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Contaduría y Administración

Accounting & Management

Contaduría y Administración 66 (5), Lecciones de la pandemia de Covid-19, 2021, 1-26

The economics of pandemics: Cyclical effects and recovery strategies of state manufacturing consumption in facing the COVID-19 pandemic in México

La economía de la pandemia: efectos cíclicos y estrategias de recuperación del consumo manufacturero estatal ante la pandemia de la COVID 19 en México

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Received July 16, 2021; accepted September 30, 2021
Available online March 9, 2023

Abstract

With the purpose of contributing to a better comprehension regarding the recovery of the Mexican economy during the COVID 19 pandemics, the objective of this investigation consists in identifying the differences between the strategies of economic adaptation to upgrows and contractions in state's manufacturing sales associated to variations in COVID 19 contagions. Our results, obtained my means of a two-stage methodology, indicate 11 states applied precautionary strategies, 14 states adopted less precautionary strategies, and at least 18 states were effective in implementing a strategy of recovery.

JEL Code: C22, C51, I10, E32, L60
Keywords: economics of pandemics; COVID 19; economic recovery; cyclical effects; markovian regime switching; México

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Peer Review under the responsibility of Universidad Nacional Autónoma de México.

http://dx.doi.org/10.22201/fca.24488410e.2021.3576

Resumen

Con el propósito de contribuir a la comprensión del proceso de recuperación de la economía mexicana durante la pandemia por la COVID 19, el objetivo de esta investigación consiste en identificar las diferencias en las estrategias de adaptación económica durante los periodos de contracción y repunte positivo en las ventas manufactureras estatales asociados a las variaciones del número de contagios. Los resultados obtenidos, a partir de una metodología en dos etapas, indican que 11 estados implementaron estrategias predominantemente precautorias durante las fases de contracción y repunte en las ventas manufactureras, 14 estados habrían adoptado estrategias de adaptación a la pandemia por la COVID 19 menos precautorias, y 18 estados lograrían implementar con efectividad al menos una medida de recuperación.

Código JEL: C22, C51, I10, E32, L60
Palabras clave: economía de la pandemia; COVID 19; recuperación económica; efectos cíclicos; cambio de régimen markoviano; México

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Introduction

The interest shown in the economic studies exposing the multiple repercussions that the containment measures at the onset of the COVID-19 pandemic had on the affected countries' economies contrasts with the scant attention given to the economic recovery process that followed the great contraction. Some of the initiatives in various studies that sought alternatives to reactivate economies and protect the population's health recommended the implementation of economic stabilization measures based on stimulating consumption or protecting employment in conjunction with social distancing (Baldwin, 2020). They also recommended preventive health measures and intensive use of information and communication technologies (Wei, 2020), (Torres, 2020), as well as selective isolation based on the mass application of serological tests (Quah, 2020). Evidence from more recent research seems to support the latter type of strategy (Fotiou & Lagerborg, 2021).

Nevertheless, two coincidental aspects that should be noted in the above research are, on the one hand, the absence of an explanation of how economic recovery strategies would adapt to fluctuations in the number of infections, and on the other hand, that in practice most of the countries affected by COVID-19 had to learn to implement these strategies as the pandemic evolved. Both aspects are relevant to understanding the recovery patterns of the economies if it is considered that some of the countries—particularly those with fiscal constraints to implement stabilization measures based on stimulating supply and demand and the massive application of serological tests—would have based their economic recovery strategies on the monitoring of variations in the number of COVID-19 infections.

In the case of Mexico—after the notable 19% reduction in domestic consumption and in other key economic variables during April 2020 as a result of lockdown, distancing, and reduction of mobility to reduce the spread of COVID-19—, economic agents and government authorities adopted measures that

http://dx.doi.org/10.22201/fca.24488410e.2021.3576

would seek to make health protection compatible with the performance of state economies. A preliminary review of the monthly behavior of state manufacturing sales suggests that after the contraction associated with the increase in the number of COVID-19 infections, some states such as Aguascalientes, Baja California, and Baja California Sur would have promoted the reactivation of consumption during periods of positive variations in the number of infections, while other states such as Mexico City and the State of Mexico would have waited to promote consumption until they achieved a decrease in the number of infections registered (Table A1 in Appendices). In this sense, the statistical figures suggest that the states would have implemented differentiated strategies of economic adaptation to the pandemic.

In this context, to contribute to the understanding of the recovery process of the Mexican economy during the COVID-19 pandemic, the objective of this research is to identify the differences in the economic adaptation strategies implemented by economic agents and state governmental authorities as a result of the variations in the number of COVID-19 infections. The analysis mainly focuses on the behavior of state manufacturing sales during periods of contraction and rebound associated with the number of COVID-19 infections since this transmission channel is crucial in the sequence of effects that are induced in different key variables of state economies (Torres, 2020). The specific questions are: Is it possible to identify economic adaptation strategies associated with the fluctuations in the number of COVID-19 infections in Mexican states? If so, what are the differences between these adaptation strategies? To answer these questions, a two-stage methodology is proposed that, first, makes it possible to infer the probabilities of contraction and rebound in manufacturing sales using a Markovian model with regime switching, and second, estimates the cyclical effects on manufacturing sales resulting from changes in the number of infections.

This paper is structured as follows: The first section sets out the motivation and purpose of the research. The second section reviews the literature, mainly empirical, that studies the economic recovery process in different countries. The third section provides an overview of sales behavior and the number of COVID-19 infections. The fourth section presents the methodological aspects and the databases used. The fifth section analyzes the empirical evidence obtained. Finally, the conclusions are presented.

