The impact of export restrictions on production: A synthetic controls approach*

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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 domestic markets, and reducing domestic prices. This paper aims at filling this gap by estimating the impact of quantitative restrictions on cattle beef exports in Bolivia, applying a synthetic controls 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 domestic markets bears important implications for the design of policies in the future.

JEL Classification Codes: D22, F14, O13, O24.

Keywords: production, export controls, export restrictions, trade policy, synthetic controls.

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1 Introduction

After the considerable increase in commodity prices that occurred in the second half of the 2000s many countries around the world imposed restrictions to exports, specially on agricultural products. The main objective was preventing foodstuffs shortages. These restrictions took two forms: quantitative restrictions to exports (QRE), such us bans or quotas, and export taxes.[1] Although under general assumptions a quantitative restriction has an equivalent export tax that guarantees the same results, policy makers were clearly biased to adopt quantitative restrictions. A review of policies adopted by 29 countries that restricted exports between 2006 and 2011 shows that 25 used QRE as their main instrument (see Table A1 in the Appendix). In spite of the generalized use of quantitative restrictions on exports (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 addressed the question on the effectiveness of QRE found mixed results. On the one hand, Fellmann, Hélaine, and Nekhay (2014) show that a temporary restriction to export in Russia, Ukraine, and Kazakhstan, imposed after a harvest failure, reduced domestic prices in Ukraine and Kazakhstan. Similarly, Diao and Kennedy (2016) find that an export ban of maize in Tanzania reduced its domestic price. On the other hand, Götz, Glauben, and Brümmer (2013), Djuric and Götz (2016), and Götz, Qiu, Gervais, and Glauben (2016) report that wheat export controls in Russia, Serbia, and Ukraine did not reduced the domestic price.

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

Our empirical strategy uses the synthetic control approach developed by Abadie and

[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 reviewed the restrictions applied after 2007.

Gardeazabal (2003) and extended in Abadie, Diamond, and Hainmueller (2010) in order to identify the effect that QRE on cattle beef in Bolivia has on total production and production for domestic markets. We use data from the Food and Agricultural Organization of the United Nations, which has the most reliable, complete, and public available dataset on food production and exports. We complement this information with country-level data from the World Economic Outlook Database. Our final dataset is an annual country-level panel data covering the period 1961-2013. One of the main advantages of this dataset is that it provides us with more that 45 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 counter-factual scenario. Provided producers were 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. Interestingly, we report that producers overreacted to the policy yielding to a remarkably decline in production for domestic market after QRE were implemented. This finding, together with the increase in domestic price, is consistent with a shift in the supply curve. In fact, we find strong evidence that producers reduce their supply for the domestic market. After the restrictions were applied, the livestock of cattle beef continue growing in a steady rate but there was a significant change in the age composition of cattle beef, thus providing evidence on a lower production of meat and a lower replacement of cattle beef.

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 domestic market is still prevalent among policy makers. For instance, the WTO regulation explicitly allows its members to implement temporary QRE when there are foodstuffs shortages.[2] Our findings raises a note of caution on this policy prescription, by providing empirical evidence that QRE can cause a remarkable reduction in production

[2] GATT 1994. Article XI*: General Elimination of Quantitative Restrictions: 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.

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 existent literature by using a methodology that let us construct a plausible counter-factual scenario in order to identify the causal effect of QRE on production. In particular, under the assumption that in 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 much assumptions and structure to the model.

Our paper follows a growing literature that uses a synthetic controls approach in the domain of economic development. For instance, Cavallo, Galiani, Noy, and Pantano (2013) examine the short and long-run average causal impact of catastrophic natural disasters on economic growth. Billmeier and Nannicini (2013) study the impact of trade liberalization on GDP growth. Pieters, Curzi, Olper, and Swinnen (2016) study the effect of democratic reforms on child mortality. Finally, our paper also contributes to the literature that studied the relationship between exports and domestic production. This literature focused on the relationship between exports and production through productivity considering three main channels: reallocation of resources (Melitz 2003, Bernard, Eaton, Jensen, and Kortum 2003, Melitz and Redding 2014, Pavcnik 2002), learning-by-exporting (see, De Loecker 2013), and investment in new technologies (Bustos 2011). By focusing on the effect of trade liberalization or trade facilitation these papers show that trade improves productivity, and therefore increase production. Our paper is analogous in the sense that we show that a restriction to export causes a reduction in production—and even more important, in the domestic availability of the product. However, the mechanism that causes the contraction in production in our case it is not related to productivity but to the incentives the restriction creates on producers.

The remainder of the paper is organized as follows. In section 2, we describe the implementation of QRE in Bolivia. In section 3, we describe the identification strategy. In section 4, we present our main results, discard alternative explanations for the findings, and a present robustness analysis. Finally, section 5 concludes.

