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The Impact of Export Restrictions on Production: A Synthetic Control Approach

ABSTRACT In spite of the generalized use of quantitative restrictions on exports, there is little empirical research on their effectiveness to achieve the intended effects of reducing exports, increasing production for the domestic market, and reducing domestic prices. This paper aims at filling this gap by estimating the impact of quantitative restrictions on beef cattle exports in Bolivia, applying a synthetic control approach. Our main finding is that export restrictions have a negative impact not only on total production, but also on production for the domestic market. This fact, together with an increase in the domestic price, is consistent with a supply shift. The fact that export controls can shift supply and actually harm production for the domestic market bears important implications for the design of policies in the future.

JEL Codes: D22, F14, O13, O24

Keywords: Production, export controls, export restrictions, trade policy, synthetic controls

After the considerable increase in commodity prices that occurred in the second half of the 2000s, many countries around the world imposed restrictions on exports, specially on agricultural products. The main objective was preventing foodstuff shortages. These restrictions took two forms: quantitative restrictions on exports (QRE), such as bans or quotas, and export taxes.[1] Although under general assumptions a quantitative restriction has an equivalent export tax that guarantees the same results, policymakers were clearly biased to adopt quantitative restrictions. A review of policies

ACKNOWLEDGMENTS The authors thank Joshua Angrist and Hector Malarin for helpful comments and Laura Baensch for excellent research.

1. See, for instance, Anderson (2009), Mitra and Josling (2009), Kim (2010), Abbott (2011), Liefert, Westcott, and Wainio (2012), Martin and Anderson (2011), and Sharma (2011), who review the restrictions applied after 2007.

adopted by twenty-nine countries that restricted exports between 2006 and 2011 shows that twenty-five used QRE as their main instrument.[2] In spite of the generalized use of QRE, there is little empirical research documenting their effectiveness. In this paper, we aim to fill this gap by studying the effect of QRE on production decisions.

The few papers that address the effectiveness of QRE find mixed results. On the one hand, Fellmann, Hélaine, and Nekhay show that a temporary restriction on exports in Russia, Ukraine, and Kazakhstan, imposed after a harvest failure, reduced domestic prices in Ukraine and Kazakhstan.[3] Similarly, Diao and Kennedy find that an export ban on maize in Tanzania reduced its domestic price.[4] On the other hand, Götz, Glauben, and Brümmer, Djuric and Götz, and Götz report that wheat export controls in Russia, Serbia, and Ukraine did not reduce the domestic price.[5]

Therefore, the empirical question on whether QRE are actually effective in increasing production for the domestic market and reducing domestic prices is still open. To address this question, we exploit QRE imposed on beef cattle in Bolivia in 2008.

Our empirical strategy uses the synthetic control approach developed by Abadie and Gardeazabal and extended by Abadie, Diamond, and Hainmueller to identify the effect that QRE on beef cattle in Bolivia have on total production and production for the domestic market.[6] We use data from the Food and Agriculture Organization of the United Nations, which has the most reliable, complete, and publicly available data set on food production and exports. We complement this information with country-level data from the World Economic Outlook Database. Our final data set is an annual country-level data panel covering the period 1961–2013. One of the main advantages of this data set is that it provides us with more that forty-five years of information to construct the synthetic controls.

Our results show that, as expected, QRE reduced the total volume of beef production with respect to a counterfactual scenario. Since producers were

2. The twenty-five countries that used QRE as their main instrument are as follows: Bangladesh, Belarus, Bolivia, Cambodia, Chad, Ecuador, Egypt, Ethiopia, Guinea, Honduras, India, Indonesia, Jordan, Kazakhstan, Kenya, Malawi, Myanmar, Nepal, Serbia, Sri Lanka, Syria, Tanzania, Ukraine, Vietnam, and Zambia. Only four focused on export taxes: Argentina, China, Pakistan, and Russia. See Sharma (2011), and Liefert, Westcott, and Wainio (2012).

3. Fellmann, Hélaine, and Nekhay (2014).

4. Diao and Kennedy (2016).

5. Götz, Glauben, and Brümmer (2013); Djuric and Götz (2016); Götz and others (2016).

6. Abadia and Gardeazabal (2003); Abadie, Diamond, and Hainmueller (2010).

not able to export, they reduced their production. We also find that QRE not only reduced total production, but also reduced production for the domestic market. Producers overreacted to the policy, leading to a remarkable decline in production for the domestic market after QRE were implemented. This finding, together with the increase in domestic prices, is consistent with a shift in the supply curve. In fact, we find strong evidence that producers reduced their supply for the domestic market. After the restrictions were applied, livestock continued growing at a steady rate, but there was a significant change in the age composition of beef cattle, thus providing evidence of lower meat production and a lower replacement of beef cattle.

Our paper contributes to the literature in several dimensions. First, the paper contributes to the ongoing debate about international regulations. The idea that QRE can help to increase production for the domestic market is still prevalent among policymakers. For instance, the World Trade Organization (WTO) explicitly allows its members to implement temporary QRE when there are foodstuff shortages.[7] Our findings raise a note of caution about this policy prescription by providing empirical evidence that QRE can cause a remarkable decrease in production for domestic markets, worsening foodstuffs shortages instead of preventing them.

Second, to the best of our knowledge, this is the first paper that applies synthetic control methods to consistently assess the effects of export restrictions in a single country and on a single product, where measurement is less prey to the difficulties present when aggregating across products. Hence, we complement the existing literature by using a methodology that lets us construct a plausible counterfactual scenario in order to identify the causal effect of QRE on production. In particular, under the assumption that in the absence of QRE, Bolivia and its synthetic counterpart would continue to have a similar trend, our approach allows the identification of the causal link between QRE and production without imposing too many assumptions and structure on the model.

Our paper follows a growing literature that uses a synthetic control approach in the domain of economic development. For instance, Cavallo and others examine the short- and long-run average causal impact of catastrophic natural disasters on economic growth; Billmeier and Nannicini study the impact

7. Export prohibitions or restrictions are allowed "when temporarily applied to prevent or relieve critical shortages of foodstuffs or other products essential to the exporting contracting party" (General Agreement on Tariffs and Trade, Article XI: General Elimination of Quantitative Restrictions, Paragraph 1, p. 314).

of trade liberalization on the growth of gross domestic product (GDP); and Pieters and others study the effect of democratic reforms on child mortality.[8] Finally, our paper also contributes to the literature on the relationship between exports and domestic production, which highlights three main channels: reallocation of resources, learning by exporting, and investment in new technologies.[9] By focusing on the effect of trade liberalization or trade facilitation, this literature shows that trade improves productivity and therefore increases production. Our paper is analogous in the sense that we show that a restriction on exports causes a reduction in production—and, even more important, on the domestic availability of the product. However, the mechanism that causes the contraction in production in our case is not related to productivity but to the incentives the restriction creates for producers.