Review of the literature

Among the numerous studies on the economic repercussions of the containment measures implemented at the beginning of the pandemic in various countries, it has been found that the modification in purchasing habits would result in mainly contractionary variations in the level of spending, which are crucial for understanding the initial impact on the rest of the key variables of the economy. In this regard, Cox et al. (2020), based on the information available in the bank accounts of U.S. households, found that spending was reduced during the first months of the pandemic in the different income strata, apparently due to a change in their consumption habits. For their part, Baker et al. (2020) found that during the COVID-19 pandemic, consumption seems to react before employment or production and that its trajectory initially describes an increase in spending, for example, for credit card payments and food, and then declines. In the case of Mexico, Campos-Vázquez and Esquivel (2021) found that the change in mobility patterns associated with containment measures had a significant impact on consumption, finding that, during the second quarter of 2020, the number of point-of-sale transactions declined 23% more than would have occurred in the absence of the pandemic. From a sectoral perspective, the authors also documented that this contraction has been most notable in consumer spending on tourism, transportation, and restaurants or fast food services. Torres (2020), on the other hand, demonstrates that a surprise surge in the number of confirmed cases in an epidemiological variable that includes COVID-19 would induce a greater negative impact on the consumption of semi-durable goods and manufacturing production in Mexico.

In this regard, Baldwin (2020) proposes resorting to measures to protect the economy for a sufficient time until the epidemiological curve of contagion is flattened. In their work, Wei (2020) and Torres (2020)—the latter concerning the manufacturing industry in Mexico—suggest that preventive health measures and intensive use of information and communication technologies should necessarily accompany economic reactivation and stabilization measures. Quah (2020), on the other hand, suggests that the combination of economic recovery measures with selective isolation based on mass serological testing implemented by government authorities in Singapore represented an effective response to the COVID-19 pandemic. In a more recent study by Fotiou and Lagerborg (2021), the authors seem to confirm the proposal made by Quah (2020), finding that countries that combined early implementation of restrictive measures with mass screening tests, tracing of infected persons, and public information campaigns achieved lower COVID-19-associated mortality rates, higher economic growth, and lower fiscal costs.

These studies share a common aspect in the absence of an explanation for understanding how economic agents would adapt their economic recovery strategies to fluctuations in the number of COVID-19 infections. In the studies that propose the implementation of containment measures based on selective isolation, the early identification of infected persons would allow the selective withdrawal of consumers and workers, avoiding a massive direct impact on the sales and production of companies. However, it is unclear how economic agents would respond to protect themselves given an increase in infections. In this regard, the study of economic adaptation strategies to variations in the number of COVID-19 infections is relevant because it contributes to the understanding of recovery patterns, particularly in the Mexican manufacturing sector, a driver of economic growth and employment (De Jesús, 2019).

The transmission of COVID-19 infections and the recovery of state manufacturing sales in Mexico

The analysis of the economic recovery developed in this research requires first identifying the sequences of effects that, given the fluctuations in COVID-19 infections, can be transmitted to the Mexican economy through the measures established for their containment and prevention. Therefore, the identification of this sequence will make it possible to focus the analysis of the economic recovery on the channel, and particularly on the stage, which is central to understanding the differences in the adaptation process of the state economies. Figure 1 describes the transmission mechanism that, in accordance with the economic literature, summarizes the sequence of effects that occurred due to the containment measures implemented at the beginning of the pandemic by several countries, including Mexico. In this sequence, for example, an acute increase in the number of infections would lead to the implementation of various containment measures, such as partial closure of economic activities, reduced mobility of people, and quarantines, which would subsequently have immediate repercussions on the functioning of the Mexican economy through changes in the behavior of consumers and businesses (Torres, 2020). This mechanism, however, is also useful for understanding the recovery process of state economies.

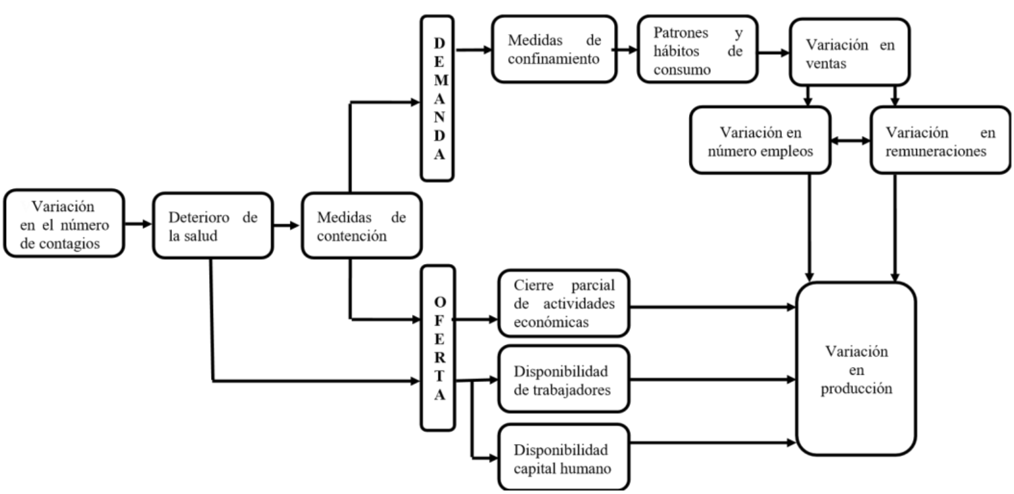

Figure 1. Transmission mechanism of the number of infections into the economy
Source: created by the authors

http://dx.doi.org/10.22201/fca.24488410e.2021.3576

In this regard, Tables 1 and 2 present, respectively, the monthly growth in the number of COVID-19 infections and the monthly growth of manufacturing sales in the states of Mexico, distributed in percentiles to summarize their behavior. These tables show that the greatest contraction in state manufacturing sales occurred in April, with some states reaching a negative variation of 38% due to the implementation of measures to contain the transmission of the new coronavirus as of March. However, the records of the behavior of the number of infections show that the lockdown measures and partial closure of activities would be insufficient to stop infections among the Mexican population, with some states reaching growth of up to 522% in May, compared to the previous month, and a little more than halfway through the year there were even states with monthly variations in the number of infections close to 82%. At this point, it seemed to be clear, mainly for the Mexican business sector, that a consecutive implementation of the initial containment measures would be incompatible with the performance of the Mexican economy, but also that they would have to move toward a process of adaptation that would protect the health of workers and consumers at the same time as the economy.