2 Implementation of QRE in Bolivia

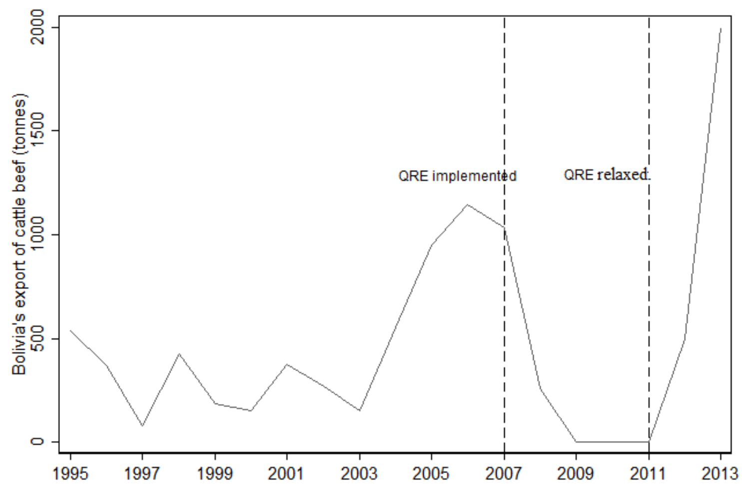
With the objective of guaranteeing food security and achieving food sovereignty the Bolivian government imposed controls on the exports of cattle beef in 2008.[3] The controls took the form of quantitative restrictions on exports (QRE) and were implemented through a series of administrative decrees. More specifically, a prohibition to export cattle beef 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.[4] In addition, this QRE lasted for a long period of time. The fact that the restrictions on other products lasted a short period of time introduced uncertainty to the beef producers about the duration of the restrictions. In March 2012, the government relaxed the restriction allowing producers to export beef after the domestic market was cleared. In August 2013, the beef export quota was increased. The lack of a formal definition of market clearing condition introduced additional uncertainty in the producers about the quantity they would be allowed to export.

The government of Bolivia took very seriously the compliance to the policy. The National Customs Authority in Bolivia was responsible for coordinating the National Armed Forces and National Police to enforce the restrictions in the Bolivian borders and domestic roads. Should a producer be caught trying to export, all the goods and vehicles are confiscated and the producer is charged with a criminal offense. Figure 1 shows a sharp decline in beef

[3] Food sovereignty is defined as the right of peoples and sovereign states to democratically determine their own agricultural and food policies (IAASTD 2008).

[4] The government also imposed restrictions on exports for 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. For those reasons, we focus our study solely on the restrictions to export cattle beef.

Figure 1. Trends in exports of beef (cattle) (tonnes)



exports after QRE were imposed in February 2008. Exports remained low, around zero tonnes, and there was again a sharp increase when the restrictions were relaxed in early 2012.

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

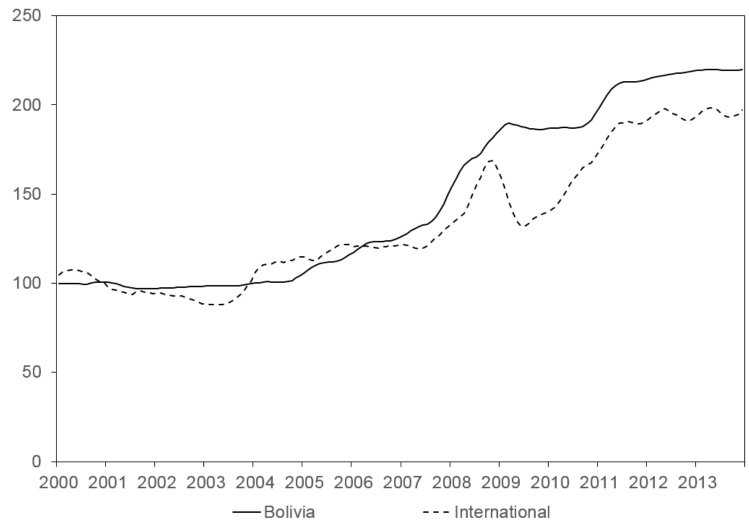
3 Identification strategy

3.1 Synthetic controls estimates

We use the synthetic controls approach developed by Abadie and Gardeazabal (2003) and Abadie, Diamond, and Hainmueller (2010) in order to study a) the impact of QRE on total production and; b) the impact of QRE on production for the domestic markets.[5] Ideally, we want to consider the difference between our outcome variable (Q =volume of produc-

[5] Given that 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 price.

