Measuring Non-Tariff Barriers by Combining Cointegration Tests and Simulation Models with an Application to Russian Chicken Imports

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Abstract

Non-tariff barriers (NTBs) to agricultural trade are believed to have increased as tariffs fell. Hence, measuring NTBs has become important and several alternative methods to do so are used. We develop a method that combines cointegration tests and an equilibrium model. We use these two seemingly disparate methods not only to estimate the size of NTBs, but also to assess its economic impact. We apply our method to the Russian chicken import ban and find larger impacts as compared to a common method based on price gaps. Trade policy analysts can use our method to convert the implicit economic assumptions of cointegration test results into explicit measures of NTBs or other factors that can explain the observed pattern in time series price data and estimate their impacts.

Key words: Cointegration test, Non-tariff barriers, Partial equilibrium model.

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Tariffs in many countries have gradually been reduced by bilateral and multilateral agreements, including in the context of the General Agreement on Tariffs and Trade (GATT) and the World Trade Organization (WTO). The most recent multilateral agreement, the Uruguay Round, also resulted in the conversion of import quotas on agricultural products into tariffs or tariff-rate quotas. However, there is the risk that countries could increase non-tariff barriers (NTBs) to trade. NTBs are all barriers to trade except for tariffs or TRQs. NTBs might lead to increased costs for or outright bans on foreign-made goods based on safety, labeling, environmental, labor, or phytosanitary grounds, although many such constraints might very well be justified rather than tariffs in disguise. If NTBs were increased as tariffs were reduced, then policy analysis might be inaccurate: if analysis focuses on import quota elimination and tariff reductions without regard to potentially offsetting increases in NTBs, then the economic impact will be overestimated.

NTBs are present more often in the agricultural sector as compared to other industries (Winchester 2009). According to the United Nations Conference on Trade and Development (UNCTAD 2012), trade restrictiveness is higher in the agricultural sector than the manufacturing sector. Moreover, the ad valorem equivalent of NTBs is greater than the ad valorem equivalent of all tariffs in the agricultural sector (Draganov 2012). Therefore, measuring NTBs is important to analyze the impact of international agricultural trade policy.

Measuring NTBs is necessary because analysts know that NTBs might distort markets and international trade (Deardorff and Stern 1998). UNCTAD and other organizations have attempted to quantify NTBs to analyze more accurately the economic impacts of NTBs in spite of the fact that NTBs are difficult to measure or to compare to tariffs. There are alternative ways to measure NTBs such as price-based, quantity-based and combinations of these two methods. Price based methods calculate a price gap between the domestic price and the international price in order to estimate the tariff equivalent of NTBs (Linkins and Arce 2002; Deardorff and Stern 1998; Chemingui and Dessus 2008; Andriamananjara et al. 2004; Dean et al. 2005). Quantity based methods normally utilize a gravity model bilateral trade flows between countries in order to measure NTBs (Disdier and Marette 2010; Winchester 2009).

Some studies combine these methods to measure NTBs. Yue, Beghin, and Jensen (2006) quantify the tariff equivalent of Japanese Technical Barriers to Trade (TBT) in the apple market and assess the impact of removing TBT and tariff. They use a simple constant elasticity of substitution (CES) model as the gravity equation approach and the price wedge method to measure TBT. Liu and Yue (2009) also estimate NTBs, specifically sanitary and phytosanitary (SPS) and customs and administrative procedures, by the same approach (Yue, Beghin, and Jensen 2006). They use additional factor-augmenting technical progress to explain the change of product quality. Then, they calculate the tariff equivalent of NTBs, such as TBT or SPS, as the difference between prices of domestic and import in the Japanese apple market. These articles attempt to use a combination of price and quantity methods to estimate the tariff equivalent of NTBs.

While price based and quantity based methods estimate the size of NTBs, simulation models estimate the economic impact of policy changes, including changes in NTBs. In particular, partial equilibrium (PE) models can assess a specific market and we easy to approach with limited data sources. Calvin and Krissoff (1998) build a PE model to assess the import impact of the removal of tariff and technical barrier in U.S – Japanese apple trade. Paarlberg and Lee (1998) also build and use a PE model, but they focus on Foot and Mouth Disease risk to study the trade effects of an optimal tariff corresponding to the risk. These articles show that PE model assess the economic impact from some policy changes.

The purpose of this article is to introduce a new method to measure NTBs. The method follows these steps. First, cointegration tests are used to estimate the relationship between prices of a commodity in two countries, taking tariffs into account. Second, a PE model is built to represent the market. This model includes explicit parameters to represent the tariff equivalent of NTBs. Third, the tariff equivalent of NTBs of the simulation model is adjusted until cointegration test results in simulated price data from the PE model match cointegration test results in historical data. The result of this procedure is an estimated value of the tariff equivalent of NTBs that could explain historical price relationships. Finally, recognizing that an NTB is not only one possible reason for prices not to be cointegrated, an alternative explanation, namely imperfect substitution, is also tested. NTB results can be compared to NTBs estimates from other studies, if available, for partial validation. The simulation model can be used to estimate market impacts of changes in the NTBs that can serve as an additional measure of the size of NTBs along with the tariff-equivalent.