In terms of the sequence of effects shown in Figure 1, the adaptation strategy based on the implementation of social distancing, the use of masks, and sanitation, would seek to decrease the uncertainty of the population about being infected by the new coronavirus, which, when transmitted to consumer behavior, would stimulate sales. Tables 1 and 2 show that this adaptation strategy, which seeks to make consumer protection compatible with the performance of state economies, would have worked with different variants. One variant, for example, would have a precautionary character when states promote safe consumption, but their sales describe a countercyclical behavior with respect to the variation in COVID-19 infections. This strategy would have been implemented by some states during May when, in the face of a rebound in contagions, a greater contraction in state manufacturing sales would have been avoided. However, the precautionary nature of this variant is most clearly observed during September, when the reduction in the number of infections, together with health protection measures, would have contributed to the increase in manufacturing sales. On the other hand, a second variant describes the implementation of a less precautionary strategy that promotes safe consumption, inducing an increase in sales at the same time as the number of COVID-19 infections increases, as can be seen in June, July and December.

http://dx.doi.org/10.22201/fca.24488410e.2021.3576

Table 1
Evolution of monthly growth in the number of new COVID-19 infections in Mexico during 2020

Distribution	March	April	May	June	July	August	September	October	November	December
75th percentile	52.05	208.64	522.03	104.22	82.77	35.91	-25.65	65.06	49.22	44.27
50th percentile	26.22	66.60	302.27	80.73	43.91	0.52	-39.44	20.77	18.81	2.31
25th percentile	3.11	11.43	147.49	23.46	10.43	-27.08	-51.11	-1.57	-5.70	-23.22

Source: created by the authors using information from INEGI

Table 2
Evolution of monthly manufacturing sales growth in the states of Mexico during 2020

Distribution	March	April	May	June	July	August	September	October	November	December
75th percentile	4.99	-5.57	-2.47	63.15	23.63	1.68	7.73	1.59	2.09	4.75
50th percentile	0.42	-16.94	-5.89	18.55	7.07	-1.25	4.11	-0.52	-0.83	3.09
25th percentile	-3.21	-38.27	-10.39	5.64	-0.80	-6.43	1.37	-3.65	-3.58	-0.82

Source: created by the authors using information from INEGI

A review of the above figures suggests that the implementation of adaptation strategies aimed at reconciling safe consumption with economic performance has occurred differentially across Mexico's states. An overview of these state differences can be seen in Table 3, which describes the moving correlation between the monthly growth of manufacturing sales and the number of COVID-19 infections between March and December 2020[1]. For example, Baja California and Baja California Sur resorted to this type of strategy during April, as indicated by the change in the direction of the moving correlation coefficient, when their manufacturing sales decreased by 52% and 13%, respectively (Table A1 in Appendices).

The change observed in the sign of the moving correlation coefficient between April and May suggests that Aguascalientes, Coahuila, Chiapas, Chihuahua, Guanajuato, Hidalgo, and Puebla implemented precautionary measures to reduce the fear among consumers of being infected, thus avoiding a greater reduction in their manufacturing sales in the latter month (Table A1 in Appendices). Other states would have resorted to precautionary strategies that intensified as the number of infections increased during these same two months, as occurred, for example, in Veracruz and Yucatan, whose moving correlation coefficients also increased in magnitude.

[1]The moving correlation was calculated with a three-month window, including the current month.

http://dx.doi.org/10.22201/fca.24488410e.2021.3576

Most of the states that initially adopted a precautionary nature in their strategies to reactivate manufacturing consumption would modify them during the next two months to less precautionary strategies that led to positive changes in their sales (Table A1 in Appendices). However, the combination of these strategies would have contributed to defining the adaptation measures that the states would use for the rest of the year. For example, Mexico City and the states of Hidalgo and Tamaulipas consistently implemented precautionary strategies that required closely synchronizing the opening of establishments, accompanied by consumer protection measures, with the monthly behavior of the number of COVID-19 infections. Table 3 shows that these three states have a mostly negative moving correlation coefficient with a high magnitude. On the other hand, some states, such as Aguascalientes and Coahuila, have resorted more frequently to implementing less precautionary measures that favor consumption during periods of increased infections. Table 3, in this case, shows positive moving correlation coefficients in most months in both states, while other states that occasionally resorted to less precautionary measures show changes in the sign or magnitude of the calculated coefficient.

Table 3
Moving correlation between monthly growth in the number of COVID-19 infections and final manufacturing sales in the states of Mexico during 2020

State	March	April	May	June	July	August	September	October	November	December
Aguascalientes	-0.99	-0.34	0.55	-0.25	-0.79	0.97	0.68	0.86	0.03	0.20
Baja California	0.62	-0.96	-0.48	-0.99	-0.87	-0.89	0.37	0.67	-0.05	-1.00
Baja California Sur	0.99	-0.51	-0.73	-0.92	-0.80	-0.66	-1.00	-0.65	-0.99	0.82
Campeche	0.38	0.15	-0.95	-0.98	-0.85	0.47	0.99	0.93	1.00	0.46
Coahuila	0.81	-0.99	0.46	0.95	0.93	0.89	0.75	0.91	0.71	0.06
Colima	0.34	0.73	-0.80	-0.61	-0.94	0.65	-0.66	-1.00	-0.20	0.32
Chiapas	0.34	-0.80	0.16	-0.18	-0.40	0.45	0.95	-0.84	-1.00	-1.00
Chihuahua	-0.72	-1.00	0.49	-0.30	-0.68	-0.87	-0.76	-0.99	-0.50	-0.48
Mexico City	1.00	-0.90	-0.93	-0.98	-1.00	-0.98	-0.76	-0.99	-0.43	0.42
Durango	0.18	-1.00	-0.05	0.67	0.77	-0.38	-0.97	-0.80	-0.78	-0.79
Guanajuato	-0.95	-0.95	0.36	0.12	-0.31	0.90	0.99	0.99	-0.89	-0.92
Guerrero	-0.49	0.78	0.95	0.10	0.82	0.57	-0.35	-0.90	-0.96	-0.88
Hidalgo	-0.18	-0.99	0.01	-0.23	-0.58	-0.72	-0.88	-0.96	-0.98	-0.68
Jalisco	0.35	1.00	-0.21	0.25	-0.51	0.61	-0.79	-1.00	-0.82	-0.44
State of Mexico	-0.94	-1.00	-0.67	-0.95	-0.57	0.98	0.69	-0.48	-0.67	-0.16
Michoacán	-0.92	-0.95	-0.71	-0.50	-0.93	0.56	-0.69	-0.11	-0.38	1.00
Morelos	0.23	-0.15	0.85	-0.22	0.39	0.81	-0.38	-0.93	0.12	0.97
Nayarit	0.18	0.91	0.23	0.60	0.74	0.42	-0.83	-0.94	-0.84	0.07
Nuevo León	0.01	0.26	0.48	0.81	0.31	0.92	-0.79	-0.99	-0.89	-0.77