Figure 2. Cattle beef price index



Note: Price index, monthly average 2000-2004 = 100, six month moving average. Source: Bolivia, own elaboration based on National Institute of Statistics' price data. International, Price index of bovine meat, FAO.

tion, and S = volume of production for the domestic market) after the QRE intervention and where that variable would have been in the absence of that intervention (counterfactual outcome). In order to estimate the counterfactual scenario we use a synthetic controls approach. Synthetic controls provides a suitable approach for evaluating policies implemented in only one country and at the national level. In those cases it is not possible to use difference-in-differences, and therefore researchers used to rely in a before and after strategy that identifies in the time series variation and usually requires very strong assumptions to be credible. Synthetic controls resembles the difference-in-differences approach in a setting where there is only one treated unit and under a mild set of assumptions. In our setting, under the plausible assumption that there are not other shocks affecting production that are collinear to the QRE, synthetic controls approach allow 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 determinations 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 in order to minimize the difference in pre-intervention 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 allows to meet the assumption of parallel trends conditional on observable characteristics prior to the implementation of QRE. Therefore, under the assumption that in absence of QRE Bolivia and its synthetic counterpart would continue to follow a similar trend, 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 $i = (1, ..J)$ denote the J countries that export (or produce in the case of the analysis on 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 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 before, Y_{1t}^{N} is unobservable by definition, so we use the synthetic control method in order to consistently estimate it. In particular, given a set of non-negative weights $W = [w_2, ..., w_J]$, the synthetic control estimator of the potential outcome is defined as a weighted average of the outcomes of the countries in the donor pool:

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

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

Finally, the question on 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: $Z_{1it}, ...Z_{kit}$ $\forall i = 1, ..., J$. Among this predictors, we may include characteristics such as GDP per capita, harvested area, and population. More importantly, we may also include pre-intervention 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 $Z_{1i}, ..., Z_{ki}$. Following Abadie and Gardeazabal (2003) and Abadie, Diamond, and Hainmueller (2010), we proceed to choose the weights $w^* = \{w_2^*, ..., w_J^*\}$ by minimizing the square difference between the pre-treatment values of the predictors k of the affected unit and the donor pool. That is, for $t \leq t^{'}$,

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

Once w^* is computed, the pre-intervention trend and the post-intervention trend 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 post-intervention 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 pre-treatment levels of the affected unit and the synthetic control group, there might still be differences in pre-treatment levels. In consequence, to account for this potential problem, we also subtract pre-treatment differences from post-treatment 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 between the different treatments. Thus, we normalize the difference-in-difference estimates using the pre-treatment average of the synthetic control. For this reason, in the post-intervention period $t = t^{'}, ..., T$, the normalized difference between treated and synthetic control outcomes is given by

$$\hat{\beta} = \frac{\frac{1}{T-(t'+1)} \sum\limits_{(t'+1)}^{T} \left(Y_{1t} - \sum\limits_{i=2}^{J} w_i^* Y_{it} \right) - \frac{1}{t'} \sum\limits_{t=1}^{t'} \left(Y_{1t} - \sum\limits_{i=2}^{J} w_i^* Y_{it} \right)}{\frac{1}{t'} \sum\limits_{t=1}^{t'} \left(Y_{1t} - \sum\limits_{i=2}^{J} w_i^* Y_{it} \right)}, \tag{5}$$

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 pre-intervention period. Note that the second term of the equation approximates zero when the synthetic control group adjusts better to the pre-treatment values of the treated unit.[6]

3.2 Inference

To evaluate the significance of our estimates we conduct a series of in space and in time placebo studies. The idea behind this inference studies is that our confidence that a particular synthetic control estimate reflects the impact of the intervention would be undermined if we

[6] For further reference 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.

obtained estimated effects of similar or even greater magnitudes in cases (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 to create a distribution of placebo effects against 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 with those from the placebos, we can derive the likelihood that estimate would have been observed if there had been no QRE. In particular, we rank the ratios between Post and Pre-treatment RMSPE for every placebo and the implied p-value is constructed by computing the proportion of ratios that that are higher than the estimated gap for Bolivia.[7] 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 dates when the intervention did not occur. Again, results would be severely undermined if we obtain effects of similar magnitude for dates when the intervention did not take place.

3.3 Data

The main source used for agricultural data is the Food and Agricultural Organization of the United Nations, which has the most reliable and complete dataset for food production and exports. We use data for the volume of production, exports, and imports covering the period 1961-2013. We merged this dataset to the World Economic Outlook database generated by The World Bank. From this dataset we obtained information on GDP per capita (US$), agriculture share of the GDP, food exports as % of merchandise exports, total trade as %

[7] 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 pre-treatment RMSPE twenty times higher than Bolivia. Results are robust if we discard differences five, ten or fifteen times higher.

of GDP, among other variables. We only kept countries that were beef producers and from which we have information on their GDP per capita at least for the period 1980-2013. The final database is an annual country-level panel data for the period 1961-2013. Our donor pool includes a sample of 170.

4 Empirical results

We use the synthetic controls method in order to estimate the effect of the QRE on the total production of beef and the 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 (1981-1990, 1991-2000, 2001-2008) of GDP per capita (in US dollars), agricultural share of GDP, food exports as % of total merchandise exports, and trade as % of GDP. We also control for GDP per capita in 2008 and agricultural share of GDP in 2008 to improve the fit in the last year before the intervention. To control for differences in recent growth rate, we include GDP per capita growth rate between 2003 and 2008. Most importantly, in order to improve the fit of synthetic Bolivia to the pre-treatment trend of Bolivia, we include in each estimation the pre-treatment 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 predict the post-treatment potential outcome. Hence, instead of including all outcome lags, we only include 4 decennial averages of the outcome variable (1971-1980, 1981-1990, 1991-2000, and 2001-2008) and the value of the outcome variable in 2008.[8]

[8] Results in the paper are robust to including the 48 lags of the outcome variable as predictors. All results mentioned and not reported are available upon request.