The remainder of the paper is organized as follows. We start by describing the implementation of QRE in Bolivia and outlining our identification strategy. We then present our main results, discard alternative explanations for the findings, and provide a robustness analysis. The final section concludes.

Implementation of QRE in Bolivia

With the objective of guaranteeing food security and achieving food sovereignty, the Bolivian government imposed controls on the export of beef cattle in 2008.[10] The controls took the form of QRE and were implemented through a series of administrative decrees. More specifically, a prohibition on exporting beef cattle was established in February 2008, and in contrast with other products, there was no other policy to affect domestic supply or domestic prices of beef.[11] In addition, this QRE lasted for a long time. The fact that the restrictions on other products were shorter introduced uncertainty for the beef producers about the duration of the restrictions. In March 2012 the government relaxed

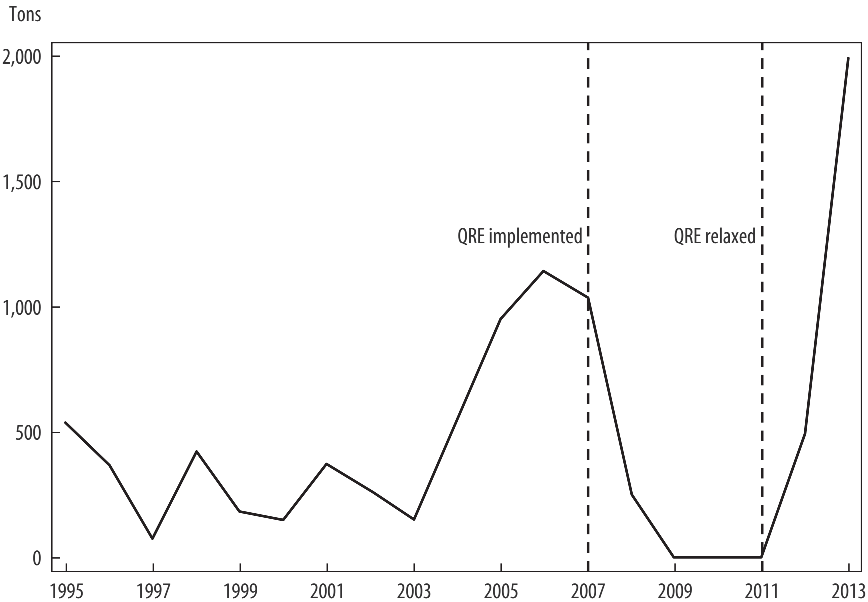
8. Cavallo and others (2013); Billmeier and Nannicini (2013); Pieters and others (2016).

9. Melitz (2003); Bernard and others (2003); Melitz and Redding (2014); Pavcnik (2002); de Loecker (2013); Bustos (2011).

10. Food sovereignty is defined as "the right of peoples and sovereign states to democratically determine their own agricultural and food policies" (McIntyre and others, 2009).

11. The government also imposed restrictions on exports of other products, such as maize, rice, sugar, wheat, sunflower oil, soybeans, and chicken. In some cases the restrictions did not last more than a year. In other cases the restriction was accompanied by other policies aimed at controlling domestic prices. We therefore focus our study solely on the restrictions on beef cattle exports.

FIGURE 1. Trends in Beef Exports

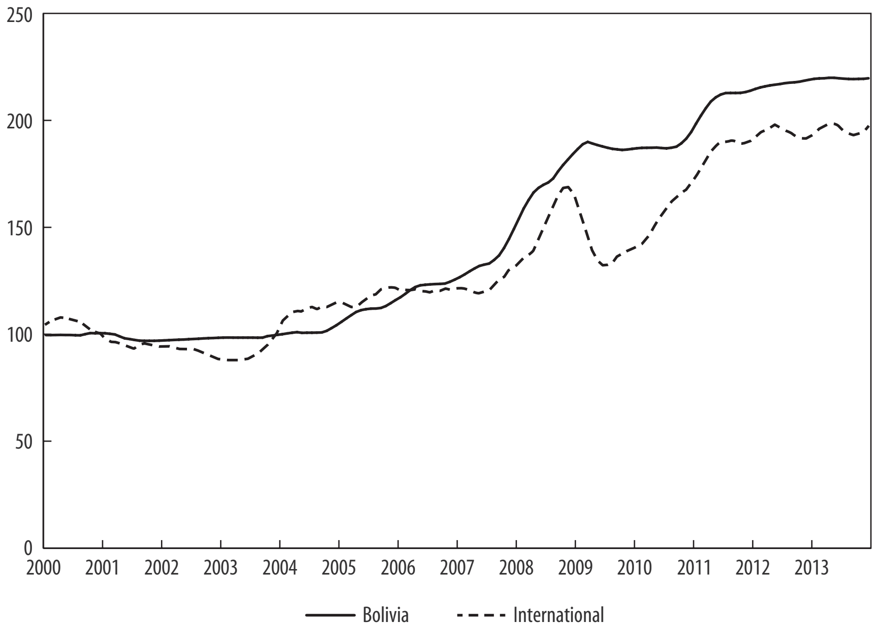


the restriction, allowing producers to export beef after the domestic market was cleared, and in August 2013 the beef export quota was increased. The market-clearing condition was not formally defined, however, which introduced additional uncertaintyfor the producers about the quantity they would be allowed to export.

The government of Bolivia took compliance with the policy very seriously. The National Customs Authority in Bolivia was responsible for coordinating the National Armed Forces and National Police to enforce the restrictions on the Bolivian borders and domestic roads. If a producer was caught trying to export, all the goods and vehicles were confiscated and the producer was charged with a criminal offense. Figure 1 shows a sharp decline in beef exports after QRE were imposed in February 2008. Exports remained low, at around zero tons, until the restrictions were relaxed in early 2012.

According to the government's objectives, the restrictions on exports should have led to a reduction in the domestic price of beef. Figure 2 shows that this was not the case. In fact, after the implementation of the export restriction, the domestic price of beef continued growing; it even grew faster than the international beef price.

FIGURE 2. Beef Price Index[a]



Source: Authors' elaboration, based on price data from the Bolivian National Institute of Statistics and the FAO Meat Price Index.
a. The price index is a six-month moving average, where the monthly average of 2000–04 = 100.