Oaxaca	-0.51	0.43	0.98	0.58	0.57	-0.25	-0.88	-0.79	0.39	0.03
Puebla	-0.32	-0.37	0.09	-0.21	-0.97	0.04	0.73	-0.28	-0.72	0.60
Querétaro	-0.28	0.07	0.28	-0.26	-0.85	-0.98	-0.09	-0.86	-0.92	-0.93
Quintana Roo	-1.00	-0.30	0.27	-0.58	0.33	1.00	0.28	-0.23	-0.58	-0.37
San Luis Potosí	-0.77	0.14	0.14	-0.05	-0.90	0.30	0.89	-0.07	-0.30	-0.61
Sinaloa	-0.71	-0.07	-0.86	-0.96	-0.94	0.46	-0.96	-0.99	-0.98	-0.98
Sonora	-0.73	0.69	0.96	-0.14	-0.84	0.96	0.56	0.28	-0.45	0.43
Tabasco	0.63	0.32	0.96	-0.68	-0.67	-0.10	-1.00	-0.69	-0.95	-0.39
Tamaulipas	0.95	0.06	-0.13	0.42	-0.96	0.72	0.92	-0.95	-0.99	-0.70
Tlaxcala	0.75	-0.88	-0.84	-0.67	0.77	0.89	0.88	-0.74	-0.76	-0.64
Veracruz	0.75	-0.60	-0.87	-0.80	-0.87	0.44	-0.34	-0.89	-0.64	0.67
Yucatán	0.74	-0.62	-0.90	-1.00	-0.93	0.99	0.76	-0.27	0.16	-0.71
Zacatecas	-0.06	0.74	0.74	0.74	-0.53	0.75	1.00	0.91	-0.03	-0.49

Source: created by the authors using information from INEGI Note: the moving correlation was calculated with a three-month window.

Methodological aspects

To provide empirical evidence on state differences in the strategies implemented by consumers, entrepreneurs, and government authorities to adapt their economic decisions to fluctuations in the number of COVID-19 infections, a two-stage methodological strategy is used to identify and quantify these differences during periods of contraction and rebound in the behavior of state manufacturing sales. The first stage in this methodological approach consists of estimating a probability distribution that helps to identify the phase of contraction or rebound that most likely describes the monthly behavior of state manufacturing sales. The second stage consists of implementing an economic-epidemiological model that quantifies the effects of fluctuations in the number of infections during the contraction or rebound phases of state manufacturing sales identified during the first stage.

Stage 1

The decision to estimate a probability distribution in this first stage is mainly because it provides a statistic to describe the monthly fluctuations of state manufacturing sales, particularly since the beginning of the COVID-19 pandemic. To achieve this purpose, the estimation of different Markovian autoregressive models with regime switching was used, according to the initial proposal of Hamilton (1989). Although this methodological approach has been used mainly to analyze the cyclical behavior of macroeconomic variables, its flexibility offers different methodological advantages that favor the study of the economic

http://dx.doi.org/10.22201/fca.24488410e.2021.3576

recovery process during the pandemic. These include its application to different types of time frequencies, the possibility of extending the number of regimes, its treatment of the probabilistic cyclical behavior of an economic variable as an unobserved dimension, and the endogenous estimation of the probability distribution, thus avoiding the identification of cyclical behavior by inspection.

A contribution by Hamilton (1989) studies the nonlinear behavior of a stationary stochastic process in a time series whose nonlinearity arises from the discrete shifts in its state or regime that manage to modify the dynamics of the series. In particular, the author defines a time series $\{\tilde{y}_t\}$ composed of a trend n_t and an autoregressive process of order r, denoted $\tilde{z}_t$, whose further differentiation leads to the following specification:

$$yt = \alpha 1st + \alpha 0 + zt \tag{1}$$

In this expression, the time series $\{y_t\}$ describes a stationary stochastic process made up, in turn, by s_t, which represents the state or regime in which the series is currently found, and by the stationary autoregressive process z_t[1]. The state or regime, s_t, in which y_t is found is not observable; however, it is possible to attribute a transition probability among the states or regimes according to the following Markovian process:

$$\text{Prob}[S_t = 1 \mid S_{t-1} = 1] = p$$

$$\text{Prob}[S_t = 0 \mid S_{t-1} = 1] = 1 - p$$

$$\text{Prob}[S_t = 0 \mid S_{t-1} = 0] = q$$

$$\text{Prob}[S_t = 1 \mid S_{t-1} = 0] = 1 - q \tag{2}$$

In this Markovian process, p and q represent the probabilities that the series y_t has to remain in the same state or regime as the previous period, $S_t = 1$ or $S_t = 0$, respectively, while 1 - p and 1 - q are the probabilities that it has to move to a different state or regime. The sequence describing the shift between regimes follows, in turn, the first-order autoregressive process $s_t = (1 - q) + \lambda s_{t-1} + v_t$, with $\lambda \equiv -1 + p + q$. In this study, therefore, the monthly growth of state manufacturing sales represents the observed stationary stochastic process, $\{y_t\}$, from which it is intended to obtain the sequence of probabilities in