4.1 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, the synthetic Bolivia is a weighted average of Vietnam (22.4%), Pakistan (21.6%), Gambia (16.5%), Turkey (12.4%), Liberia (11.0%), Ethiopia (5.3%), Djibouti (4.3%), Burundi (3.6%), Zambia (1.3%), and Madagascar (0.9%). All other countries in the donor pool obtain zero weights. The first two columns of Table 1 compares the pre-treatment characteristics of Bolivia to those of the synthetic Bolivia. Overall, the results suggest that the synthetic Bolivia is very similar to the actual Bolivia in terms of pre-treatment per capita GDP averages, agriculture value added, food exports, trade openness, and GDP growth between 2003 and 2008. It is also clear that synthetic Bolivia has an excellent performance in matching Bolivia's pre-treatment trend in the volume of beef production.

In the case of the production for the domestic market, the synthetic Bolivia is a weighted average of Vietnam (26.2%), Gambia (13.8%), Egypt (13.5%), Turkey (9.0%), Ethiopia (8.6%), Liberia (6.9%), Guatemala (5.9%), Pakistan (4.2%), Iraq (3.8%), Syrian Arab Republic (3.4%), Papua New Guinea (2.9%), and Burundi (1.8%). All other countries in the donor pool obtain zero weights. The last two columns of Table 1 compares the pre-treatment characteristics of Bolivia to those of the synthetic Bolivia. Overall, the results suggest that the synthetic Bolivia adjusts well to decennial averages of GDP per capita, agriculture share, food exports as % of merchandise exports, and trade openness. It is also clear that Bolivia's GDP growth between 2003 and 2008 is fairly similar to the GDP growth of its synthetic counterpart. Finally, from the inspection of the production for domestic markets, we can observe that synthetic Bolivia has an excellent performance in matching Bolivia's pre-treatment decennial averages in volume of production for domestic markets.

Table 1. Balance: Predictors pre-treatment mean, total production

	Outcome variable: Total production		Outcome variable: Production for domestic market	
	Bolivia	Synthetic Bolivia	Bolivia	Synthetic Bolivia
Avg. outcome variable between 1971 and 1980 (tonnes)	71,618	73,014	70,929	70,543
Avg. outcome variable between 1981 and 1990 (tonnes)	119,535	118,320	119,606	118,356
Avg. outcome variable between 1991 and 2000 (tonnes)	142,473	141,930	142,575	142,660
Avg. outcome variable between 2001 and 2008 (tonnes)	191,721	192,644	191,186	191,332
Value outcome variable in 2008 (tonnes)	248,680	247,028	248,603	248,228
Avg. GDP per capita between 1981 and 1990 (dollars)	818	535	818	673
Avg. GDP per capita between 1991 and 2000 (dollars)	908	780	908	796
Avg. GDP per capita between 2001 and 2008 (dollars)	1,146	1,297	1,146	1,343
GDP per capita in 2008 (dollars)	1,737	1,870	1,737	2,094
GDP per capita growth between 2003 and 2008 (%)	89.4	82.1	89.4	83.9
Avg. agriculture share between 1981 and 1990 (% of GDP)	18.9	17.6	18.9	18.2
Avg. agriculture share between 1991 and 2000 (% of GDP)	16.2	16.8	16.2	16.7
Avg. agriculture share between 2001 and 2008 (% of GDP)	14.3	14.5	14.3	14.2
Agriculture share in 2008 (% of GDP)	13.1	14.4	13.1	13.9
Avg. trade openness between 1981 and 1990 (% of GDP)	47.3	45.8	47.3	45.8
Avg. trade openness between 1991 and 2000 (% of GDP)	48.5	50.8	48.5	54.1
Avg. trade openness between 2001 and 2008 (% of GDP)	63.1	68.8	63.1	73.1
Avg. food exports between 1981 and 1990 (% of merch. exports)	7.7	9.5	7.7	9.6
Avg. food exports between 1991 and 2000 (% of merch. exports)	23.9	14.9	23.9	18.3
Avg. food exports between 2001 and 2008 (% of merch. exports)	23.3	23.5	23.3	25.8

4.2 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 panel A of Figure 3, where we plot pre-treatment and post-treatment 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%, with an implied p-value of 3%. The highest effect, in absolute terms, is observed after some years. As observed in Panel (b), the gap in production of cattle beef between Bolivia and synthetic Bolivia is around $65,000$ tonnes in 2009, and increases to $110,000$ tonnes the years after that. However, if we analyze Panel (a), we see that there is an initial decline of $50,000$ tonnes in Bolivia's production (from $250,000$ to $200,000$) and then Bolivia's production remains constant while the gap is augmented because of the growth of synthetic Bolivia.

