699	9,313	2,037	5,130	5,736	14,443
1990	6,264	12,113	4,762	9,209	11,026	21,322
1994	10,325	15,439	9,991	14,939	20,316	30,378
1995	10,469	14,983	11,334	16,220	21,803	31,203
2000	10,897	12,840	12,175	14,346	23,072	27,187
2005	11,815	11,815	13,962	13,962	25,777	25,777
2009	9,698	8,598	17,609	15,611	27,307	24,208
Annual Growth rate (1980-1994)	13.49	6.70	18.41	11.32	15.53	8.61
Annual Growth rate (1995-2009)	-0.54	-3.89	3.20	-0.27	1.62	-1.80

Source: Korean Statistical Information Service

Note: 1), 2), and 3) are deflated by the consumer price index (2005=100)



Source: Korean Statistical Information Service

Figure A1. Widening gap between agricultural revenue and net farm income