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Economic impact of Covid's first wave in Mexico and Bolivia: A counterfactual perspective

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Abstract
The Mexican and Bolivian monthly index of global economic activity along with ARMA models are used to graph and measure the impact of the Covid pandemic shock on both economies, individually. The accumulated difference between the observed and counterfactual values show an overall -10.48% and -12.64% loss of economic activity respectively in the 10 months from February to November 2020 of the first Covid wave, with a short-run recovery reaching 93% and 97% of their counterfactual level by November given their built-in economic forces but restrained by the pandemic.
Keywords: Covid-19; Interrupted Time Series Analysis.
JEL Classification: C22, E32, E37, O54

Impacto económico de la primera oleada de Covid en México y Bolivia: una perspectiva contrafactual

Resumen
Se utiliza el índice mensual de actividad económica global de México y Bolivia junto con modelos ARMA para graficar y medir el impacto del choque pandémico Covid en ambas economías, individualmente. La diferencia acumulada entre los valores observados y contrafactuales muestra una pérdida global de actividad económica de -10,48% y -12,64%, respectivamente, en los 10 meses comprendidos entre febrero y noviembre de 2020 de la primera oleada de Covid, con una recuperación a corto plazo que alcanza el 93% y el 97% de su nivel contrafactual en noviembre, dadas sus fuerzas económicas intrínsecas pero frenadas por la pandemia.
Palabras clave: Covid-19; Análisis de series temporales interrumpidas.
Clasificación JEL: C22, E32, E37, O54

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Introduction

The World Health Organization declared the novel coronavirus outbreak a public health emergency of international concern in January 30, 2020. The coronavirus Covid-19 first appeared in China by late 2019, but soon the news of its spread throughout Asia and Europe in late February and March was extensive as well as their social distancing and preventive policies for its containment, including lockdown decisions by many countries. Early cases in the Americas were registered in March and April which also led to decisions on social distancing and preventive measures and eventually to national lockdowns in many countries in order to protect public health. This was a moment when humanity was facing a situation of unknown outcome; the global spreading of a deadly infectious disease with no vaccines at hand. Moreover, the pandemic was more than just a global epidemic that disrupted international mobility, transport and trade. Within a country it was a complex dynamic mix of Covid's epidemiology, government's health, economic and social policy, and community, household and individual own reactions and decisions.

Following wide variation among countries, the pandemic shock had the inevitable secondary effect of reducing economic activity within countries. Understanding and measuring the pandemic's economic impact is important for several reasons: (i) governments need to know how deep was the economic recession generated and its characteristics in order to adjust economic and social policy; (ii) they need to follow-up the economic recovery, its characteristics, pace and recoils; (iii) they need to understand the changes in household's own decisions respect to labor, health and safety risks given their wide range of circumstances.

The follow-up of the economic effects of the pandemic was done with readily available measures of economic performance produced by country governments and international organizations, like the quarterly and annual percent change in GDP as well as changes in many other macroeconomic indicators, including the monthly economic activity index. When the information is not yet available than forecasts of GDP and its linear-trend growth path based on potential output is a standard practice as can be read in reports like the IMF's World Economic Outlook (2021). Based on this information, the actual and projected output gap was used by the IMF as a reference for their recommendations regarding the adjustment of short-term fiscal and monetary policy during the pandemic. Based on the same information it was also possible to obtain the difference between the observed and the pre-pandemic forecast of GDP as a measure of the pandemic's economic impact (Furceri *et al*, 2021).

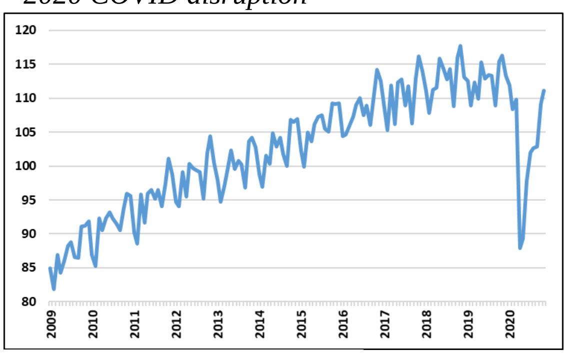
This article adds to the production of measures of the pandemic's economic impact. Its contribution is that it uses the concept of counterfactual and a variation within the interrupted time series (ITS) framework, to generate a measure of aggregate economic impact and degree of recovery when applied to the monthly global economic activity index. It has the advantage of producing monthly information that can be graphed for better visualization and that it can be applied to the economic activity index at the sectoral level (Barja, 2021) and the subnational level. The concept of a counterfactual is the basis for causal inference in the field of impact evaluation, were the random control trial (RCT) is the method of reference for cross section data (Angrist, 2009). Applications to time series data appear in the subfield of interrupted time series (ITS) analysis (McDowall, *et al*, 2019). The article uses two Latin American countries as an example of its application; Mexico one of the largest and Bolivia one of the smallest in terms of both population and per-capita GDP. It would be expected that given its lower per-capita GDP, the Bolivian economy might have been hit harder by the pandemic shock in relative terms.