Identification Strategy

We use the synthetic control approach developed by Abadie and Gardeazabal and Abadie, Diamond, and Hainmueller to study the impact of QRE on total production and the impact of QRE on production for the domestic market.[12] Ideally, we want to consider the difference between our outcome variable (Q = volume of production, and S = volume of production for the domestic market) after the QRE intervention and the counterfactual outcome in the absence of that intervention. To estimate the counterfactual scenario, we use a synthetic control approach. Synthetic controls provide a suitable approach for

12. Abadie and Gardeazabal (2003); Abadie, Diamond, and Hainmueller (2010). Because the international price index of meat used in figure 2 is not published for individual countries, we cannot estimate the impact of QRE on domestic prices.

evaluating policies implemented in only one country and at the national level. In those cases, it is not possible to use difference-in-differences methods, so researchers used to rely on a before-and-after strategy that identifies variation in the time series and usually requires very strong assumptions to be credible. Synthetic controls resemble the difference-in-differences approach in a setting where there is only one treated unit and a mild set of assumptions. In our setting, under the plausible assumption that there are no other shocks affecting production that are collinear to the QRE, the synthetic control approach allows us to construct a counterfactual scenario for Bolivia and identify the causal impact of QRE on production, without making assumptions about the structural model underlying the determination of prices and quantities in the economy.

The synthetic control method is based on the idea that a weighted combination of unaffected units may resemble the characteristics of the treated unit substantially better than any untreated unit alone. In our exercise, the methodology works by assigning an analytical weight to each country that has not implemented QRE. These weights are computed to minimize the difference in preintervention outcomes (Q or S) between the treated unit (Bolivia) and the pool of potential comparison countries. Hence, synthetic Bolivia is the weighted average of the untreated countries' outcomes that meets the assumption of parallel trends conditional on observable characteristics prior to the implementation of QRE. Therefore, under the assumption that Bolivia and its synthetic counterpart would continue to follow a similar trend in the absence of QRE, this approach enables us to identify the impact of QRE on the volume of production and the volume of production for the domestic market.

Formally, let the index $i = (1, \ldots, J)$ denote the J countries that export (or produce, in the case of the analysis of production) a specific product. Without loss of generality, we assume that Bolivia is the first country ($i = 1$) and that it is the only one exposed to QRE. The remaining $J - 1$ countries were not affected by the intervention and constitute the set of potential comparisons used to construct synthetic Bolivia (donor pool). Define Y_{it} as the observed outcome variable (Q_{it}, or S_{it}) for country i at time $t \in [1, T]$. Let $t = t'$ be the year in which Bolivia's government imposed QRE. Denote with Y_{1t}^{N} the counterfactual outcome, that is, the outcome that would have been observed for the treated unit ($i = 1$) after t' in the absence of QRE. Then, the effect of QRE on the outcome variable is given by

$$\alpha = Y_{1t} - Y_{1t}^{N}. \tag{1}$$

As discussed, Y_{1t}^N is unobservable by definition, so we use the synthetic control method to consistently estimate it. In particular, given a set of nonnegative weights $W = [w_2, \ldots, w_J]$, the synthetic control estimator of the potential outcome is defined as a weighted average of the outcomes of the countries in the donor pool:

$$\hat{Y}_{1t}^N = \sum_{i=2}^{J} w_i Y_{it} \qquad \forall \qquad t > t', \tag{2}$$

with $w_i \geq 0 \; \forall \, i = 2, \ldots, J$ and $\sum_{i=2}^{J} w_i = 1$.

Finally, the question how to choose the optimal weights for each potential comparison country arises. For each country i, we observe a set of k predictors of the outcome: $Z_{1it}, \ldots, Z_{kit} \; \forall \, i = 1, \ldots, J$. These predictors include such characteristics as GDP per capita, harvested area, and population. More important, we also include preintervention values of the observed outcome to use the previous trends to construct the synthetic control. The synthetic control method selects a set of weights in such a way that the resulting synthetic control resembles the affected unit before the intervention along the values of the variables $Z_{1i}, \ldots, Z_{ki}$. Following Abadie and Gardeazabal and Abadie, Diamond, and Hainmuller, we proceed to choose the weights $w^* = \{w_2^*, \ldots, w_J^*\}$ by minimizing the square difference between the pretreatment values of the predictors k of the affected unit and the donor pool. That is, for $t \leq t'$,

$$w^* = argmin \left\{ \begin{array}{c} \left(Z_{11t} - \sum_{i=2}^{J} w_i Z_{1it} \right)^2 + \left(Z_{21t} - \sum_{i=2}^{J} w_i Z_{2it} \right)^2 \\ + \cdots + \left(Z_{k1t} - \sum_{i=2}^{J} w_i Z_{kit} \right)^2 \end{array} \right\}. \tag{3}$$

Once w^* is computed, the pre- and postintervention trends for the outcome variable for the synthetic control can be obtained by calculating the corresponding weighted average for each year, using the donor countries with positive weights. As mentioned above, the postintervention values for the synthetic control group serve as the estimates of the potential outcome of the treated unit. Therefore, the estimated effect of the intervention is given by

$$\hat{\alpha} = Y_{1t} - \hat{Y}_{1t}^N = Y_{1t} - \sum_{i=2}^{J} w_i^* Y_{it}. \tag{4}$$

Even though the synthetic control method chooses the optimal weights in order to minimize the square differences between the pretreatment levels of the affected unit and the synthetic control group, there might still be differences in pretreatment levels. To account for this potential problem, we also subtract pretreatment differences from posttreatment differences (as in a difference-in-differences approach). Additionally, as the level of outcome variables varies across countries, working with normalized variables allows us to compare the different treatments. Thus, we normalize the difference-in-differences estimates using the pretreatment average of the synthetic control. For this reason, in the postintervention period $t = t', \ldots, T$, the normalized difference between treated and synthetic control outcomes is given by

$$(5) \quad \hat{\beta} = \frac{\left[1/T - (t'+1)\right] \sum_{(t'+1)}^{T} \left(Y_{1t} - \sum_{i=2}^{J} w_i^* Y_{it} \right) - \frac{1}{t'} \sum_{(t=1)}^{t'} \left(Y_{1t} - \sum_{i=2}^{J} w_i^* Y_{it} \right)}{\frac{1}{t'} \sum_{(t=1)}^{t'} \left(Y_{1t} - \sum_{i=2}^{J} w_i^* Y_{it} \right)},$$

where the first term of the equation is the difference between the affected unit and its synthetic counterpart after the QRE, and the second term is the same difference in the preintervention period. The second term of the equation approximates zero when the synthetic control group adjusts better to the pretreatment values of the treated unit.[13]