[1]The z_t component describes a stationary autoregressive process of order r according to the following expression: $z_t = \phi_1 z_{t-1} + \phi_2 z_{t-2} + \cdots + \phi_r z_{t-r} + \varepsilon_t$, where $\phi_i = 1 \ldots r$ are the parameters associated with the autoregressive terms, and ε_t is considered as i.i.d. $N(0, \sigma^2)$.

order to infer the state or regime in which this economic indicator has been found as of the onset of the pandemic. Only two possible regimes are considered, $S_t = 1$ or $S_t = 0$, to describe the dynamics that characterize the monthly fluctuations of state manufacturing sales. In this regard, in a growth dynamic, the regimes $S_t = 1$ and $S_t = 0$ are interpreted respectively as a situation of fast and slow growth. In a cyclical dynamic, on the other hand, both regimes represent situations of rebound or contraction in this indicator. The transition probabilities that make it possible to infer the state or regime that characterizes the monthly fluctuations of manufacturing sales in the 32 Mexican states were obtained from the implementation of the nonlinear filter algorithm proposed by Hamilton (1989).

Stage 2

To identify state differences in the strategies implemented by economic agents and local government authorities in Mexico to adapt to the fluctuations observed in the number of COVID-19 infections, the estimation of an economic-epidemiological model is proposed according to the following specification:

$$y_t = \mu + \beta_i P_i[S_t = s_t, \dots, S_{t-r+1} = s_{t-r+1} | y_t, \dots, y_{-r+1}] ep_t + \varepsilon_t \text{ con } i = 0{,}1 \tag{3}$$

In this empirical model, the variable y_t represents the monthly growth of manufacturing sales in the Mexican states; ep_t is an epidemiological variable that describes the monthly state growth in the number of infections of pneumological infectious diseases similar to COVID-19; and P_0 and P_1 represent, respectively, the probabilities that help to infer whether monthly state sales are in a contraction phase, $S_t = 0$, or in a rebound phase, $S_t = 1$. The interaction between the vector of probabilities and the epidemiological variable helps distinguish, in turn, the periods in which fluctuations in the number of contagions coincide with a phase of contraction or rebound in state manufacturing sales. The parameters β_i associated with the interactive variable make it possible to identify the behavior of economic agents and government authorities during both phases in response to fluctuations in the number of infections. In this regard, obtaining both parameters during this second stage avoids a potential over-parameterization if, on the other hand, they were to be obtained in a single stage.

Along the same line, a negative sign in this parameter during a phase of contraction would imply that consumers, employers, and government authorities would have decided to restrict consumption in the face of an increase in the number of infections, thus implementing a precautionary strategy in favor of health care. In turn, the prevalence of a negative sign in this parameter—even in a rebound phase in manufacturing sales—would also reflect a precautionary behavior that seems to favor consumption when

http://dx.doi.org/10.22201/fca.24488410e.2021.3576

the number of infections decreases. Nevertheless, in this situation, the skewness in the magnitude of the parameter during both phases would reflect a differentiated behavior. If, for example, the magnitude of the parameter is lower during the sales rebound phase, it would imply that economic agents and government authorities are willing to favor consumption, although they would still demonstrate precautionary behavior. On the other hand, a positive sign in this parameter during a rebound phase suggests that healthcare behavior would be less precautionary in these states because they would favor consumption even during periods of increased COVID-19 infections.

Databases

Manufacturing sales were measured based on the value at constant prices of final sales made by manufacturing industries classified in SCIAN sectors 31 to 33 for the 32 states of Mexico, with a monthly frequency, from 2013 to 2020. The calculation was made based on information at current prices reported by INEGI through the Monthly Manufacturing Industry Survey (EMIM, Spanish: Encuesta Mensual de la Industria Manufacturera) and the Consumer Price Index for cities from INEGI. The measurement of the epidemiological variable consisted of a splice between the number of cases confirmed as infectious pneumological diseases and the number of COVID-19 infections in the 32 states of Mexico, from 2013 to 2020, also with a monthly frequency. This strategy made it possible to have a general measurement that, by combining the relative stability of the behavior of the number of confirmed pneumological cases, enabled the identification of the fluctuations observed in the number of COVID-19 infections. The statistical information was obtained, in both cases, from the weekly records published by the National Epidemiological Surveillance System of the Federal Ministry of Health.

Regime shifts in growth dynamics and cyclical fluctuations in state manufacturing sales: Empirical evidence

Different Markovian autoregressive models with two unobservable regimes were estimated according to the methodological strategy proposed in stage 1, which made it possible to characterize the dynamics describing the monthly growth behavior of state manufacturing sales in Mexico during the sample period. The results in Table 4 indicate that manufacturing sales in 7 states describe a growth dynamic characterized by a transition between slow and fast monthly growth regimes. In this regard, for example, the state of Baja California has an average monthly growth of 0.19% during its slow growth stages, while

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this magnitude increases notably during its fast growth stages. In the states of Campeche and Guanajuato, on the other hand, manufacturing sales would reach an average monthly growth of a little over 70% during the fast growth periods, although, with a rate of 1.64%, manufacturing sales in Campeche would grow at the highest rate observed during the slow growth stages. Estimates suggest that manufacturing sales would also increase rapidly, albeit at a slower rate, in the State of Mexico, Quintana Roo, and San Luis Potosi during the higher growth stages and at rates around 0.5% during the low growth stages. In the state of Puebla, however, the dynamics of manufacturing sales describe a less accentuated transition between the stages of slow and fast growth, with a difference of approximately 2.6%.