Our combination of two seemingly disparate methods of analysis allows us to develop a consistent estimate of the tariff equivalent of NTBs. Simulation models are criticized, compared to experimental approaches, since they require many assumptions. However, the main distinction between simulation and experimental approaches is not necessarily the assumptions, but the extent to which they are made explicit (Keane 2010). Just (2008) also mentions that all econometric models need assumptions, but the difference is whether or not these assumptions are explicit and that explicit assumption can be tested and validated. Moreover, recent innovations in simulation model validation tie market price outcomes to structural parameters (Valenzuela et al. 2007; Beckman, Hertel, and Tyner 2011). Therefore, one contribution of this paper is to convert the implicit economic assumptions of cointegration test results of selected agricultural commodities into explicit measures of NTBs or other factors that can explain the observed pattern in time series price data.

The article is structured as follows. The next section develops the conceptual framework to calibrate a simulation model to cointegration test results. An empirical application is presented in the third section. The last section concludes with a comparison of another method and an assessment of the viability of this method.

Conceptual Framework

The existence of NTBs can be detected by cointegration test results in historical data. This test and other price based methods of studying NTBs rely on the theoretical implication, as discussed below, that an NTB can cause prices of a good in two countries to move differently. On the other hand, simulation models can include representations of trade of a good between countries. The representation of trade in the simulation models can in principle be constructed to reproduce existing policies and trade patterns. Here, we propose to use such a simulation model and calibrated its parameters to measure NTBs.

Therefore, cointegration and simulation model approaches are used to confirm the existence of NTBs and measure NTBs, as discussed in this section.

Cointegration analysis

Cointegration can test if two non-stationary prices of a commodity in different countries move together in the long-run. Although this argument is well known, we note a few key points here. If prices are cointegrated, then the result suggests that the markets of the two countries are integrated (Baffes 1991). On the other hand, if the test results suggest non-cointegration, then there are many possible reasons for markets not to be integrated. For example, Goodwin (1992) argues that ignoring transportation cost results in failure of a long-run equilibrium relationship. McNew and Fackler (1997) also suggest that transaction cost influences to make poor cointegration relation by showing simulation. We assume that the existence of NTBs is another reason for non-cointegration. Additionally, product differentiation could explain a non-cointegration, as the prices of dissimilar goods need not move alike.

Simulation model framework

The simulation models applied here is a structural model with parameters representing the possible NTB and an assumption of product differentiation based on country of origin (e.g. Armington assumption). Simulation models generate estimates of market prices that are consistent with the assumptions made explicit in equations and parameters, including those elements that represent trade and consumer demand. In this case, supply and demand for the domestically produced good are

(1) $S_t^D = a_0 + a_1 S_{t-1}^D + a_2 P_t^D + a_3 P_t^F + e_{S^D}$, and

(2) $D_t^D = b_0 + b_1 P_t^D + b_2 P_t^I + b_3 I_t + e_{D^D}$.

The demand equation for the imported product is

(3) $D_t^I = c_0 + c_1 P_t^D + c_2 P_t^I + c_3 I_t + e_{D^I}$.

Domestic supply depends on the output price, P_t^D and input price, P_t^F, with some delays associated with biological processes of producing an agricultural commodity. This representation assumes naïve price expectations. Each demand equation depends on price of the domestically produced good, P_t^D, price of the imported good, P_t^I, and income per capita, I_t. The degree of product differentiation is captured with the cross-price parameters, b_2 and c_1, with corresponding changes to own-price parameters, b_1 and c_2. A price transmission equation relates the price of the imported commodity and a foreign or world price:

(4) $P_t^I = d_0 + d_1 P_t^W * XR_t * (1 + \tau) + e_{P^I}$,

where P_t^W is the foreign price, XR_t is the foreign exchange rate, and τ is ad valorem tariff (or specific tariff). They are key elements of the equation that explains the link from the world price to the price that domestic buyers pay for the commodity once it is imported. Parameter d_0 and $d_1$indicate degree that the domestic market is integrated with the world market.

Domestic price is determined by the market-clearing equation,

(5) $S^D = D^D$.

From equations (1)-(5), we can derive the reduced-form price equation as

(6) $P_t^D = \frac{1}{b_1 - a_2}\left(a_0 + a_1 S_{t-1}^D + a_3 P_t^F + e_{S^D} - b_0 - b_2 P_t^I - b_3 I_t - e_{D^D}\right)$

$= \frac{1}{b_1 - a_2}\left(a_0 + a_1 S_{t-1}^D + a_3 P_t^F - b_0 - b_2(d_0 + d_1 P_t^W XR_t(1+\tau)) - b_3 I_t\right)$.

The equilibrium domestic price is a function of exogenous data, namely the lagged domestic prices, world price, exchange rate, tariff rate and income per capita, as well as the structural parameters. Taking the first derivative, the change in domestic price caused by a change in the world price is

(7) $\frac{\partial P_t^D}{\partial P_t^W} = -\frac{b_2}{b_1 - a_2} d_1 XR_t(1+\tau) > 0$ for $a_2 > 0, b_1 < 0, and\ b_2 > 0\ and\ d_1 > 0$.

The partial derivative of domestic price with respect to world price, $\frac{\partial P_t^D}{\partial P_t^W}$, is positive if the laws of demand and supply hold ($b_1 < 0$ and $a_2 > 0$), domestic and imported commodities are substitutes ($b_2 > 0$) and at least some price transmission exists ($d_1 > 0$).