Inference

To evaluate the significance of our estimates, we conducted a series of in-space and in-time placebo studies. The idea behind this inference study is that our confidence that a particular synthetic control estimate reflects the impact of the intervention would be undermined if we obtained estimated effects of similar or even greater magnitudes in countries or years where the intervention did not take place. In particular, in-space placebo studies apply the synthetic control method to estimate placebo effects for every potential control unit in the donor pool. This allows us to create a distribution of placebo effects against

13. We define $\hat{\beta}_Q$ as the coefficient when the outcome variable is the volume of production and $\hat{\beta}_S$ as the coefficient when the outcome variable is the volume of production for the domestic market.

which we can then evaluate the effect estimated for the treatment unit. Then, a quantitative comparison between the distribution of placebo effects and the synthetic control estimate can be implemented through the use of implied *p* values. By comparing the root mean square prediction error (RMSPE) for the treated units with those from the placebos, we can derive the likelihood that the estimate would have been observed if there had been no QRE. In particular, we rank the ratios between post- and pretreatment RMSPE for every placebo and then construct the implied *p* value by computing the proportion of ratios that are higher than the estimated gap for Bolivia.[14] Our confidence that a large synthetic control estimate reflects the effect of the intervention would be severely undermined if the magnitude of the estimated effect fell well inside the distribution of placebo effects. Similarly, in-time placebo studies apply the synthetic control method to estimate the effect in periods when the intervention did not occur. Again, our results would be severely undermined if we obtained effects of similar magnitude for periods when the intervention did not take place.

Data

Our main source for agricultural data is the Food and Agriculture Organization (FAO) of the United Nations, which has the most reliable and complete data set for food production and exports. We used data for the volume of production, exports, and imports covering the period 1961–2013. We merged this data set with the World Economic Outlook database generated by the World Bank. From this data set, we obtained information on GDP per capita (US$), the share of agriculture in GDP, food exports as a percentage of merchandise exports, and total trade as a percentage of GDP, among other variables. We only kept countries that are beef producers and for which we have information on their GDP per capita at least for the period 1980–2013. The final database comprises annual country-level panel data for the period 1961–2013. Our donor pool includes a sample of 170 countries.

14. The RMSPE measures lack of fit between the path of the outcome variable for any particular country and its synthetic counterpart. As there are some placebo countries that do not have a good synthetic control (ill-fitting placebo runs), we discard countries with a pretreatment RMSPE twenty times higher than Bolivia's. Results are robust if we discard differences five, ten, or fifteen times higher.

Empirical Results

We use the synthetic controls method to estimate the effect of the QRE on total beef production and on production for the domestic market. Specifically, the affected unit is Bolivia ($i = 1$), and the remaining 169 countries that are beef producers constitute the potential donor pool. We estimate separate synthetic controls for each outcome variable. The characteristics that we include as predictors are the decennial averages (1981–90, 1991–2000, 2001–08) of GDP per capita (in U.S. dollars), agricultural share of GDP, food exports as a percentage of total merchandise exports, and trade as a percentage of GDP. We also control for GDP per capita in 2008 and the agricultural share of GDP in 2008 to improve the fit in the last year before the intervention. To control for differences in recent growth rates, we include the GDP per capita growth rate between 2003 and 2008. Most important, to improve the fit of synthetic Bolivia to the pretreatment trend of Bolivia, we include in each estimation the pretreatment value of the outcome variable as separate predictors. As pointed out by Kaul, Klobner, Pfeifer, and Schieler (2015), using all outcome lags as separate predictors could render all other covariates irrelevant, regardless of their importance to predicting the potential posttreatment outcome. Hence, instead of including all outcome lags, we include only four decennial averages of the outcome variable (1971–80, 1981–90, 1991–2000, and 2001–08) and the value of the outcome variable in 2008.[15]

Constructing a Synthetic Version of Bolivia

Before examining the estimated effect of the QRE, we briefly discuss the quality of synthetic Bolivia for each outcome variable. In the case of the total volume of production, synthetic Bolivia is a weighted average of Vietnam (22.4 percent), Pakistan (21.6 percent), Gambia (16.5 percent), Turkey (12.4 percent), Liberia (11.0 percent), Ethiopia (5.3 percent), Djibouti (4.3 percent), Burundi (3.6 percent), Zambia (1.3 percent), and Madagascar (0.9 percent). All other countries in the donor pool obtain zero weights. The first two columns of table 1 compare the pretreatment characteristics of

15. Results in the paper are robust to including the forty-eight lags of the outcome variable as predictors. All results mentioned and not reported are available on request.

TABLE 1. Pretreatment Mean of Predictor Variables: Actual versus Synthetic Bolivia

	Total production		*Production for domestic markets*	
Predictor variable	*Bolivia*	*Synthetic Bolivia*	*Bolivia*	*Synthetic Bolivia*
Avg. outcome variable, 1971–80 (tons)	71,618	73,014	70,929	70,543
Avg. outcome variable, 1981–90 (tons)	119,535	118,320	119,606	118,356
Avg. outcome variable, 1991–2000 (tons)	142,473	141,930	142,575	142,660
Avg. outcome variable, 2001–08 (tons)	191,721	192,644	191,186	191,332
Value outcome variable in 2008 (tons)	248,680	247,028	248,603	248,228
Avg. GDP per capita, 1981–90 (U.S. dollars)	818	535	818	673
Avg. GDP per capita, 1991–2000 (U.S. dollars)	908	780	908	796
Avg. GDP per capita, 2001–08 (U.S. dollars)	1,146	1,297	1,146	1,343
GDP per capita in 2008 (U.S. dollars)	1,737	1,870	1,737	2,094
GDP per capita growth, 2003–08 (%)	89.4	82.1	89.4	83.9
Avg. agricultural share, 1981–90 (% of GDP)	18.9	17.6	18.9	18.2
Avg. agricultural share, 1991–2000 (% of GDP)	16.2	16.8	16.2	16.7
Avg. agricultural share, 2001–08 (% of GDP)	14.3	14.5	14.3	14.2
Agricultural share in 2008 (% of GDP)	13.1	14.4	13.1	13.9
Avg. trade openness, 1981–90 (% of GDP)	47.3	45.8	47.3	45.8
Avg. trade openness, 1991–2000 (% of GDP)	48.5	50.8	48.5	54.1
Avg. trade openness, 2001–08 (% of GDP)	63.1	68.8	63.1	73.1
Avg. food exports, 1981–90 (% of merch. exports)	7.7	9.5	7.7	9.6
Avg. food exports, 1991–2000 (% of merch. exports)	23.9	14.9	23.9	18.3
Avg. food exports, 2001–08 (% of merch. exports)	23.3	23.5	23.3	25.8

Bolivia to those of synthetic Bolivia. Overall, the results suggest that synthetic Bolivia is very similar to actual Bolivia in terms of pretreatment per capita GDP averages, agricultural value added, food exports, trade openness, and GDP growth between 2003 and 2008. Synthetic Bolivia also has an excellent performance in matching Bolivia's pretreatment trend in the volume of beef production.