Besides this introduction, section 2 presents some background, section 3 explains methodology and data while sections 4 and 5 present the pandemic's impact measure and graphical visualization for each country's overall economy. The last section summarizes along with final comments.

Antecedents

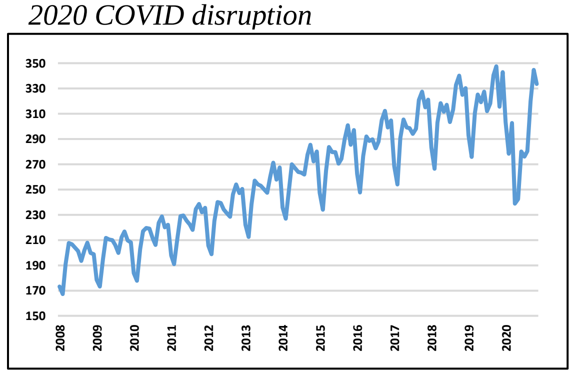
Figures 1 and 2 show the magnitude of Covid's first wave impact on the Mexican and Bolivian economies, which disrupted their growth tendency and seasonality, compared to the imagined continuation of their series if Covid didn't happen (counterfactual). Economic outcome for each country is represented here by their monthly Global Index of Economic Activity (IGAE in Spanish)[1]. When monthly statistics of Covid's economic impact began to appear during 2020 they were automatically reported as variations respect to its value 12 months ago in 2019. This practice was fine up to 2019 because that variation implicitly included the data's tendency as well as recognition of seasonality[2]. However, the same exercise in 2020 would be wrong because tendency in both series shifted down to the right and changed its slope, and their monthly seasonal behavior basically disappeared. It would be more appropriate to compare the observed series against its counterfactual or the monthly series for 2020 describing how the economy would have behaved if Covid didn't happen which would maintain both tendency and seasonality.

Figure 1: Mexican monthly IGAE and the 2020 COVID disruption



Source: Mexican Central Bank.

Figure 2: Bolivian monthly IGAE and the 2020 COVID disruption



Source: Bolivian INE.

Note: Graphs are at different scales thus their magnitude variations cannot be compared.

This article is about measuring the impact of Covid's first wave by aggregating the distance between the observed and counterfactual of the IGAE series from February to November 2020, for Mexico and Bolivia. The counterfactual monthly series is produced from a forecast of economic activity without Covid, strictly based on all the past information of the series itself. This

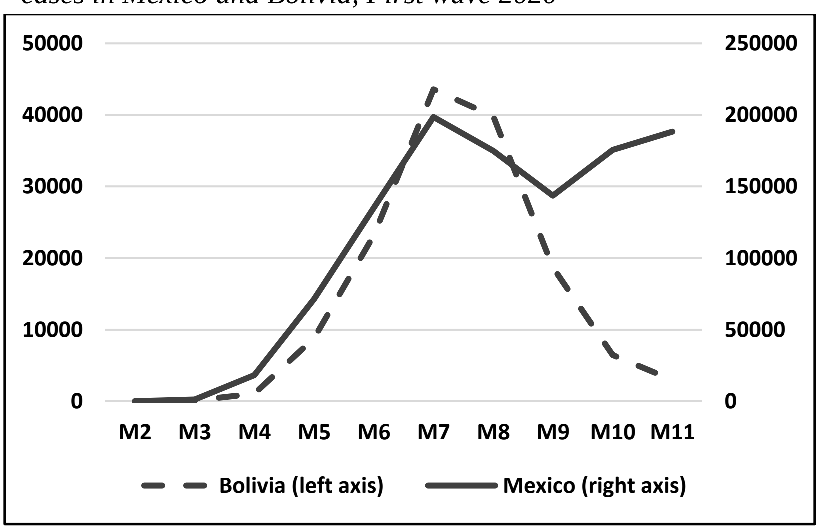
[1] Both countries register their monthly IGAE at different scales, therefore their magnitudes numerically and graphically are not comparable.
[2] The Bolivian series much clearly shows months of low, intermediate and high economic activity regularly happening every year.