Panel B in Figure 3 shows the results for the production of cattle beef for the domestic market. In contrast to the effects expected by the government of Bolivia, we find that QRE causes a remarkable fall in the volume of production for domestic market. In particular, the average effect of the QRE is 56% with an implied p-value of 2%. Furthermore, the inspection of Panel (c) and Panel (d) of Figure 3 provides insights to better understand the nature of the effect of QRE on production for domestic markets. First, notice in Panel (b) that the year after QRE, production for domestic markets declines from $245,000$ tonnes to $185,000$ tonnes. This is the direct effect of QRE on production for domestic markets. Second, notice that after this shock, production for domestic market remains constant throughout the following years. This fact suggests that once producers adjust their decisions accordingly, they need not to reduce production for domestic markets further in the years after the policy. Then, the effect is intensified by the fact that synthetic Bolivia continue growing while Bolivia's domestic production remains at a constant level.

Arguably, there are demographic reasons for not expecting a constant growth in production for domestic markets. For instance, production for domestic markets 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. On this ground, in Panel (b) we can observe that as production for domestic markets increased in the donor countries, the differences between Bolivia and its synthetic counterpart became even larger after some years. While Bolivia's production remained constant, other countries took advantage of the growing foreign market.

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

4.3 Inference

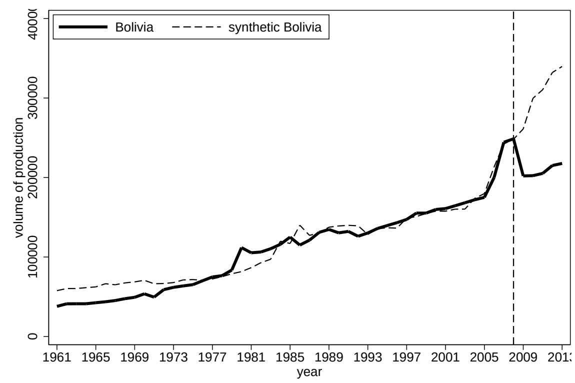
To assess if the impact is statistically significant we construct a simulated distribution of for each outcome by imposing the QRE to every country different from Bolivia. By doing this, we obtain synthetic control placebo estimates for countries that did not experience QRE. Hence, we are able to compare the estimated effect of QRE in Bolivia to the distribution of placebo effects obtained for the other countries.[9] If the effect of QRE on Bolivia's beef production is significant, we expect that the estimated effect for Bolivia to be large relative to the distribution of placebo effects. Results are presented in Figure 4. Panels A and B show the results for the total production and the production for domestic market, respectively. In

[9] For exposition, we discard countries with pre-treatment root mean square prediction error (RMSPE) 20 times higher than Bolivia. Results are robust to other cutoffs such as 15, 10 or 5.

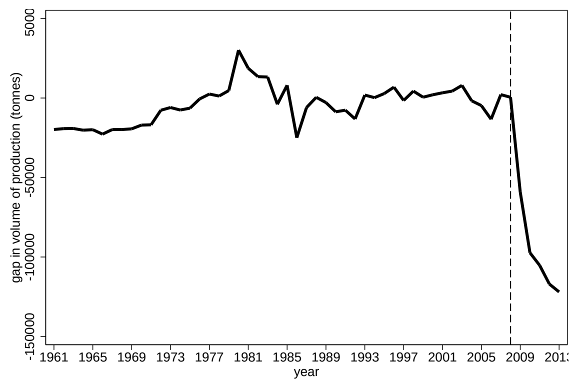
Figure 3. Trends in production of cattle beef (tonnes)