In the case of production for the domestic market, synthetic Bolivia is a weighted average of Vietnam (26.2 percent), Gambia (13.8 percent), Egypt (13.5 percent), Turkey (9.0 percent), Ethiopia (8.6 percent), Liberia (6.9 percent), Guatemala (5.9 percent), Pakistan (4.2 percent), Iraq (3.8 percent), Syrian Arab Republic (3.4 percent), Papua New Guinea (2.9 percent), and Burundi (1.8 percent). All other countries in the donor pool obtain zero weights. The last two columns of table 1 compare the pretreatment characteristics of Bolivia to those of synthetic Bolivia. Overall, the results suggest that synthetic Bolivia adjusts well to decennial averages of GDP per capita, the share of agriculture, food exports as a percentage of merchandise exports, and trade openness.

Bolivia's GDP growth between 2003 and 2008 is fairly similar to the GDP growth of its synthetic counterpart. Finally, with regard to production for the domestic market, synthetic Bolivia has an excellent performance in matching Bolivia's pretreatment decennial averages in volume of production for domestic markets.

The Effect of the QRE

After the implementation of QRE in Bolivia, the volume of production became remarkably lower than total production of synthetic Bolivia. This finding is summarized in figure 3, where we plot pre- and posttreatment levels of the total volume of production (panel A) and the difference between Bolivia and synthetic Bolivia in absolute terms (panel B). The average effect of the QRE on total production is 42 percent, with an implied p value of 3 percent. The highest effect, in absolute terms, is observed after some years: the gap in production of beef cattle between Bolivia and synthetic Bolivia rose from around 65,000 tons in 2009 to 110,000 tons thereafter. However, there is an initial decline of 50,000 tons in Bolivia's production (from 250,000 to 200,000) and then Bolivia's production remains constant, while the gap widens because of the growth of synthetic Bolivia.

Figure 4 shows the results for beef production for the domestic market. In contrast to the effects expected by the government of Bolivia, we find that QRE caused a remarkable fall in the volume of production for the domestic market. In particular, the average effect of the QRE is 56 percent, with an implied p value of 2 percent. The figure provides two key insights to better understand the nature of the effect of QRE on production for the domestic market. First, the year after QRE, production for the domestic market declined from 245,000 tons to 185,000 tons. This is the direct effect of QRE on production for the local market. Second, after this shock, production for the national domestic market remained constant. This suggests that once producers adjusted their decisions, they did not need to reduce production further in the years after the policy. The effect is intensified, however, by the fact that synthetic Bolivia continued growing while Bolivia's domestic production remained constant.

Arguably, there are demographic reasons for not expecting a constant growth in production for the domestic market. For instance, production is constrained by the size of Bolivia's market. However, the initial gap between Bolivia and its synthetic counterpart cannot be explained by this demographic constraint because production for the domestic market has been below its historic values for the entire period. As production for domestic markets

FIGURE 3. Trends in Beef Production: Total Production

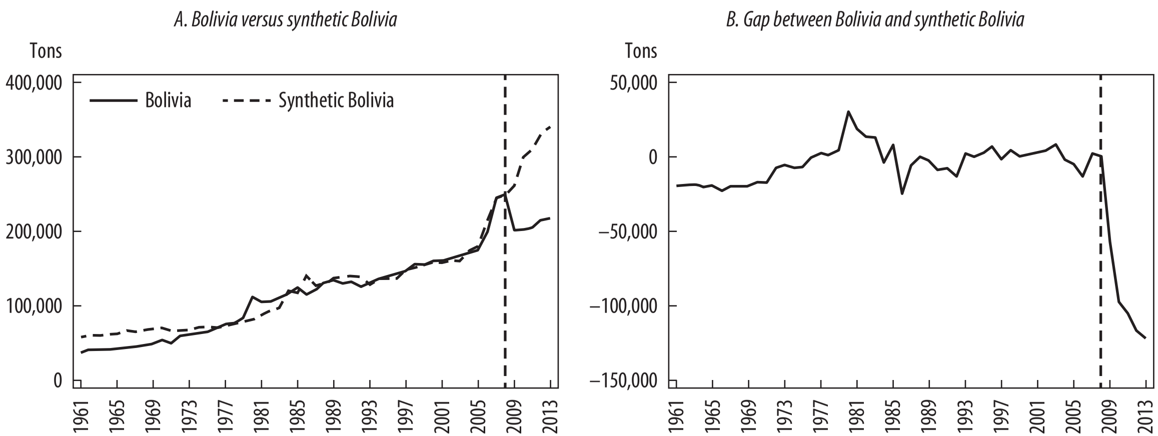
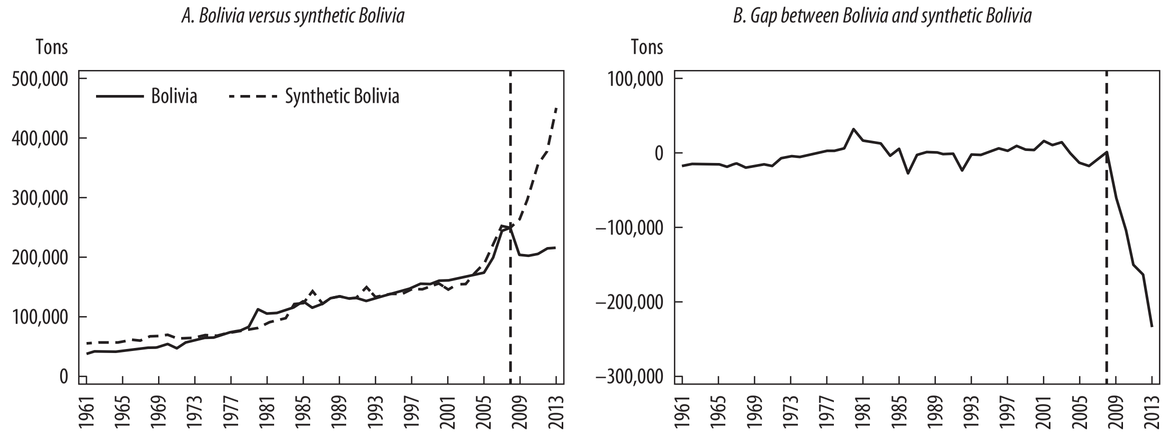


FIGURE 4. Trends in Beef Production: Production for the Domestic Market



increased in the donor countries, the differences between Bolivia and its synthetic counterpart became even larger after some years (see panel B). While Bolivia's production remained constant, other countries took advantage of the growing foreign market.