The magnitudes of those parameters decide the size of impact of domestic price with respect to world price. For example, if the products are quite similar, so b2 and b1 become very large in absolute value, then the ratio ($\frac{b_2}{b_1 - a_2} d_1$) in equation (7) might approach unity. If the products are considered to be quite distinct, then product differentiation could cause b2 and b1 to approach zero, and there is reason to expect that this ratio will tend towards zero, as well. Similarly, consider the implications of the parameter that governs the transmission of world price changes to the internal price of the imported goods, d1. If price transmission is nearly zero, then d1 is nearly zero so the change in the domestic price for a given change in the world price is approximately zero. This relationship could hold even if the goods are strong substitutes, with b2 and b1 substantially different from zero. If price transmission is one-for-one, then d1 equals one so this ratio would be higher than if d1 is zero. In the case of near-perfect substitutes and strong price transmission, the ratio of the change in domestically made good price to the change in world price would approach one.

Measuring NTBs

The method to quantify NTBs works by calibrating parameters in the simulation model based on the evidence of cointegration test results from historical data. The process requires, first, cointegration experiments over historical price data. The second step is to calibrate price transmission parameters in the structural model so that a cointegration test over the simulated price data from the model generates the same test result as the cointegration test over the actual historical data. The third step is to measure the NTB as the difference between the hypothetical base case with perfect price transmission and the calibrated model result with the lower price transmission calibrated to historical data.

We do not assert that the NTB is necessarily the explanation for prices failing to move alike. Here, we offer product differentiation as an alternative cause for prices not to be cointegrated, as noted earlier. Thus, we have three possible cases that are relevant (table 1). Each case has a different assumption and consequently requires that the key model parameters are calibrated differently.

Hypothetical base case: The model has very high elasticity of substitution (b1, b2, c1, and c2 all large in absolute value) and full price transmission ($d_1 = 1$). With little product differentiation and complete price transmission, simulated domestic and world prices are cointegrated.

Product differentiation case: The model has low elasticity of substitution (b1, b2, c1, and c2 are all low in absolute value) and full price transmission ($d_1 = 1$). The elasticities of demand are calibrated to produce simulated price data that are not cointegrated, and the cointegration test statistic is the same as the estimated value based on historical data.

NTB case: The model has very high elasticity of substitution (b1, b2, c1, and c2 are all large in absolute value) and partial price transmission that is ($d_1 < 1$). We calibrate d_1 to produce simulated data so that domestic and world prices are not cointegrated, and the value of the cointegration test statistic is equal to the test statistic from the cointegration test over actual historical price data.

This last case corresponds to the method we outline earlier. The tariff equivalent of the NTB can be measured by comparing the base case and the NTB case. For example, the difference between prices of the imported good for domestic buyers from the hypothetical base case and the NTB case represents an indication of the size of the NTB.

Each case corresponds to a theoretical framework that would generate a certain set of empirical cointegration test results (Figure 1). The hypothetical base case represents the potential that world price and domestic price move together with near-perfect substitution and full price transmission. When import price increases by 1%, then there is an immediate and strong effect on the demand for the domestic product. Therefore, the demand curve for the domestic product shifts out. Given the shift and the own-price elasticity (but ignoring the corresponding shift in import demand), the prices move alike. This case corresponds to high price transmission (d1 near one) and low product differentiation (b1, b2, c1, and c2 are large in absolute terms).

In the case of product differentiation, the own- and cross-price elasticities are low. Hence, the response to import price is less in the domestic market because of low elasticity of substitution, although the change in world price is transmitted in full into the domestic market. This case corresponds to price transmission (d1 near unity) and high product differentiation (b1, b2, c1, and c2 are small in absolute value)

Lastly, the NTB case shows that import price is not fully transmitted to domestic market. Even though domestic and imported good are nearly perfect substitutes – and could in principle be represented as perfect substitutes – the world price change is stopped at the border, without influencing domestic market conditions. This case corresponds to low price transmission (d1 near zero) and low product differentiation (b1, b2, c1, and c2 are large in absolute terms). Comparing the relative price changes shows that the domestic and world prices can be cointegrated if product differentiation is limited and price transmission is strong, namely the conditions of the first case. However, if one of the two assumptions is invalid, domestic and world prices are not cointegrated in these diagrams, as changes in world price are not transmitted to the domestic price.

Empirical Application

The method is applied to analyze the Russian ban on chicken imports from the United States. In 2008, the United State export of chicken to Russia represented 18 percent of total US chicken exports, but this share fell sharply after 2009 to 6 percent in 2013 (USDA-FAS 2014). Some analysts argue that the ban was not put in place for the stated purpose, relating to safety, but was instead intended to reduce imports of chicken from the U.S. (Koopman and Laney 2014).

The chicken producer price in Russia was 72.3 rubles per kg in January 2008 and rose to 112.4 rubles per kg in December 2014 (Ministry of Agriculture of the Russian Federation). At the same time, US composite wholesale chicken price was 169 cents per pound in January 2008 and 199.43 cents per pound in December 2014 (USDA-ERS). The percent changes in Russian chicken producer price and US composite chicken price are 55% and 18% between 2008 and 2014, respectively. The Russian chicken producer price increased three times faster than US composite wholesale chicken price during the period from 2009 to 2014 (figure 2).

The domestic production has increased gradually since 2000 while the import share has fallen since 2009 (table 2). With less imported chicken available in Russia, the consumption of domestically produced chicken has increased. These data suggest that the ban might have helped to explain the decreasing role of imports in Russia's chicken market. This finding suggests that the ban represented an NTB, justified scientifically or not, that could be subject to empirical analysis. Therefore, this case of government intervention is an example of an NTB that can be subject to analysis using the method outlined above.