Additionally, the estimates suggest that manufacturing sales in Baja California and the State of Mexico have the highest probability of remaining in the same slow or fast growth regime as in the previous period. For example, with a probability p=q=0.98, manufacturing sales in Baja California would continue in a fast or slow growth regime, provided that they were also in one of them in the previous period. The state of Puebla similarly shows a high persistence in the dynamics of its manufacturing sales of remaining in one of both types of regimes, although in this case the probabilities are lower. In the remaining 7 states, manufacturing sales have a lower probability of remaining in the fast-growth regime, as can be seen in San Luis Potosí, whose probability is, in this case, p=0.02. This lower persistence implies that the fast-growth stages would have a shorter duration than the slow-growth stages, whose probability is q=0.98.

In contrast, the estimates show that the dynamics of monthly growth in manufacturing sales in the remaining 17 states is characterized by a cyclical behavior that describes the transition between stages of contraction and rebound in this indicator (Table 4). A common feature in this set of states that describes the cyclical dynamics of their manufacturing sales is the skewness between both regimes. In the states of Aguascalientes and Nayarit, for example, it can be seen that the estimated magnitude in the positive growth stage, $\propto_0 + \propto_1$, notably exceeds the estimated magnitude during the contraction stage, $\propto_0$. Although the difference between the estimated magnitudes in both regimes is minor, the cyclical dynamics of manufacturing sales in Baja California Sur, Chiapas, Durango, Guerrero, Jalisco, Michoacán, Morelos, Sonora, and Tabasco describe a similar skewness. In Tabasco, in particular, the magnitude of contractions and rebounds in average monthly growth is similar.

Nevertheless, in 7 states, the estimated magnitude of the contraction, $\propto_0$, exceeds the estimated magnitude in the positive growth stage, $\propto_0 + \propto_1$. This type of asymmetry means, therefore, that this set of states would have greater difficulty in recovering their sales after a contraction if the probability of remaining in this contractionary stage is equal to or greater than the probability of remaining in the positive growth stage, as seems to occur in the states of Colima, Hidalgo, and Tamaulipas. Figures A2

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and A3, located in the Appendixes, show the probabilities that make it possible to infer whether the monthly growth of state manufacturing sales would be in a contractionary regime during the year 2020.

Table 4
Estimates of Markovian autoregressive models with two regimes for state manufacturing sales in Mexico in the period 2013-2020

State	$\propto_0$	P (0→0) =q	$\propto_0 + \propto_1$	P (1→1) =p
Aguascalientes	-0.12	0.97	33.19	0.75
Baja California	0.19	0.98	106.37	0.98
Baja California Sur	-1.12	0.78	5.33	0.64
Campeche	1.64	0.95	72.26	0.68
Colima	-5.74	0.32	4.08	0.36
Chiapas	-1.76	0.83	12.92	0.98
Mexico City	-4.98	0.8	-0.16	0.04
Durango	-0.87	0.85	4.37	0.7
Guanajuato	0.34	0.98	73.85	0.56
Guerrero	-2.92	0.62	4.36	0.47
Hidalgo	-2.38	0.7	1.67	0.27
Jalisco	-1.36	0.39	2.69	0.89
State of Mexico	0.59	0.95	11.61	0.98
Michoacán	-0.47	0.77	6.05	0.69
Morelos	-3.08	0.71	10	0.86
Nayarit	-3.37	0.8	24.65	0.98
Oaxaca	-8.75	0.37	6.04	0.61
Puebla	1.04	0.73	3.71	0.78
Quintana Roo	0.57	0.96	10.17	0.61
San Luis Potosí	0.69	0.98	16.05	0.02
Sonora	-0.89	0.86	9.46	0.55
Tabasco	-2.93	0.5	3.57	0.55
Tamaulipas	-2.3	0.42	1.29	0.4
Tlaxcala	-3.74	0.2	3.56	0.64
Veracruz	-2.4	0.0	0.81	0.42

Source: Calculations by the authors

http://dx.doi.org/10.22201/fca.24488410e.2021.3576

Note: the Bayesian information criterion (BIC) was used to choose the most appropriate specification for each of the estimated state models

Quantification of the cyclical effects of fluctuations in the number of COVID-19 infections on manufacturing sales and identification of adaptation strategies

Table 5 shows the results of the estimation of the economic-epidemiological model proposed in expression (3) to identify state differences in the adaptation strategies adopted by economic agents and government authorities to fluctuations in the number of COVID-19 infections during the phases of contraction, $S_t = 0$, and rebound, $S_t = 1$, in manufacturing sales during the period between March and December 2020. The negative sign obtained in the estimation of the parameters β_0 and β_1 associated with the interactive variable suggests that 11 states implemented predominantly precautionary strategies during the contraction and rebound phases in manufacturing sales. However, the response in these states to variations in the number of new coronavirus infections during both cyclical phases is asymmetric, therefore indicating that reopening and consumer protection measures were carried out with different intensities. In this line, in Baja California, the estimated coefficient $\beta_0 = -0.25$ suggests that the contraction in manufacturing sales would respond to the increase in the number of COVID-19 infections, in clear agreement with a precautionary strategy. However, the sign and greater magnitude of the coefficient $\beta_1 = -4.04$ show that reopening and safe consumption measures would have been promoted with greater intensity when the number of COVID-19 infections decreased. The statistical significance of both estimated coefficients indicates that the strategies would have been implemented effectively during both phases.

The results of the estimations also suggest that Mexico City and the state of Michoacán would have implemented a similar precautionary strategy that would have taken advantage of the periods of decline in the number of infections by the new coronavirus to stimulate their state economies by promoting safe consumption measures. In Mexico City, the smaller difference between the magnitudes of the estimated coefficients shows that it would have followed a more balanced precautionary strategy during both cyclical phases, although slightly inclined toward the stage of rebound in manufacturing sales.