A. Total production

(a) Bolivia vs. synthetic Bolivia

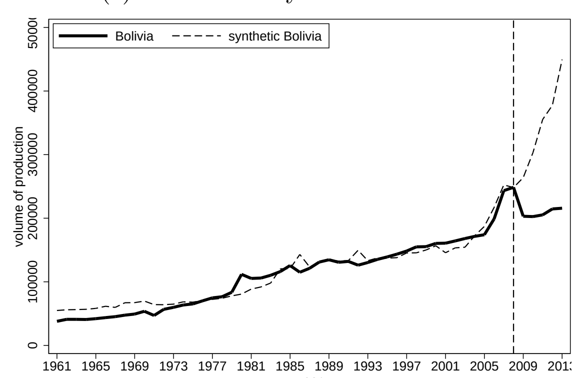


(b) Gap between Bolivia and synthetic Bolivia

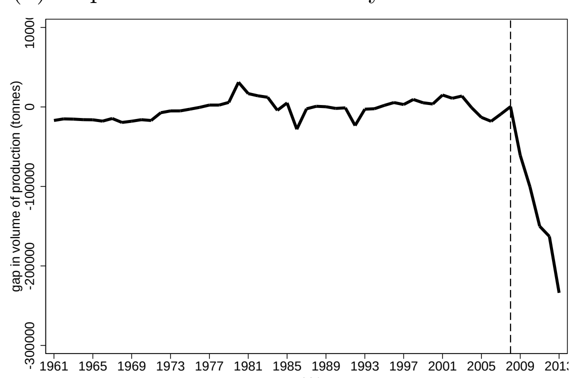


B. Production for domestic market

(c) Bolivia vs. synthetic Bolivia



(d) Gap between Bolivia and synthetic Bolivia



panels (a) and (c) we show the % gap when we assign the treatment to Bolivia and the % gap for the other 169 comparison countries. As expected, when we reassign the treatment to the 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% and 1% (in absolute terms) of the distribution of the impact on total production and production for the domestic market. Similarly, panels (b) and (d) of Figure 4 reports the ratio between the post-QRE root mean square prediction error (RMSPE) and the pre-QRE RMSPE for Bolivia and for the other 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 post intervention 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 inspection of the figure it is clear that Bolivia's ratio is unusually high, both for the total production and the production for the domestic market. Bolivia post-QRE RMSPE 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 $95th$ percentile of the distribution—3.44 and 5.39, respectively—and clearly lie beyond the $99th$ percentile of each distribution. Put it 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.

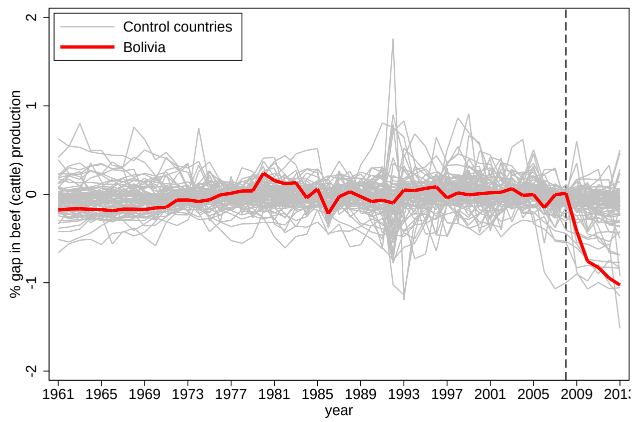
4.4 A placebo test for an anticipated effect

To assess the credibility of our results we conduct a placebo test. We compare 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