simple procedure solves the problem of comparing and aggregating values respect to their behavior 12 months ago, which is not a measure of impact, besides usually not presented within confidence intervals. It is also important to notice that the counterfactual perspective for measuring impact is different to the concept of potential product, where the objective is to produce a forecast into the future as a way of informing macro policy about how actual data is behaving respect to potential. An objective where tendency matters but short-term seasonality does not. From the counterfactual perspective, the objective is to measure impact of a past event, where both tendency and seasonality matter.

This way of measuring impact is more in line with the literature of interrupted time series analysis (ITS), which makes a clear reference to a counterfactual and it also takes into account other time series technical issues like stationarity, autocorrelation and white noise residuals. However, under ITS impact is usually expressed as a change in level and slope respect to the counterfactual at the moment the shock occurred, which is done by separating the series between the before and after the shock. This does not apply in the Covid pandemic case because the pandemic shock was not a one-month event but rather developed throughout 2020 and continued onto 2021, therefore the series cannot be separated into a before and after the shock. This problem is solved here by measuring impact as the accumulated difference between the observed and counterfactual series, which can be non-linear, and it takes seasonality into account and can be presented within confidence intervals.

News about the pandemic originated by the coronavirus Covid-19 reached Mexico and Bolivia in February 2020. Soon after both countries began the planning and execution of a response policy. Figure 3 shows the period of the first wave pandemic shock to both countries, understanding pandemic shock as comprising the dynamic interaction between Covid's epidemiology, government's Covid policy, civil society's reactions and constraints to the international economy, all of which impacted directly or indirectly the functioning of their economies as a secondary effect. The pandemic's second wave began immediately after in December in both countries and continued over into 2021. This article concentrates only on the first wave's 10-month shock to the economy from February to November 2020.

Figure 3: Variation in the monthly average number of Covid-19 cases in Mexico and Bolivia, First wave 2020



Source: OurWorldInData.org

The net economic effect from the Covid pandemic shock to the Mexican and Bolivian economies, individually, has been ultimately captured in their monthly General Economic Activity Index (IGAE in Spanish), published by the Mexican National Institute of Statistics and Geography (INEGI) and the Bolivian National Institute of Statistics (INE). Based on this index, the purpose of this short article is to graph and measure the magnitude of Covid's impact on economic activity in both countries.

Methodology and data

When the time series of an aggregate economic variable like IGAE experiences a shock it automatically generates two paths, the one affected by the shock and expressed in the actual or observed behavior of the series and the one that the time series most probably would have followed if the shock did not happen or counterfactual. The counterfactual is strictly obtained from the best forecast of the series based on all its past information and behavior resulting in the most likely path among the many possible. The cumulative distance overtime between these two series would be the natural measure of the shock's impact. This way of computing impact has the advantage of not requiring that the shock itself be expressed in a complex set of treatment-type variables that must enter a regression equation, as in ITS.

Three important caveats are needed to complement the argument. First, for true impact attribution it must be observed that no other unrelated shocks impacted the same time series at the same time or at least it should be possible for those other shocks to be controlled away. Second, the effect of all planned or unplanned changes in society's behavior directly or indirectly related to the pandemic shock are captured within the outcome variable IGAE and therefore are already considered part of the impact measure without need to separate the contribution of each and every change. Third, the time series must be long enough and their characteristics of non-stationarity and autocorrelation in the mean and variance must be considered and treated with care for reliable average measurements and their confidence intervals.

This perspective falls within the quasi-experimental class of interrupted time series (ITS) analysis mostly used in health policy research (Hudson *et al.*, 2019), but where the problems of non-stationarity, autocorrelation and seasonality must be taken into account (Schaffer *et al*., 2021). However, instead of computing impact as changes in the level and trend of the outcome variable, the proposal here is to compute the accumulated distance between the observed and counterfactual series. The reason is that the Covid pandemic shock was not a one-month event but rather continued over time.