Cointegration analysis

Monthly Russian chicken producer prices and U.S. composite wholesale chicken prices are used to test cointegration test. Data for both chicken prices are from January 2005 to December 2014. The U.S. chicken price is converted from dollars to rubles. Before cointegration analysis, we check whether each price is stationary or not. We conduct the Augmented Dickey-Fuller (ADF), Phillips-Perron (PP) and KPSS unit root test. KPSS is a complementary test to ADF and PP.

Table 3 indicates statistical results of the unit root tests of price levels using the alternative tests. The null hypothesis in ADF and PP is that it is non-stationary and the null of the KPSS is that it is stationary. Test statistics for the two prices with both drift, and drift and trend in level are not statistically significant in ADF and PP and tests of the two prices with drift are statistically significant in KPSS. However, Table 3 shows that test statistics for prices in first difference are statistically significant in ADF and PP, and are statistically insignificant in KPSS. Therefore, they have a unit root, I(1), as non-stationary.

For cointegration analysis with non-stationary prices, we conduct the Engle-Granger method as a residual-based approach. First, we estimate

(8) $P_t^D = \mu + \beta * P_t^I + \varepsilon_t.$

This is a regression of Russian chicken price, P_t^D, on the import price of U.S. chicken, P_t^I.[1] The estimated coefficient on the import price, $\hat{\beta}$, is the response of Russian chicken price to the import price of U.S. chicken. This coefficient is analogous to the impact of domestic price with respect to world price, as defined in equation (7). The estimated value of the parameter , $\hat{\beta}$, is 0.4. This result is consistent with the theoretical expectations from the structural model, including product substitution. The residual of the estimated equation is

(9) $\hat{\varepsilon} = P_t^D - \hat{\mu} - \hat{\beta} * P_t^I$.

In the same manner of unit root test using the residuals of non-stationary variables, the null hypothesis of the Engle-Granger method using ADF and PP tests is that the residual is non-stationary. If the two tests (ADF and PP) reject the null hypothesis, then we conclude that there is a long-term relation between the two variables, namely that they are cointegrated. KPSS test is used as a complementary test.

Table 3 shows that the two prices are not cointegrated by any of the three alternative tests. Various factors can cause non-cointegrated prices. Initially, we assume that non-cointegration is caused by the NTB in Russia that restricts chicken imports. There could be other reasons, such as imperfect substitution or consumer preferences that we test explicitly later. However, the review of this policy presented earlier and the evidence of non-cointegration support the hypothesis that an NTB causes domestic and import prices to move differently. In the next section, the statistical results of the cointegration test are used as a reference point for validation of the model, corresponding

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[1] The import price of U.S. chicken is by multiplying U.S. composite wholesale chicken price, exchange rate and 1 plus the *ad valorem* tariff rate.

to the cases summarized in table 1. We calibrate parameters mainly based on the tau statistic (-2.41) of the ADF test with drift as calculated based on historical data.

Structural model

Our model is a simultaneous equation model. Production, domestic consumption, and producer price are endogenous. Therefore, the risk of simultaneous bias is addressed using two-stage least square (2SLS) estimation. For a first stage, instrumental variables, which should be closely correlated with endogenous variables, but uncorrelated with the dependent variable and error term, are used (Wooldridge 2012). We use production cost, gross domestic product, and lagged independent variables for instrumental variables that satisfy these conditions. Moreover, the model is a dynamic. Since we have some lagged dependent variables on the right-hand side to reflect partial adjustment processes, past variables affect current variables so that the model can generate dynamically simulated data.

The model is estimated over annual data from 2000 to 2014 (table 4). The results presented in the second column are not calibrated. The third, fourth, and fifth columns show calibrated parameters. In addition to key parameters, less important parameters, such as a lagged production (a_1) and the ratio of own price to feed cost (a_2) in the supply side, trend (b_4) in the domestic consumption, and GDP per capita (b_3) and (c_3) in both domestic consumption and import consumption are held constant in all cases, having been determined initially by the 2SLS estimation of the base model.

Key parameters are calibrated to correspond to each possible case. Because the hypothetical base case and NTB cases have the same assumption about the degree of substitution, the same parameters appear in the third and fifth columns. However, the case with a different assumption about product differentiation is apparent in the demand parameters chosen in column four. The main distinguished element of the calibration exercise relates to price transmission. For the hypothetical base case, we assume full price transmission so that domestic and import prices can be cointegrated. However, for the NTB case, this price transmission parameter, d_1, is calibrated at a value less than one. This calibration will cause the domestic and world price not to be cointegrated. In the product differentiation case in the fourth column, there is full price transmission by assumption. This case explores the potential for product differentiation to cause domestic and world prices not to be cointegreated.

A stochastic process is used to generate simulated data. The model is calibrated to recently observed market data, and the residual values are drawn at random from a normal distribution. The variances of the distributions are determined from the error of the estimation. We draw at random on the residual distribution of the world price with mean equal to 0 and the standard deviation equal to 11.017. Each world price draw implies different endogenous outcomes for Russian chicken market variables, including price. Drawing only from errors in the world price creates a consistent stochastic process that will drive domestic price changes according to the structural assumptions of the proposed cases. Through the stochastic simulation approach, we generate 170 observations.