On the other hand, the results obtained reveal different variants in the states that would have also sought to implement precautionary strategies during both cyclical phases. In this regard, although the sign obtained in both coefficients is negative in Chiapas and the State of Mexico, only the one estimated for the sales rebound phase is statistically significant, implying that the precautionary measures used during the stages of declining sales were ineffective in the face of increases in the number of infections. On the other hand, in the states of Colima, Guerrero, Puebla, and Veracruz, the estimated coefficient during the contractionary phase of manufacturing sales, β_0, is lower than that obtained for the rebound phase, β_1, suggesting that these states would have accentuated the precautionary measures for health protection over the precautionary measures for economic reopening and safe consumption during the rebound phases, particularly in the last three states mentioned, whose lack of statistical significance in the β_1 coefficient indicates that the implementation of some stimulus or reopening measure would have been insufficient to boost consumption.

Likewise, the results obtained show that 14 states would have adopted less precautionary adaptation strategies to the COVID-19 pandemic since the rebound phases in their manufacturing sales coincide with the increase in the number of infections. On this occasion, the sign obtained for the estimated coefficient β_0 is negative, implying a precautionary behavior similar to that observed in the first set of states mentioned above. In contrast, the estimated coefficient β_1 appears with a positive sign suggesting that these states would have promoted the reopening of activities and implementation of safe consumption measures during the episodes of increased infections. In some states, such as Aguascalientes, Baja California Sur, Jalisco, and Tamaulipas, the statistical significance of both estimated coefficients shows that the combination of the two types of measures was effectively implemented, although with a greater tendency toward the rebound phase, as suggested by the skewness between their magnitudes. On the other hand, in the states of Campeche, Guanajuato, Morelos, and Oaxaca, although they would have effectively implemented a strategy of reopening activities and safe consumption during the rebound phase in their manufacturing sales, the absence of statistical significance in the β_0 coefficient suggests that the restrictive measures adopted during the increase in the number of infections would have been ineffective. In the remaining 5 states, the signs of the estimated coefficients, β_0 and β_1, suggest that they would have implemented similar strategies during the stages of contraction and rebound in their manufacturing sales. However, the absence of statistical significance in both cases shows that the specific measures to boost consumption and consumer protection would have been carried out unlinked to the behavior of the number of COVID-19 infections.

Table 5
Cyclical effects of fluctuations in the number of Covid-19 infections on state manufacturing sales in Mexico between March and December 2020

State	St=0		St=1	
	Bo	t statistic	B1	t statistic
Aguascalientes	−0.15	−1.95	1.67	2.31
Baja California	−0.25	−2.80	−4.04	−12.96
Baja California Sur	−0.06	−3.66	0.21	3.9

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Campeche	−0.10	−1.38	3.14	18.89
Colima	−0.12	−2.63	−0.04	−1.92
Chiapas	−0.01	−1.79	−0.26	−2.15
Mexico City	−0.04	−2.44	−0.07	−8.52
Durango	−0.002	−0.83	−0.04	−0.92
Guanajuato	−0.062	−1.18	0.91	7.6
Guerrero	−0.008	−2.67	−0.017	−0.67
Hidalgo	−0.04	−3.39	0.000	3.33
Jalisco	−0.08	−2.29	0.18	2.22
State of Mexico	−0.03	−1.58	−0.09	−16.17
Michoacán	−0.02	−2.02	−0.34	−2.92
Morelos	−0.05	−1.82	0.22	3.21
Nayarit	0.001	0.1	−0.48	−1.24
Oaxaca	0.006	0.012	0.02	2.25
Puebla	−0.21	−1.92	−0.42	−1.47
Quintana Roo	−0.007	−0.46	−57.62	−1.33
San Luis Potosí	−0.05	−1.61	0.02	0.41
Sonora	−0.01	−0.17	0.15	1.06
Tabasco	0.002	0.33	0.003	0.67
Tamaulipas	−0.03	−4.66	0.05	2.96
Tlaxcala	−0.04	−1.82	0.08	1.46
Veracruz	−0.04	−9.77	−0.04	−1.07

Source: Calculations by the authors

Conclusions

The contractionary effects that the initial measures of lockdown, distancing, and reduced mobility had on the functioning of the Mexican economy in an attempt to slow the spread of COVID-19 led economic agents and local government authorities to adopt measures that sought to make the protection of health and the performance of state economies compatible. Notwithstanding, the absence of similar national and international experiences that could serve as a reference for the adoption of these measures led to the differentiated design and implementation of strategies for economic adaptation to the pandemic. In this regard, intending to investigate the recovery process of the Mexican economy, particularly in manufacturing consumption, this paper identifies state differences in the adaptation strategies implemented by economic agents and governmental authorities to the variations in the number of COVID-19 infections.

The empirical evidence obtained through the application of a two-stage methodology made it possible to identify the adoption of two strategies for adapting state manufacturing sales to variations in the number of COVID-19 infections, with some specific strategic variants: 1) One strategy, with a predominantly precautionary character, describes states whose manufacturing sales recovery process was based on countercyclical adaptation measures. The states, in this case, would promote the partial closure of economic activities, the imposition of limits on the capacity of establishments, and the reduction of their opening hours to serve customers, causing a decrease in manufacturing sales during episodes of an increase in the number of COVID-19 infections. In episodes with a decrease in the number of infections, on the other hand, the states would reverse these measures, causing a rebound in sales. 2) A second, less precautionary strategy describes states that would seek to balance the recovery of manufacturing sales with health protection by adopting a combination of countercyclical and procyclical measures during periods of rising COVID-19 infections. Unlike those that resorted to a predominantly precautionary strategy, these states would have chosen to reverse restrictive measures during spikes in the number of infections.

Some specific strategic variants can be identified from the skewness found between the magnitudes of the estimated coefficients measuring the cyclical effects of variations in the number of COVID-19 infections. In this line, the estimates obtained indicate that most of the states that adopted one or the other precautionary strategy describe a skewness between the coefficients, where $\beta_0 < \beta_1$, implying in both cases that these states would have sought to implement measures more inclined toward the protection of their economies than toward health. Statistical significance in one or both of the estimated coefficients provided insight into the effectiveness with which the states would have implemented both types of precautionary strategies. In this regard, the statistical significance of the estimated coefficients shows that 18 states would have effectively implemented at least one recovery measure during the contraction and rebound stages of their manufacturing sales. One implication that seems to emerge from the interstate differences in the effective implementation of these precautionary strategies—particularly if any were to become a kind of policy rule for pandemic management—suggests that the states whose implementation was effective would be those with a clear communication strategy with economic agents about measures to reconcile health protection and manufacturing sales. By reducing uncertainty, these strategies would have contributed to modifying their behavior during the episodes of decline and rebound in the number of COVID-19 infection.