ARMA-type models are used to forecast a key economic time series based on all of its past information, previous to the external shock, in order to obtain the counterfactual path or time series under the assumption of no shock. ARMA models were popularized by Box and Jenkins (1970) and Box, Jenkins and Reinsel (1994) for time series analysis and forecasting. A key advantage of ARMA-type models is their ability to capture the natural regularities in a time series by way of the autocorrelation and moving average contained in it as well as seasonal operators. Other advantage is the possibility to include deterministic-type variables like monthly dummies that can also help capture natural regularities contained in the data or in some cases dummies that can explain extreme observations, and tendency-type variables that can help capture natural linear or quadratic trends in the data. The following is a representation of the basic ARMA (p, q) model:

$$y_t = \gamma + u_t$$

$$u_t = \sum_{i=1}^{p} \rho_i y_{t-i} + \varepsilon_t + \sum_{j=1}^{q} \alpha_j \varepsilon_{t-j}$$

$$\varepsilon_t \sim N(0, \sigma^2)$$

The ARMA model is an equation of a stationary time series y_t against a linear combination of its own past *p* periods plus a linear combination of the innovation term *q* periods past through u_t; ε_t is the innovation term or regression residuals and γ is a constant term but can also include deterministic seasonal dummy variables. The ARMA process provides a way to model the evolution of the conditional mean of y_t and the regression residuals ε_t are assumed normally distributed with zero mean and constant variance σ^2. The model is estimated by maximum likelihood methods.

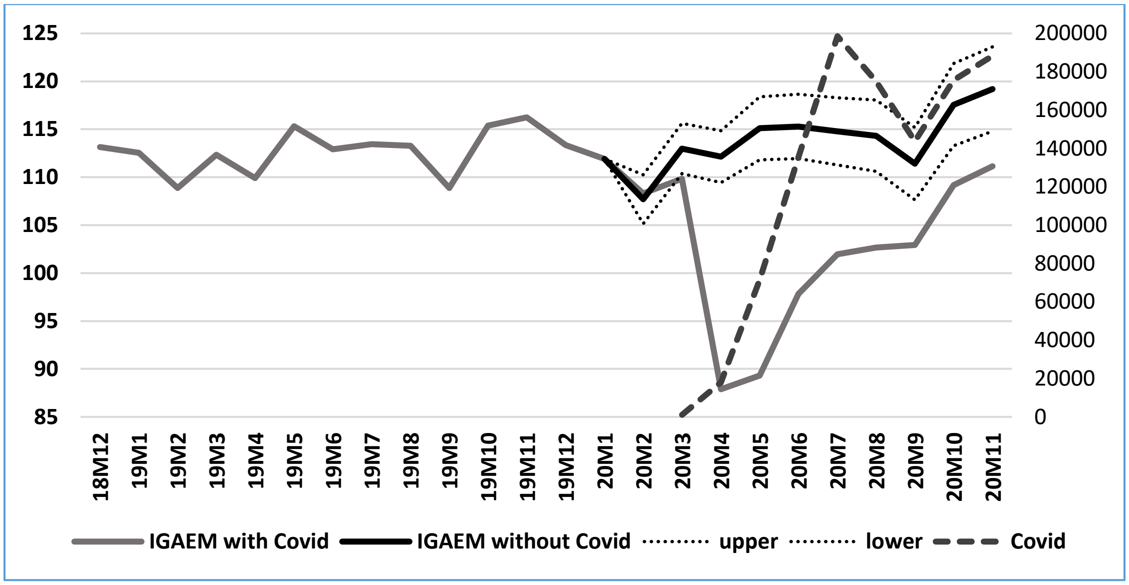
The econometric strategy in the context of the Mexican and Bolivian IGAE times series of their overall economy index, in a first stage, is to estimate ARMA models for the stationary transformation of each of them individually in search for parsimonious models with highest R-square, lowest Akaike Information Criterion and normally distributed white noise residuals in their mean and variance, and in a second stage use each model to forecast the levels of each time series index for the period of interest. This forecast would be referred to as the counterfactual or without Covid. It is expected that each country overall indexes will produce specific models adjusted to capture own seasonal and structural particularities. A prediction interval is also desirable for each point forecast to establish significance. In a third stage the objective is to produce a graphical representation of the counterfactual against the observed times series index with Covid to visualize the magnitude of Covid's impact as well as against the graph of variations of Covid cases for graphical visualization of the moments of greater impact. The measure of Covid's impact itself is computed as a percent loss of economic activity which would be the difference between the observed and counterfactual time series in levels applied to each country indexes during the period of the first wave from February to November 2020.