The simulated domestic and import prices adjusted for exchange rate and tariff are used to estimate equation (8). In each case, the change in the Russian chicken price associated with a change in the U.S. chicken price. (table 5). We assume that two prices have positive relation by the characteristics of supply and demand equations and elasticities. in equation (7). In particular, the size of the impact of the Russian chicken price with respect to import price of U.S. chicken in the hypotherical base case is 0.235. In contrast, the cases of the product differentiation and NTBs have calibrated parameters that lead the impact of U.S. chicken price on Russian chicken price to be smaller relative to the case of the hypothetical base case. From these regressions using simulated data of each case, we obtain residuals and then test for cointegration.

Russian chicken price and import price of U.S. chicken are not cointegrated over historical data (table 3). Based on these cointegration test results, especially tau statistic (-2.41), we use different assumptions to generate simulated price data that are related in the same manner as the two prices have been in historical data. Table 6 shows relationships between two prices, depending on the assumptions for each case. The product differentiation case assumes lower elasticity of substitution, e_s= 0.095, with full price transmission, $d_1 = 1$. As a result, the two prices are not cointegrated. In this case, Russian price does not perfectly respond to the change of U.S. chicken price because the two goods are dissimilar. Hence, domestic price does not change as much as the change of import price of U.S. chicken. This is one of the possible explanations why they are not cointegrated other than the presence of NTBs. In contrast, a high enough elasticity of substitution leads the two prices to be cointegrated, as shown in the hypothetical base case (table 6). If the elasticity of substitution is high enough with full price transmission, $d_1 = 1$, then two prices are cointegrated.

The NTBs case in table 6 assumes the elasticity of substitution is as high as in the hypothetical base case. However, if U.S. chicken price does not perfectly transmit to import price of U.S. chicken in Russia, then they can move differently. In this model, when $d_1 = 0.4$, domestic price and import price of U.S. chicken in domestic market are not cointegrated. Moreover, at this rate of price transmission, the cointegration test results are the same over historical and simulated data, implying a consistent market structure. The tau statistic with drift in the NTBs case is consistent with the tau statistic with drift in historical data. The results show that the change of the import price of U.S. chicken does not affect the domestic market. When the price of U.S. chicken is raised by 1%, the import price of U.S. chicken is raised by 0.4% in Russia domestic market. Therefore, we can infer that there are some import restrictions. We calculate the tariff equivalent of NTBs by the differences between PI_t in the hypothetical base and NTBs case.

Table 7 presents not only tariff and tariff equivalent of NTBs but tariff rate and the ad valorem equivalent of NTBs from 2010 to 2014. The tariff equivalent of NTBs is higher than the tariff. The tariff is calculated by multiplying U.S. chicken price, exchange rate, and tariff rate. The tariff equivalent of NTBs is the product of the U.S. chicken price, exchange rate, and the ad valorem equivalent of NTBs. The ad valorem equivalent of NTBs is calculated by dividing the difference in the two import prices of the hypothetical case and NTBs case by the U.S. chicken price (in rubles). This method of calculating the ad valorem equivalent of the NTB follows the concept of the price gap approach, although the numerator is generated by the new method described above, rather than just comparing observed price levels. Even though the tariff rate has fallen from 2010 to 2014, the ad valorem equivalent of NTBs has remained at its higher rate, or even increased further relative to the stated tariff. Figure 3 shows the import price of U.S. chicken in rubles, with and without tariff and NTBs. Once the NTB is included, the import prices are much higher than the import price without NTBs.

NTBs should be incorporated into price transmission equation of a PE model. If NTBs are ignored, then policy analysis could be inaccurate. These quantified NTBs can be useful to assess the impact of policy changes. We make scenarios in case of 1) the existence of NTBs and 2) the removal of NTBs and analyze the impact of each case. Table 8 illustrates scenarios considering the existence of NTBs calculated by the method introduced here. When we impose the quantified NTBs, the average change from 2015 to 2019 of the domestic production is increased by 9%. The domestic price is increased by 57% by the NTB. Import of chicken will be reduced to 109 thousand tons if NTBs is inserted into the price transmission equation. This assessment shows that the NTBs will protect domestic market, by preventing imports of chicken.

We also compare with other method used to quantify NTBs. We attempt to calculate NTBs by a traditional price gap approach. The price gap approach is

(10) $Ad\ valorem\ equivalent\ of\ NTBs = \frac{P^D - P^I}{P^I}$,

where the calculation is applied by subtracting the import price including tariff, P^I, from the domestic price, P^D (Chemingui 2008). To obtain the ad valorem equivalent of NTBs, the difference between domestic price and import price is divided by the import price. We use a five year average of prices, namely 2010-14. The calculated ad valorem equivalent of NTBs using this price gap method is 12%. The ad valorem equivalent of NTBs from the traditional price gap approach is smaller than in the new method introduced here. The difference appears quite large: the 12% implied by the price gap method is much lower than the 60-72% estimate using a combination of cointegration and structural model.

Table 8 shows the comparison of results from two different approaches. To find the impact of NTBs, we take the hypothetical base case model and impose the tariff equivalent of NTBs from two approaches into d_0 in the price transmission equation. The NTBs from different approaches generate different impact of production, import and Russian chicken price. The comparisons in table 8 show that the presence in the NTBs increases production and Russian chicken price, but decreases import. Moreover, as NTBs are reduced by a quarter of tariff equivalent of NTBs calculated from the new method, we can recognize that production, import and Russian chicken price go toward values when there are no NTBs.