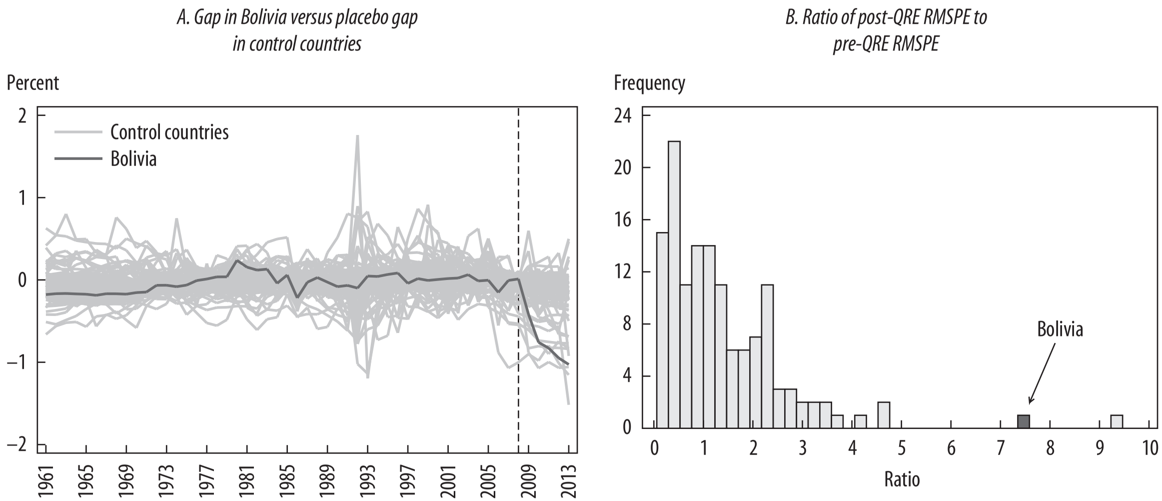
The fact that production for the domestic market declined after the implementation of QRE suggests that decisions about production for the local market depend on the possibility of exporting. In particular, one can conjecture that when producers determine their production for domestic markets, they consider whether there are QRE. If this were not the case and if production for domestic markets were exogenous to export restrictions, then we should observe a rise in production for the domestic market. In a dynamic scenario where total production is not fixed, QRE can cause a decline not only in total production but also in production for the domestic market.

Inference

To assess whether the impact is statistically significant, we construct a simulated distribution for each outcome by imposing the QRE on every country other than Bolivia. By doing this, we obtain synthetic control placebo estimates for countries that did not experience QRE. Hence, we are able to compare the estimated effect of QRE in Bolivia to the distribution of placebo effects obtained for the other countries.[16] If the effect of QRE on Bolivia's beef production is significant, we expect that the estimated effect for Bolivia will be large relative to the distribution of placebo effects. Results are presented in figures 5 and 6, which show the results for total production and production for the domestic market, respectively. As expected, when we reassign the treatment to the one hundred sixty-nine comparison countries, most of them do not experience a significant reduction in the volume of production or production for their domestic market after 2008, while we observe a sharp decline in Bolivia's outcomes. More specifically, the coefficient for Bolivia when we apply the difference-in-differences technique described above is in the highest 2 percent and 1 percent (in absolute terms) of the distribution of the impact on total production and production for the domestic market.

16. For exposition, we discard countries with a pretreatment root mean square prediction error (RMSPE) twenty times higher than Bolivia's. Results are robust to other cutoffs such as fifteen, ten, or five.

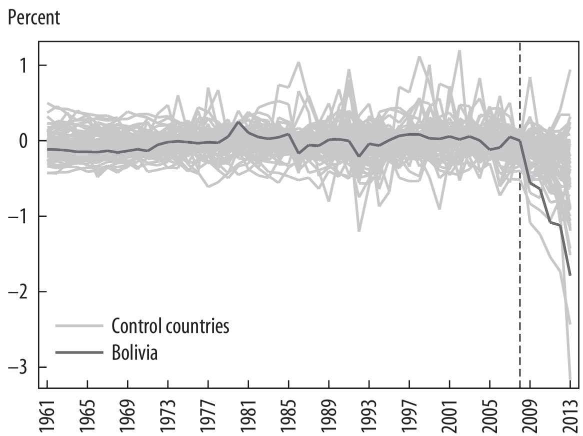
FIGURE 5. In-Space Placebo: Total Production[a]



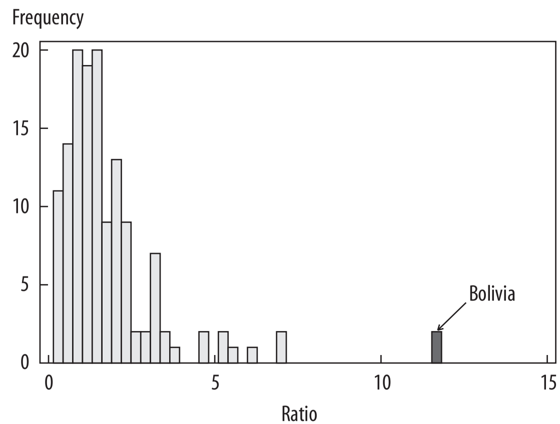
a. Discards countries with a pretreatment RMSPE twenty times higher than Bolivia's. The median of the distribution of ratios is 1.09. The ninetieth percentile is 2.71; the ninety-fifth percentile, 3.45; and the ninety-ninth percentile, 7.57.

FIGURE 6. In-Space Placebo: Production for the Domestic Market[a]

A. Gap in Bolivia versus placebo gap in control countries



B. Ratio of post-QRE RMSPE to pre-QRE RMSPE



a. Discards countries with a pretreatment RMSPE twenty times higher than Bolivia's. The median of the distribution of ratios is 1.34. The ninetieth percentile is 3.28; the ninety-fifth percentile, 5.39; and the ninety-ninth percentile, 11.75.