Regarding data sources, the Mexican IGAE time series can be freely downloaded from INEGI's or the Mexican Central Bank (link provided in the references) and the Bolivian IGAE time series can be freely downloaded from INE's webpage (link provided in the references), which also contains its methodology and sources of information. The Covid-19 data for Bolivia and Mexico can be freely downloaded from the WorldInData.org webpage (link provided in the references).

Covid's impact on Mexican economic activity

Following the econometric strategy presented above, the order of integration and estimated model for the Mexican global economic activity index (IGAEM) are presented in Annex A and B. Figure 4 is the result of the exercise where the dashed line shows the first wave of monthly variations of confirmed Covid cases, reaching its maximum in the month of July, while the previous months from late March to June were of strict quarantine. The *IGAEM with Covid* line corresponds to the evolution of IGAE as it was observed and registered by INEGI, while the *IGAEM without Covid* line is the counterfactual from February to November 2020 representing how the IGAE index would have behaved if the pandemic had not occurred (the second wave began immediately after in December 2020).

Figure 4: COVID's impact on Mexican IGAE



Variations in Covid cases are measured on the right axis.
Source: Author's elaboration based on data from INEGI.

The visual difference between the *IGAEM with* and *without Covid* lines show the magnitude of the pandemic's impact on the Mexican economic activity for the period of ten months between February and November 2020. The series with Covid changed starting March, showing a significant fall of economic activity particularly between April and May during the strict quarantine; a fall in a magnitude not experienced before in the history of the series. The series without Covid within dotted confidence intervals is the counterfactual series that reproduces with precision the seasonal behavior and tendency that would have occurred without Covid, taking into account all past information of IGAEM. The short-run recovery behavior began U-shaped, but because of the setback between July to September, when Covid's contagion could not fully come down, it ended with a W-shape tilted and prolonged to the right.

Computation of the impact itself is obtained by subtracting the line *with Covid* from the line *without Covid*; the area between what actually happened compared to what would have happened without Covid. This way of measuring impact is conceptually different to subtracting today's observed value respect to its value 12 months ago. This last would not be a measure of impact since it does not take into account that the economy would have continued growing during 2020 at the rhythm and tendency it was growing given the domestic and international context and the economy's structure. Table 1 shows the accumulated IGAEM would have grown up to 1,140.50 points but grew only up to 1,021.02 which establishes the pandemic's impact at an average accumulated -10.48% loss of economic activity in the period between February to November 2020.

Table 1: Computing COVID-19's impact on Mexican IGAE

Month	IGAEM with Covid	IGAEM without Covid	Points difference	Accumulated rate
20M2	108.32	107.70 (±2∗1.30)	0.61	0.57%
20M3	109.83	112.99 (±2∗1.30)	-3.16	-0.15%
20M4	87.89	112.14 (±2∗1.50)	-24.25	-8.05%
20M5	89.31	115.10 (±2∗1.67)	-25.79	-11.74%
20M6	97.82	115.30 (±2∗1.75)	-17.48	-12.44%
20M7	101.96	114.17 (±2∗1.98)	-12.81	-12.22%
20M8	102.65	114.33 (±2∗2.08)	-11.68	-11.93%
20M9	102.92	111.41 (±2∗2.22)	-8.49	-11.40%
20M10	109.17	117.56 (±2∗2.35)	-8.39	-10.91%
20M11	111.16	119.20 (±2∗2.51)	-8.04	**-10.48%**
Accumulated	1,021.02	1,140.50 (±2∗18.6)	-119.47	
		Pandemic's impact => (95% confidence interval) =>	**-10.48%** (-13.08%, -7.71%)	