Conclusion

Measuring NTBs is important to analyze the economic impact from trade policy change. If we ignore the existence of NTBs, then the impact of international trade policy could be inaccurate. In particular, NTBs are present more often in the agricultural sector as compared to other sectors. Therefore, measuring NTBs is becoming important in the international agricultural trade policy. However, because we do not perfectly observe NTBs in contrast to the specified tariff, quantifying the size of NTBs is difficult even if we acknowledge the existence of NTBs. There are many alternative methods to measure NTBs, such as a price comparisons, quantity based approaches and combinations of these two methods. Simulation models have been used to estimate the impact of NTBs causing trade. In addition, we introduce a new method to measure NTBs.

Our model combines cointegration tests and simulation models with an application to Russian chicken import ban. First, cointegration tests are used to estimate the relationship between chicken prices in Russia and U.S. Second, a PE model is built to represent the Russian chicken market that includes explicit parameters to represent the tariff equivalent of NTBs. Next, the tariff equivalent of NTBs of the simulation model is adjusted until simulated price data from the PE model generate cointegration test results that match the results of similar tests for historical data. The result of this procedure is an estimated value of the tariff equivalent of NTBs that could explain historical price relationships in an analogous manner to the price gap method. This calculated tariff equivalent of NTBs can be used for economic analysis of the impacts of trade policy changes in the PE model. Adding the calculated tariff equivalent of NTBs shows significant changes, as compared to ignoring NTBs in the PE model. In comparison to the traditional price gap approach, this new approach not only estimates the size of NTBs, but also assesses the impact of NTBs on markets.

There exist some limitations to our model. First, we do not consider transaction costs that could affect cointegration relations, in addition to product differentiation. Second, the PE model only focuses on the Russian chicken market without other countries and commodities. If extended to more countries and commodities, then the experiment might generate a more reasonable measurement of the NTB impacts in this case. These limitations suggest avenues for further research.

Our findings are novel from a trade policy perspective because we can convert the implicit economic assumptions of cointegration test results for Russian and US chicken prices into explicit measures of NTBs or other factors that can explain the observed pattern in time series price data in the simulation model. Therefore, our method can contribute to trade policy analysis and help researchers estimate the impact of NTBs.

Table 1. Three Cases to Measure NTBs

	Hypothetical Base case	Product differentiation case	NTBs case
Elasticity of substitution (e_s)	Very high	Very low	Very high
Price transmission (d_1)	Full price transmission	Full price transmission	Low price transmission
Cointegration test result	Cointegrated	Not Cointegrated	Not Cointegrated

Table 2. Russian Chicken Production and Consumption, 2000-2014

Year	Domestic Production (1,000 MT)	Domestic Consumption (1,000 MT)	Total Import (1,000 MT)	Total Export (1,000 MT)	Import Share (%)
2000	410	407	948	3	70
2001	485	482	1,288	3	73
2002	565	564	1,215	1	68
2003	645	644	1,100	1	63
2004	770	769	1,030	1	57
2005	950	943	1,240	7	56
2006	1,180	1,178	1,199	2	50
2007	1,410	1,408	1,230	2	47
2008	1,680	1,675	1,166	5	41
2009	2,060	2,053	929	7	31
2010	2,310	2,301	656	9	22
2011	2,575	2,550	463	25	15
2012	2,830	2,761	560	69	16
2013	3,010	2,980	540	30	15
2014	3,200	3,175	385	25	10

Source: USDA and OECD database

Note: Import share is the ratio of total import to total domestic consumption

Table 3. Results of the Unit Root Tests on Price Levels

	ADF			PP			KPSS	
	Lag	Drift	Drift and Trend	Lag	Drift	Drift and Trend	Drift	Drift and Trend
The Unit Root Tests on Price Levels								
U.S.	2	0.05	-1.06	2	0.99	0.87	0.54*	0.06
Russia	2	-0.30	-2.59	2	-0.94	-0.48	0.99**	0.28
The Unit Root Tests on First Differences of Prices								
U.S.	1	-4.73**	-4.54**	2	-7.26**	-7.47**	0.26	0.10
Russia	5	-4.48**	-4.51**	2	-7.77**	-7.76**	0.09	0.08
The Cointegration Test								
U.S. – Russia	1	-2.41	-2.19	2	0.14	0.24	0.73**	0.11

Note: *for 10 percent, ** for 5 percentage levels of significance. The 5% and 10% critical values for ADF and PP tests with drift are -2.90 and -2.59 respectively; for the tests with trend are -3.47 and -3.16 respectively. Critical values were obtained from MacKinnon (1991). The 5% and 10% critical values for the KPSS test in levels are 0.463 and 0.347 respectively; for the KPSS tests with a trend they are 0.146 and 0.119 respectively.