In both figures, the second panel reports the ratio between the post-QRE root mean square prediction error (RMSPE) and the pre-QRE RMSPE for Bolivia and for the comparison countries. RMSPE measures the magnitude of the gap in the outcome variable of interest between each country and its synthetic counterpart. Since a large postintervention RMSPE is not indicative of a large effect if the synthetic control does not closely reproduce the outcome of interest prior to the intervention, we divide the post-QRE RMSPE by its pre-QRE RMSPE. From the figure, it is clear that Bolivia's ratio is unusually high, for both total production and production for the domestic market. Bolivia's post-QRE RMSPE values for total production and production for the domestic market are around 7.6 and 11.6 times larger than the corresponding pre-QRE RMSPE. These ratios double the ratio for the ninety-fifth percentile of the distribution—3.44 and 5.39, respectively—and clearly lie beyond the ninety-ninth percentile of each distribution. Put differently, if one were to pick a country at random from the sample, the chances of obtaining a ratio as high as Bolivia's ratio would be 2/170 and 0/170, respectively.

A Placebo Test for an Anticipated Effect

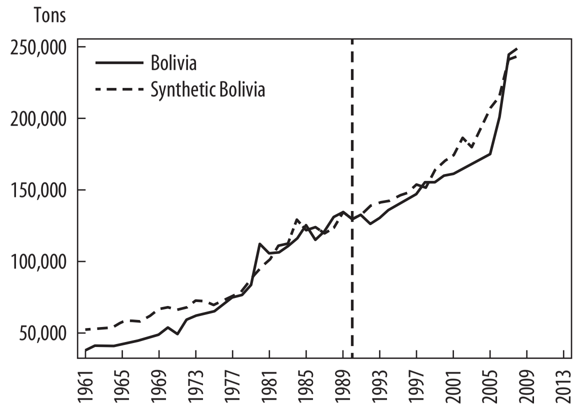
To assess the credibility of our results, we conducted a placebo test, comparing the QRE effect estimated for Bolivia to a placebo effect obtained after reassigning QRE to a period before they were actually implemented. A large placebo estimate would undermine the confidence in our results. To conduct this placebo study, we re-ran the main model with QRE assigned to 1990, about eighteen years earlier than the actual implementation.[17]

Figure 7 displays the results. Synthetic Bolivia reproduces quite well the evolution of total production and production for the domestic market for Bolivia between 1961 and 1990. Most importantly, the trajectories of Bolivia and its synthetic counterpart do not diverge considerably during the 1990–2008 period either. That is, our 1990 placebo QRE has no perceivable effect. This provides further evidence that our estimated effect is due to the QRE and not to a lack of predictive power of the synthetic control.

17. We have data for every predictor for every country between 1975 and 2013. Hence, following Abadie, Diamond, and Hainmueller, we chose 1990 because it is the middle of the pretreatment period for which we have enough information for every variable. We have computed similar in-time placebo studies where we reassign in our QRE data to 1995 and 2000, and the results are qualitatively unchanged.

FIGURE 7. In-Time Placebo: QRE in 1990

A. Total production



B. Production for the domestic market

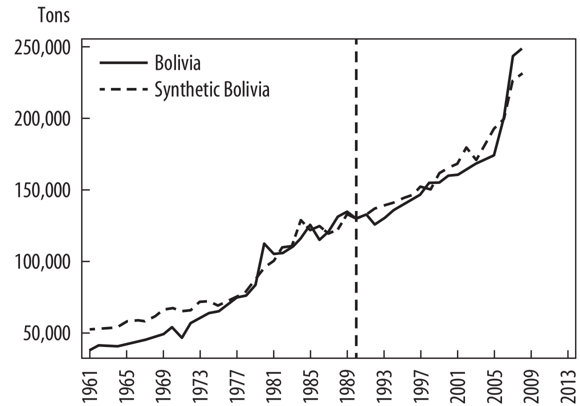
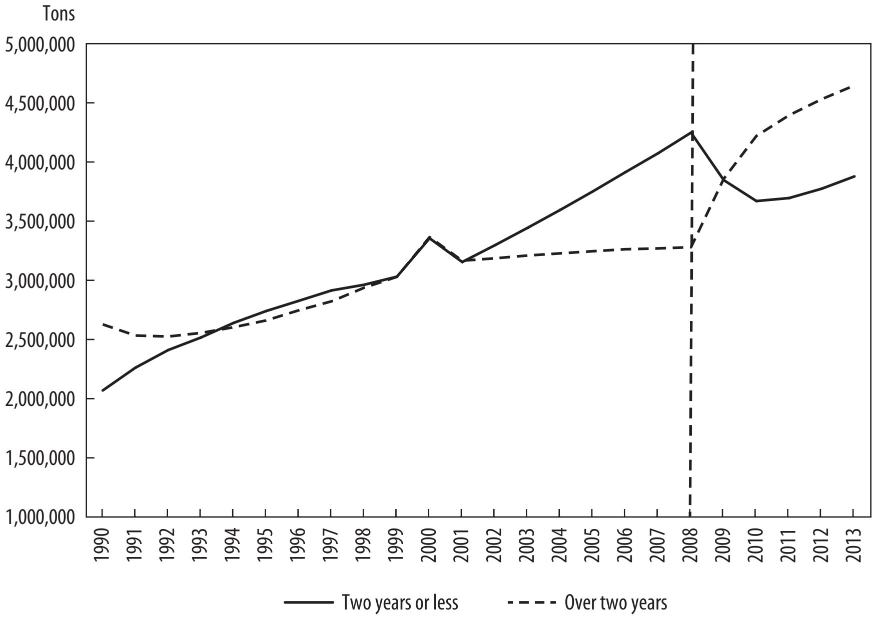


FIGURE 8. Age Composition of Beef Livestock



Can Other Factors Explain the Supply Shift?

The evidence presented in this paper is consistent with a supply shift that led to higher prices and lower production—both total and for the domestic market. A potential explanation for the supply shift is the uncertainty about the duration of the QRE and the amount producers would be allowed to export after the restrictions were relaxed.

The synthetic control method rests on the assumption that there is no other factor changing at the time the QRE are imposed. In the presence of other factors, it is not possible to claim causality. For instance, a weather-related factor that negatively affects livestock can also generate a supply shift. If that is the case, we should observe a reduction in beef livestock. This was not the case in Bolivia. The livestock continued growing at a steady rate. However, there was a significant change in the age composition of the livestock. Figure 8 shows this change in composition. After 2008 there is an increase in the number of cattle two years old or older and a reduction in the number of cattle less than two years old. This change in composition is consistent with the fact that uncertainty made producers contract beef production without replacing cattle. This change has a reversion in the trend after 2012, when QRE were relaxed.