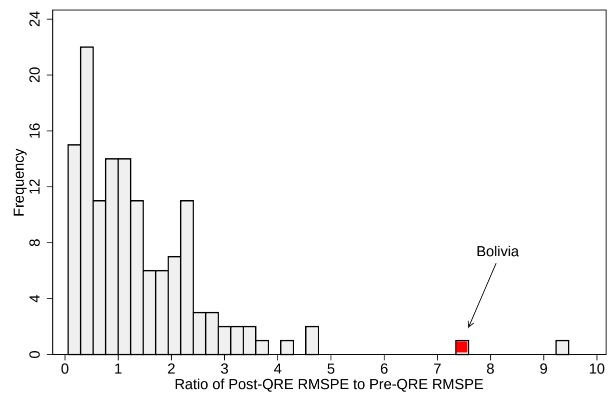
Figure 4. Inference: In space placebo

A. Total production

(a) % gap in Bolivia vs. placebo % gap in control countries

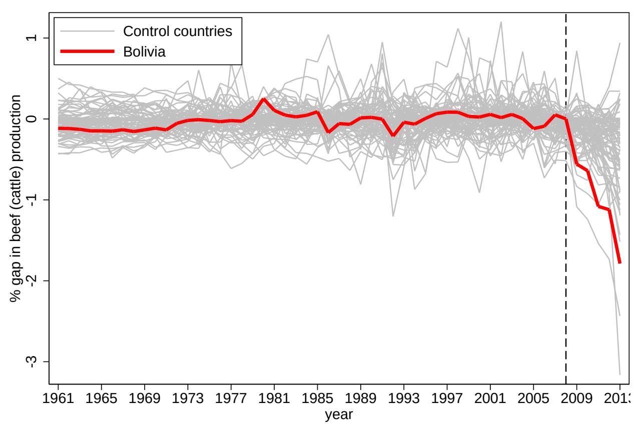


(b) Ratio of post-QRE RMSPE to Pre-QRE RMSPE

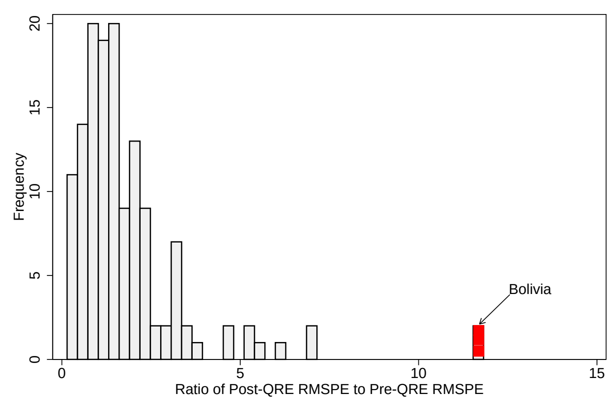


B. Production for domestic market

(c) % gap in Bolivia vs. placebo % gap in control countries



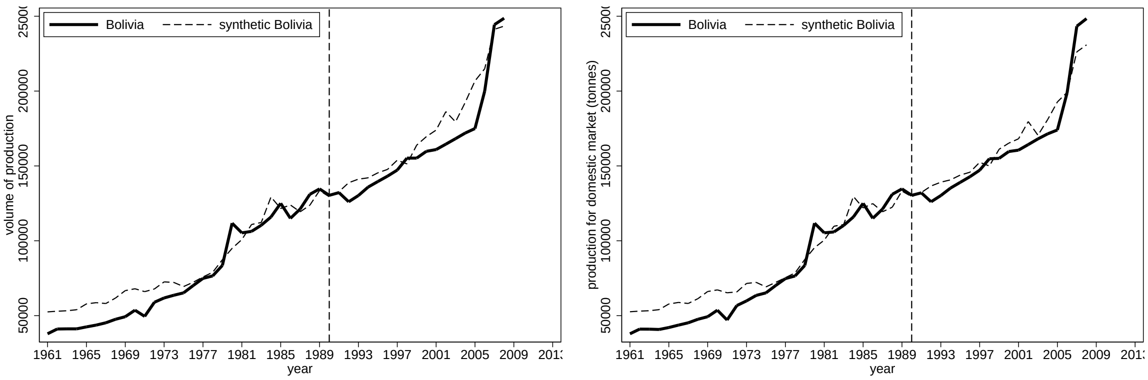
(d) Ratio of post-QRE RMSPE to Pre-QRE RMSPE



Note: Discards countries with pre-treatment RMSPE twenty times higher than Bolivia's. Median of distribution: 1.34. 3.28, 5.39, 11.75 are the $90th$, $95th$ and $99th$ percentile of the distribution of ratios, respectively.

Figure 5. In time placebo: QRE at 1990

(a) Total Production (b) Production for domestic market



in our results. To conduct this placebo study we re-run the main model for the case when QRE is assigned to 1990, about 18 years earlier than QRE actually took place.[10]

Figure 5 displays the results. The 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.

4.5 Can other factors explain the supply shift?

The evidence presented in this paper is consistent with a supply shift that lead to higher prices and lower production—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 producer would be allowed to export after the restrictions were relaxed.

The synthetic controls method rests on the assumption that there is no other factor changing at the time the QRE were imposed. In the presence of other factors it is not

[10] We have data of every predictor for every country between 1975 and 2013. Hence, following Abadie, Diamond, and Hainmueller (2015), we choose 1990 because it is the middle of the pre-treatment period for which we have enough information for every variable. We have computed similar in-time placebo studies where we reassign in our data QRE to the years 1995 and 2000, and the results are qualitatively unchanged.

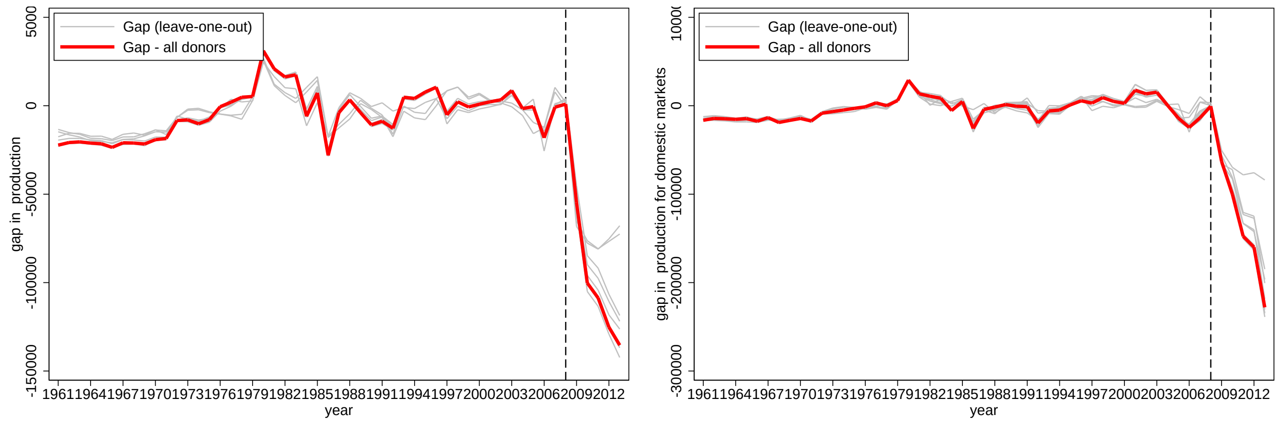
Figure 6. Age composition of the livestock of cattle beef

possible to claim causality. For instance, a weather related factor that affects negatively the livestock of cattle beef can also generate a supply shift. However, if that is the case, we should observe a reduction in the livestock of cattle beef. This was not the case in Bolivia. The livestock cattle beef continue growing at a steady rate. However, there was a significant change in the age composition of the livestock of cattle beef. In Figure 6 we show this change in composition. After 2008 there is an increase in the number of cattle beef two-year old or older, and a reduction in the number of cattle beef with less than two years old. This change in composition is consistent with the fact that uncertainty made producers contract the beef production without replacing cattle beef. It is also interesting to note that this change has a reversion in the trend after 2012 when QRE were relaxed.