Table 4. Comparison of Parameter Estimates

Parameter	No Calibration	Hypothetical base case	Product differentiation case	NTBs case
d_1	1	1[b]	1[b]	0.4[b]
a_1	0.98***	0.98***	0.98***	0.98***
a_2	0.17**	0.17**	0.17**	0.17**
Root MSE	0.04	0.04	0.04	0.04
b_1	-0.000003	-0.0097[b]	-0.0097[b]	-0.0097[b]
b_2	0.00003	0.0094[b]	0.000094[b]	0.0094[b]
b_3	0.01	0.01[a]	0.01[a]	0.01[a]
b_4	1.89***	1.89[a]	1.89[a]	1.89[a]
Root MSE	1.14	157.9	351.3	157.9
c_1	0.00008**	0.0094[b]	0.000094[b]	0.0094[b]
c_2	-0.00003	-0.01[b]	-0.01[b]	-0.01[b]
c_3	0.01	0.01[a]	0.01[a]	0.01[a]
Root MSE	1.32	293.3	597.5	293.3

Note: * and ** are significance at the 10% and 5%levels, respectively. [a] and [b] denote restriction and calibration. The intercept in price transmission equation are excluded because all d_0 set zero. The intercept of all equations are also excluded to conserve space. In the production equation, we use the double log equation to have reasonable estimates for simulation. a_2 represents the elasticity of a relative price of domestic price to feed cost.

Table 5. The Results of Regression of Russian Chicken price on Import Price of U.S. Chicken

	Hypothetical base case	Product differentiation case	NTBs case
$\frac{b_2}{b_1 - a_2} d_1$	0.235**	0.188**	0.216**
	(0.00)	(0.00)	(0.00)

Note: *for 10 percent, ** for 5 percentage levels of significance.

Table 6. Comparison of Cointegration Test Results of Historical and Simulated Data

		Lag	Rho	Pr < Rho	Tau	Pr < Tau	Cointegration result
Historical Data	Drift	1	-10.61	0.10	-2.41	0.14	Non - Cointegration
	Drift + Trend	1	-15.24	0.15	-2.19	0.49	
Hypothetical Base Case	Drift	1	-21.57	0.00	-3.49	0.00	Cointegration
	Drift + Trend	1	-21.71	0.04	-3.5	0.04	
Product Differentiation Case	Drift	1	-1.68	0.81	-1.48	0.54	Non- Cointegration
	Drift + Trend	1	-1.43	0.98	-1.87	0.66	
NTBs Case	Drift	1	-11.43	0.09	-2.43	0.13	Non- Cointegration
	Drift + Trend	1	-11.47	0.33	-2.43	0.36	

Table 7. Calculation of NTBs

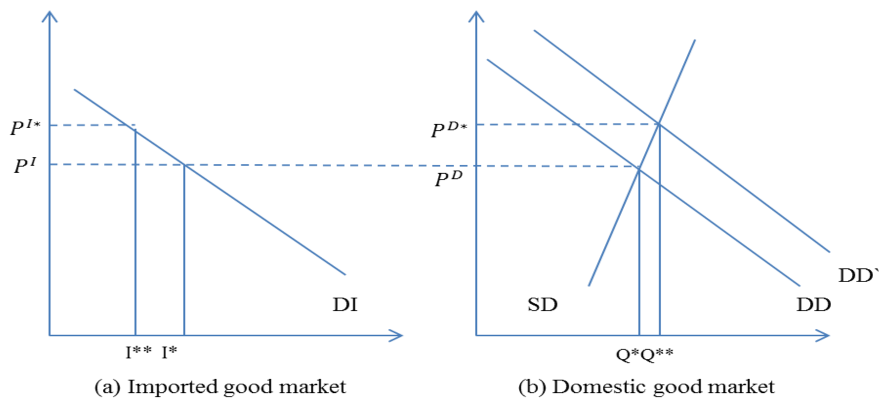
Year	Tariff (ruble/t)	Tariff equivalent of NTBs (ruble/t)	Tariff rate (%)	Ad valorem equivalent of NTBs (%)
2010	11,465	40,223	21	72
2011	8,778	36,001	17	70
2012	4,346	38,389	7	64
2013	11,675	48,943	17	70
2014	491	53,429	1	60

Table 8. Comparisons of a New Method and a Traditional Price Gap Method

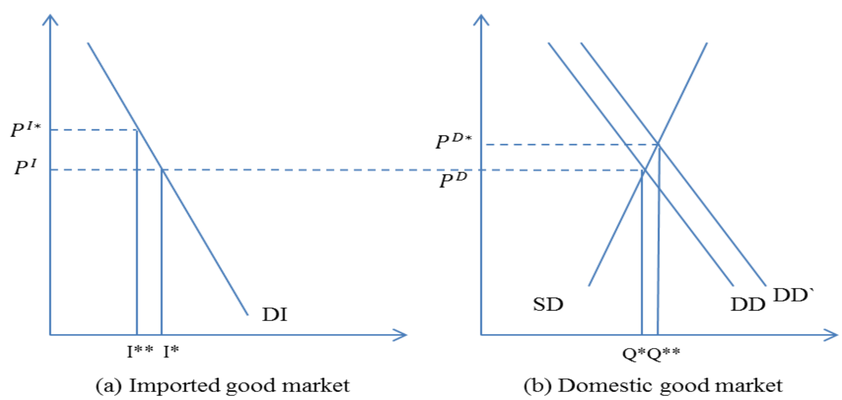
Method	No NTB	Price gap approach	New method			
NTBs	0%	12%	60%	45%	30%	15%
Production (kt)	3,971	4,054	4,339	4,257	4,169	4,074
Import (kt)	4,101	3,177	109	704	1,801	2,947
Russian chicken price (Rubles/t)	143,351	159,722	225,254	204,769	184,289	163,816

Note: Based on the hypothetical base case model, tariff equivalents of NTBs from the new method and the price gap approach are imposed into the price transmission equation. The results are the average from 2015 to 2017.