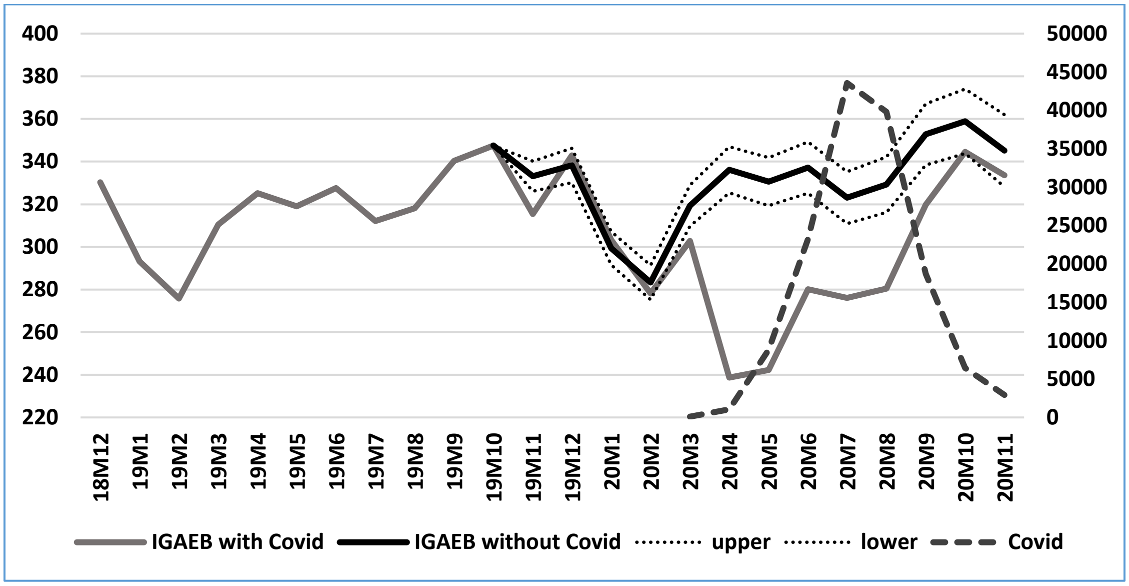
In parenthesis ±2∗S.E. is a 95% confidence interval.
Source: Author's elaboration based on data from the INEGI..

Covid's impact on Bolivian economic activity

Following the same econometric strategy, the order of integration and estimated model for the Bolivian global economic activity index (IGAEB) are also presented in Annex A and B. Figure 5 is the result of the exercise where the dashed line shows the first wave of monthly variations of confirmed Covid cases, reaching its maximum between the months of July and August, while the previous months from mid-March to early May were of strict quarantine. The *IGAEB with Covid* line corresponds to the evolution of the Bolivian IGAE as it was observed and registered by INE[3], including the November 2019 political conflict and the pandemic experience from February to the end of November 2020 when the first wave ended (the second wave began immediately after in December 2020). While the *IGAEB without Covid* line is a forecast from November 2019 to November 2020 representing how the Bolivian IGAE index would have behaved if the political conflict nor the pandemic had occurred. The forecast begins in November 2019 rather than February 2020 in order to eliminate the potential contamination from the November political conflict that impacted the economy that month and whose economic consequences might have been carried over onto 2020.

[3] The data used up to November 2020 was published in February 2021 and was considered preliminary.

Figure 5: COVID's impact on overall IGAE



Variations in Covid cases are measured on the right axis.
Source: Author's elaboration based on data from INE and Bolivia Segura.

The visual difference between the *IGAEB with* and *without Covid* lines shows the magnitude of the pandemic's impact on the Bolivian economic activity for the period of ten months between February and November 2020. The series with Covid changed starting February, showing a significant fall of economic activity particularly between April and May during the strict quarantine; a fall in a magnitude not experienced before in the history of the series. While the series without Covid within dotted confidence intervals is the counterfactual series that reproduces with precision the seasonal behavior and tendency that would have occurred without Covid, taking into account all past information of IGAE. The short-run recovery behavior began U-shaped, but because of the setback between June to August, when Covid's contagion expanded and reached its highest peaks of registered cases, it ended with a W-shape tilted and prolonged to the right. The figure also shows the economic impact of the political conflict in November 2019 with an immediate V-shape recovery. The fact that the observed and counterfactual are basically the same in December 2019 and January 2020 provides some confidence that the rest of the observed series is free from that contamination during 2020, at least in the economic sphere but certainly was not so in the political sphere.

Computation of the impact itself is obtained by subtracting the line *with Covid* from the line *without Covid*; the area between what actually happened compared to what would have happened without Covid. This way of measuring impact is conceptually different to subtracting today's observed value respect to its value 12 months ago. This last would not be a measure of impact since it does not take into account that the economy would have continued growing during 2020 at the rhythm and tendency it was growing given the domestic and international context and the economy's structure. Table 2 shows the accumulated IGAE would have grown up to 3,315.64 points but grew only up to 2,896.66 which establishes the pandemic's impact at an average accumulated -12.64% loss of economic activity in the period between February to November 2020.