Figure 7. Leave-one-out test

(a) Gap in total production

(b) Gap in production for domestic market



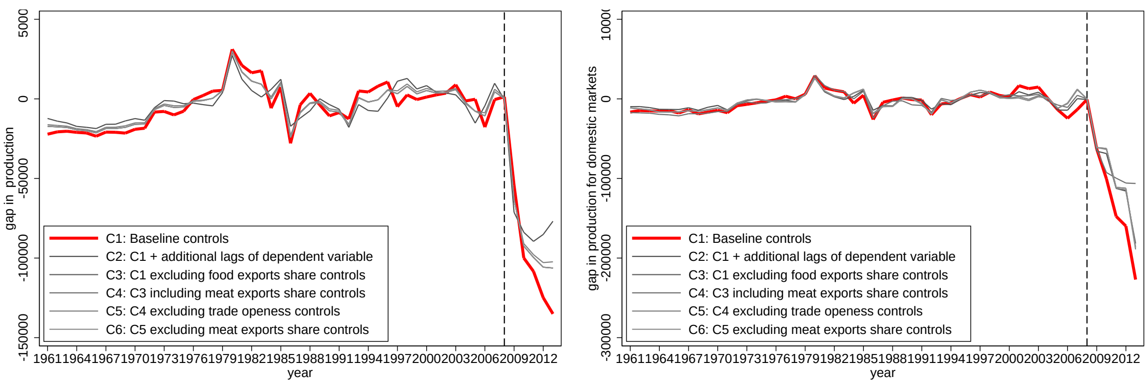
5 Robustness analysis

5.1 Leave-one-out test

In this section, we run a robustness check to test how sensitive are 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 (2015). Specifically, we iteratively estimate the baseline model to construct a synthetic Bolivia omitting one of the countries that received positive weight in the results presented before. This sensitivity check allows us to evaluate to what extent our results are driven by any particular control country. Figure 7 displays the gap between Bolivia and synthetic Bolivia for the main estimation (red thick width), while also incorporating the leave-one-out estimates for this gap (gray lines). Panel (a) shows the test for the volume of beef production, while panel (b) shows the test for the volume of beef production for domestic markets. 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.

Figure 8. Robustness check: set of relevant predictors

(a) Gap in total production (b) Gap in production for domestic market



5.2 Changes in the set of predictors

In this section, we check the sensitivity of our results to the set of predictors that we use 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, meat export shares predictors and/or excluding some of the predictors of the baseline specification. Specifically, we test the robustness of our results under 6 different specifications. First, model C1, corresponds to the baseline estimation as 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 exports 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 decades averages of meat exports share as predictors. Put it differently, in model C4 we run baseline estimation with meat exports share predictors instead of food exports share predictors. Model C5 excludes trade openness predictors from model C4. Finally, model C6 excludes from model C5 meat exports share predictors.

Results are summarized in figure 8. Panel (a) presents the gap in total production between Bolivia and synthetic Bolivia for each model. Panel (b) presents the gap in production for domestic market. Reassuring, we find that both the pre-QRE differences and the effect of the policy is qualitatively similar across the different specifications.

6 Conclusions

The price of many food commodities have increased substantially over the past years and many developing countries reacted by imposing export controls that aimed at reducing the transmission of international price fluctuations into 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 in order 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 falls after the implementation of QRE. We also find that QRE fail to achieve its intended objective when it comes to production for domestic market. Indeed, we find that QRE not only reduce total production, but also reduce production for domestic markets. This fact, joint with the increase in the domestic price of beef, is consistent with a supply shift. The age composition of the livestock cattle beef confirms the hypothesis of the supply shift and discards the possibility of a contraction in supply due to other factors. In fact, we find that the livestock of cattle beef grew and there was a significant change in the age composition of the livestock of cattle beef; while the livestock of cattle beef two years old or older increased—reduction in the production of beef—there was a reduction in the livestock of cattle beef less than two years old—there was no replacement.

Our results yield lessons that are relevant for policy makers that are still considering export controls as a way to increase production for domestic markets. QRE was the instrument preferred by most of the countries to restrict exports during the last decade and the idea that QRE can help to increase domestic market supply is still prevalent among policy makers. As an important example, WTO regulation dealing with QRE offers ample policy space and it explicitly allows its members to impose "temporary" QRE to "prevent or relieve critical shortages of foodstuffs." On this ground, our paper rises a note of caution. It highlights that 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.

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Table A1. Main export restriction instruments used by countries between 2006 and 2011.

Main Instrument	Country
QRE	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, Zambia
Export tax	Argentina, China, Pakistan, Russia

Source: Own elaboration based on Sharma (2011) and Liefert, Westcott, and Wainio (2012).