(a) Hypothetical base case with cointegrated prices



(b) Prices not cointegrated because of Product differentiation



(c) Price not cointegrated because of non-tariff barriers

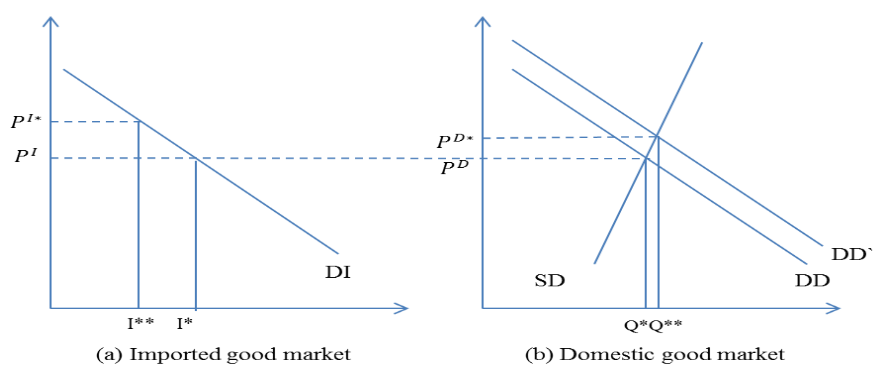


Figure 1. Conceptual Graph for Three Cases

Note: DI is the demand of imported good and DD and SD are demand and supply of domestically produced good. P^I is the import price and P^D is the domestic producer price.

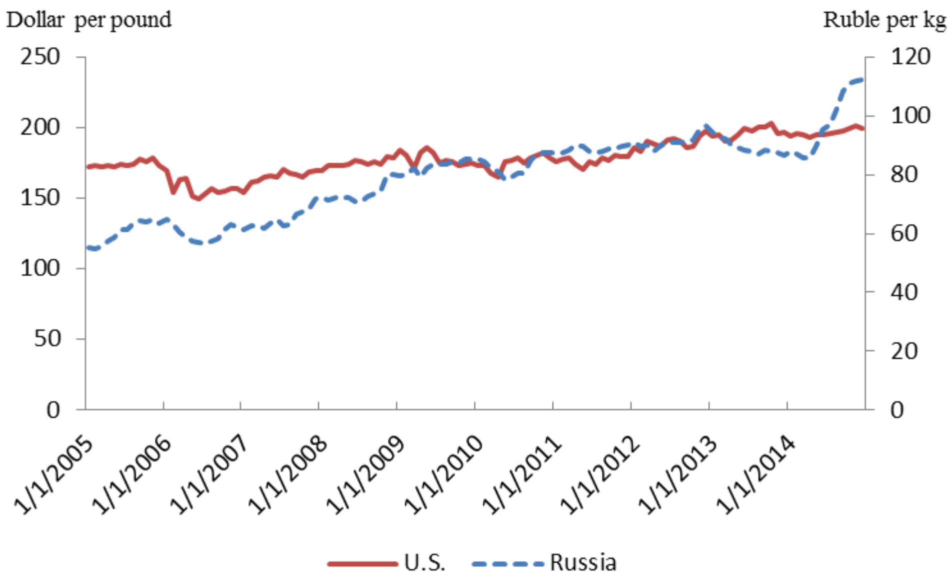


Figure 2. U.S. and Russian chicken prices

Source : USDA-ERS

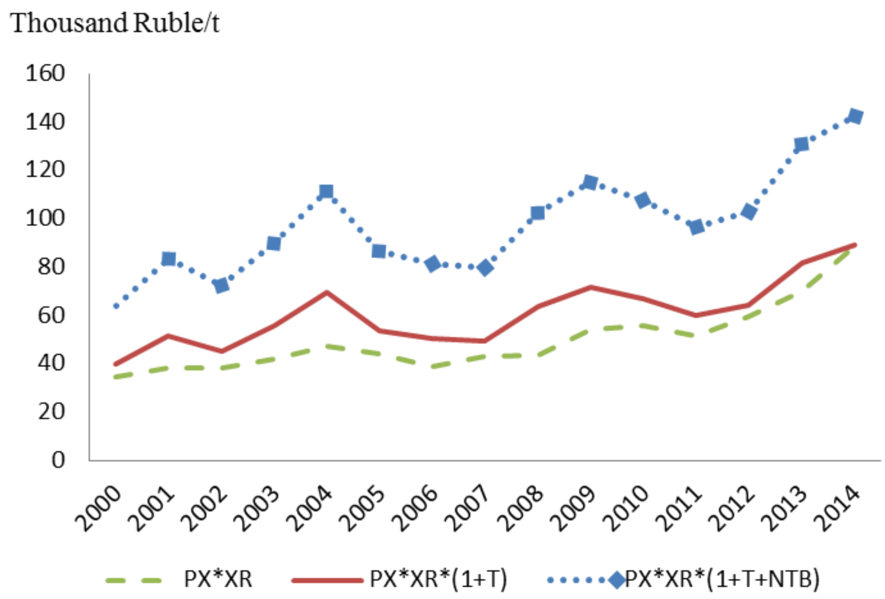


Figure 3. Import price of U.S. chicken in rubles, with and without tariff and NTB

Note: PX is U.S. chicken export price, XR is an exchange rate, T is tariff rate and NTB is calculated ad valorem equivalent of NTB.

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