Table 2: Computing Covid-19's impact on overall IGAE, Bolivia

Month	IGAE with Covid	IGAE without Covid	Points difference	Accumulated rate
20M2	278.23	283.30 (±2∗4.03)	-5.07	-1.79%
20M3	302.75	319.37 (±2∗4.82)	-16.62	-3.60%
20M4	238.71	336.12 (±2∗5.40)	-97.41	-12.69%
20M5	242.28	330.57 (±2∗5.65)	-88.29	-16.34%
20M6	280.16	337.23 (±2∗5.99)	-57.07	-16.46%
20M7	276.10	323.02 (±2∗6.09)	-46.92	-16.14%
20M8	280.43	329.19 (±2∗6.48)	-48.76	-15.94%
20M9	319.77	352.80 (±2∗7.17)	-33.03	-15.05%
20M10	344.61	358.90 (±2∗7.56)	-14.29	-13.72%
20M11	333.62	345.14 (±2∗8.45)	-11.52	**-12.64%**
Accumulated	2,896.66	3,315.64 (±2∗61.63)	-418.98	
		Pandemic's impact => (95% confidence interval) =>	**-12.64%** (-15.77%, -9.26%)	

In parenthesis ±2∗S.E. is a 95% confidence interval.
Source: Author's elaboration based on data from INE.

Summary and concluding thoughts

The article's emphasis is on methodology for measuring the impact of the pandemic shock on economic activity, using a counterfactual perspective applied to the observed IGAE time series. The counterfactual time series is produced by simple ARMA models and the impact itself is computed as the cumulative difference between the observed and counterfactual series.

Application to the Mexican and Bolivian cases informs of an average global economic activity loss of -10.48% and -12.64% respectively, during the 10-month period from February to November 2020. Besides the obvious difference in economic dimensions and degree of development, both countries lost economic activity that cannot be recovered and also lost their growth tendency up to 2019. The sooner they recover the sooner their economies stop loosing economic wealth. By the end of the first wave in November, Mexico and Bolivia were able to recover their level of economic activity by 93% and 96.7% respectively compared to their expected counterfactual level for that month.

An advantage of the methodology is that it can also inform about economic recovery from three perspectives. First, the monthly distance between the observed and its counterfactual shows how far off is the economy in a specific month. Second, weather the tendency of that distance is to close over time and at what speed. Third, full recovery and true growth can only happen when the observed series is finally above the counterfactual series. However, once the Mexican and Bolivian economies recover and begin growing back again both would also be different economies compared to 2019 due to changes in their economic sectors as well as changes in their subnational regions due to uneven recoveries, changes in people's behavior and degree of digital transformation.

Degree of digital transformation was certainly the upside of the pandemic shock. The question of how prepared was each country and their economic sectors and subnational regions to quickly change to their digital counterpart or how much additional digital adaptation was able to occur during the pandemic is important to understand the heterogeneous recovery and for public policy. Nevertheless, solution to the Covid-19 pandemic lies outside the purely economic domain, an issue beyond the scope of this article.

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ANNEX A: Order of integration

Sector	Abbreviation	Order of integration
Bolivian Global Index of Economic Activity	IGAEB	I(1)
Mexican Global Index of Economic Activity	IGAEM	I(1) none

Source: Author's elaboration based on data from INE and INEGI.

ANNEX B: Estimated models

	Bolivia	Mexico
	d(log(IGAEB))	d(log(IGAEM))
AR(1)		-0.904801** (0.067141)
AR(2)		-0.594894** (0.076699)
AR(12)	0.904805** (0.048239)	
MA(1)	-0.511206** (0.082990)	
MA(12)	-0.246195** (0.086876	
Monthly seasonal dummies	d1, d3, d4, d9	d1, d2, d3, d4, d5, d7, d9, d10, d11, d12
Observations	130	132
Period	2009M1-2019M10	2009M2-2020M1
R2	0.972078	0.893318
AIC	-6.068445	-6.043579
Jarque-Bera	2.319706	0.702336
Residuals Q-test	Prob > 5%	Prob > 5%
Residuals^2 Q-test	Prob > 5%	Prob > 5%
Convergence	40 iterations	9 iterations
Unit roots	ARMA model is stationary and invertible	AR model is stationary
Long-run model impulse-response converges to:	0.027000 (0.02358)	0.004479 (0.00031)

Numbers in parenthesis are standard errors. ** significant at 1%; * significant at 5%.
Source: Author's elaboration based on data from INE (Bolivia) and INEGI (Mexico).