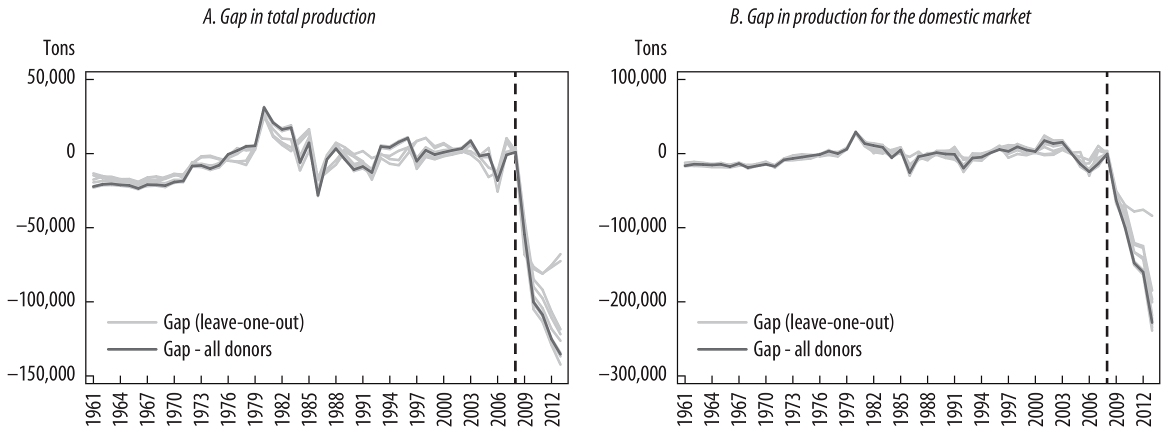
Robustness Analysis

Our first robustness check tests the sensitivity of our main results to changes in the country weights. To do so, we proceed with the leave-one-out test suggested by Abadie, Diamond, and Hainmueller.[18] Specifically, we iteratively estimate the baseline model to construct a synthetic Bolivia omitting one of the countries that received a positive weight in the results presented before. This sensitivity check allows us to evaluate the extent to which our results are driven by any particular control country. Figure 9 displays the gap between Bolivia and synthetic Bolivia for the main estimation, together with the leave-one-out estimates for this gap. Panel A shows the test for the volume of beef production, while panel B shows the test for the volume of beef production for the domestic market. Results indicate that the exclusion of any particular country from our sample of comparison countries does not affect the results. Even the smallest gap is fairly large in substantive terms.

In our second robustness test, we check the sensitivity of our results to the set of predictors used to construct the synthetic control. We find that our results remain robust to changes in the set of predictors such as adding more lags of the outcome variable, adding meat export share predictors, or excluding some of the predictors of the baseline specification. Specifically, we test the robustness of our results under six different specifications. Model C1 corresponds to the baseline estimation presented in the main section of the paper. Model C2 adds several lags of the dependent variable to the baseline estimation. Model C3 excludes food export share predictors from the baseline model C1 in order to avoid affecting the estimations with growth in other food exports. Model C4 adds to model C3 decade averages of the meat export share as predictors. In other words, in model C4 we run the baseline estimation with meat export share predictors instead of food export share predictors. Model C5 excludes trade openness predictors from model C4. Finally, model C6 excludes from model C5 meat export share predictors.

18. Abadie, Diamond, and Hainmueller (2015).

FIGURE 9. Leave-One-Out Test



The results are summarized in figure 10. Panel A presents the gap in total production between Bolivia and synthetic Bolivia for each model. Panel B presents the gap in production for the domestic market. Reassuringly, we find that both the pre-QRE differences and the effect of the policy are qualitatively similar across the different specifications.

Conclusions

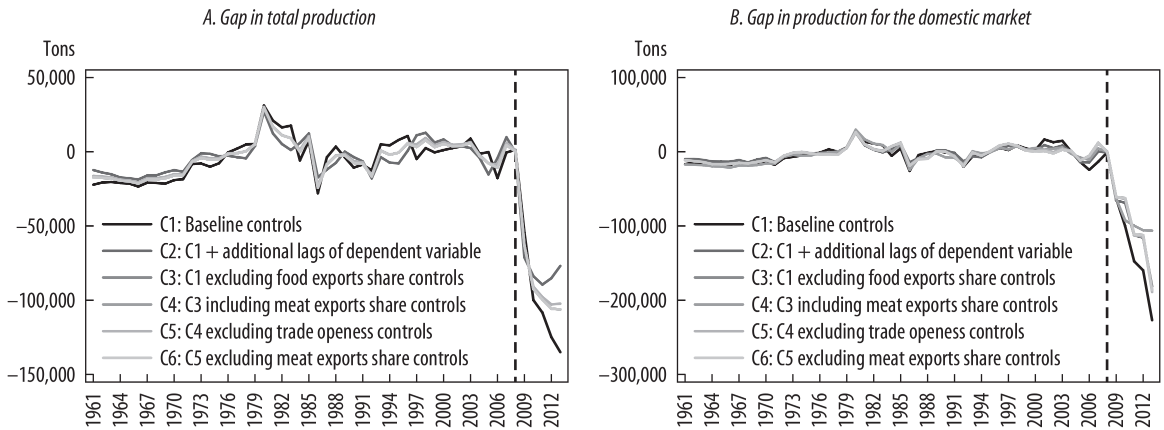
The price of many food commodities increased substantially over the past several years, and many developing countries reacted by imposing export controls aimed at reducing the transmission of international price fluctuations to domestic markets, protecting consumers. However, little research has been done to empirically confirm these relationships. In this paper, we exploit QRE imposed by Bolivia's government to empirically assess the impact of export controls on total production and production for the domestic market.

We report that the total volume of production fell after the implementation of QRE. We also find that QRE failed to achieve their intended objective in terms of production for the domestic market. Indeed, we find that QRE reduced not only total production but also production for the domestic market. This fact, together with the increase in the domestic price of beef, is consistent with a supply shift. The age composition of beef cattle confirms the hypothesis of the supply shift and discards the possibility of a contraction in supply due to other factors. In fact, we find an increase in livestock and a significant change in the age composition of cattle: there was an increase in livestock aged two years or older (that is, reduction in beef production) and a reduction in livestock less than two years old (that is, there was no replacement).

Our results yield lessons that are relevant for policymakers who are still considering export controls as a way to increase production for domestic markets. QRE were the preferred instrument of most of the countries that restricted exports in the last decade, and the idea that QRE can help to increase domestic market supply is still prevalent among policymakers. As an important example, WTO regulations dealing with QRE offer ample policy space and explicitly allow members to impose "temporary" QRE to "prevent or relieve critical shortages of foodstuffs."[19] Our paper raises a note of caution. In a context where producers may overreact to QRE, a policy of this type may not achieve the objective and may end up being detrimental for both producers and consumers.

19. General Agreement on Tariffs and Trade, Article XI: General Elimination of Quantitative Restrictions; Paragraph 1 (p. 314).

FIGURE 10. Robustness Check: Set of Relevant Predictors



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