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http://dx.doi.org/10.22201/fca.24488410e.2021.3576

Annex

Table A1
Monthly growth of manufacturing sales (VM) and number of infections (EE) in the states of Mexico during 2020 (In percentages)

	Aguascalientes		Baja California		Baja California Sur		Campeche		Coahuila		Colima		Chiapas		Chihuahua		Mexico City	
Period	VM	EE	VM	EE	VM	EE	VM	EE	VM	EE	VM	EE	VM	EE	VM	EE	VM	EE
2020M01	0.04	45.82	-0.685	62.36	-3.307	0.97	-0.059	-6.58	7.205	7.87	11.17	29.95	4.608	6.48	3.016	1.19	0.043	2.82
2020M02	5.211	25.20	0.516	11.97	-0.706	5.40	-11.621	1.66	-0.902	0.53	-2.087	25.63	0.364	10.68	1.328	9.51	-0.395	-33.56
2020M03	-3.236	66.15	-10.742	-4.52	12.116	110.66	36.475	2.60	-3.615	3.28	6.463	48.12	0.053	-6.43	-2.931	9.52	1.751	99.12
2020M04	-66.485	54.30	-52.121	202.97	-13.168	225.63	18.452	253.29	-60.596	14.03	-0.191	1.98	-10.068	22.68	-42.244	10.21	-20.716	333.45
2020M05	-4.018	209.53	6.996	146.09	1	61.49	-57.684	520.35	-1.554	135.09	-7.513	284.20	-3.293	723.42	-3.488	162.15	-11.524	320.34
2020M06	98.074	33.03	95.517	-24.34	5.139	91.86	32.37	120.27	171.394	244.62	6.218	118.50	8.365	0.91	84.71	-6.08	14.865	-13.32
2020M07	38.785	22.79	42.48	-1.09	-5.866	174.95	186.349	61.91	6.446	81.63	-1.285	156.60	-3.972	-53.24	4.686	18.31	11.095	1.54
2020M08	-1.47	6.71	-7.04	-0.06	0.537	35.35	-37.336	-52.58	-4.332	-86.05	-13.273	71.82	14.627	-37.59	-1.705	48.41	-4.475	25.69
2020M09	4.099	-22.92	-0.524	-39.39	4.113	-38.94	-29.703	-70.33	5.441	326.13	16.145	-42.83	2.415	-52.49	2.396	2.18	6.437	-14.58
2020M10	34.319	52.83	14.156	38.94	-0.801	-6.15	-4.622	40.82	2.938	60.79	3.03	16.93	-9.679	189.21	-7.809	94.56	-2.065	23.86
2020M11	5.276	129.15	-13.29	47.63	-1.657	8.52	-19.842	-23.65	-8.791	27.59	-3.233	-42.79	2.402	-65.98	1.984	99.01	1.327	102.00
2020M12	1.22	-50.82	-4.071	43.98	3.063	28.04	21.07	14.41	0.322	-29.13	12.966	-16.61	-4.956	79.04	2.022	-64.56	4.556	55.51

Source: created by the authors

http://dx.doi.org/10.22201/fca.24488410e.2021.3576

Table A1
Monthly growth of manufacturing sales (VM) and number of infections (EE) in the states of Mexico during 2020 (In percentages), cont.

	Durango		Guanajuato		Guerrero		Hidalgo		Jalisco		State of Mexico		Michoacán		Morelos		Aguascalientes	
Period	VM	EE	VM	EE	VM	EE	VM	EE	VM	EE	VM	EE	VM	EE	VM	EE	VM	EE
2020M01	3.155	-28.93	2.215	-12.80	2.81	-7.90	9.437	-8.83	-1.603	7.52	-0.549	-3.73	-1.212	14.73	11.572	76.72	33.962	-13.91
2020M02	2.001	15.64	-3.089	-0.17	-2.887	45.78	-1.156	2.25	-0.738	1.33	3.163	-29.78	1.965	18.35	-2.966	-10.50	-15.714	-34.22
2020M03	8.951	6.66	0.28	-12.00	-3.82	-0.92	-0.874	-15.06	2.684	7.73	-2.786	49.61	11.405	-4.28	-13.693	63.15	8.14	59.37
2020M04	-6.508	30.04	-64.289	20.03	-2.748	181.12	-31.07	98.38	-12.87	-20.22	-31.462	383.31	-10.702	165.55	-7.579	298.07	1.257	-2.96
2020M05	1.123	527.10	-6.025	420.19	-3.498	-8.26	-10.532	533.03	-10.338	147.95	-7.309	357.76	-6.277	383.00	-24.615	22.84	5.467	536.85
2020M06	-0.46	38.87	178.771	181.94	4.493	88.25	14.557	2.60	19.801	91.21	34.557	20.40	4.761	78.41	32.29	24.07	-9.857	83.04
2020M07	-3.75	25.22	8.915	86.20	-1.883	-73.06	-9.128	28.73	7.694	10.84	0.16	-16.40	2.569	-2.02	23.455	63.79	-0.643	32.11
2020M08	0.218	-7.60	1.467	-0.04	0.3	146.18	-0.532	46.00	-7.377	37.56	14.951	5.43	2.334	65.00	6.339	-71.37	-24.154	9.27
2020M09	2.563	-55.30	0.115	-38.39	9.513	-77.36	17.549	-44.44	6.874	-26.28	6.326	-29.42	18.438	-22.96	-11.351	146.10	51.541	-46.22
2020M10	-0.234	130.23	1.152	-5.02	-3.236	615.71	-2.243	25.85	-0.155	0.48	-6.828	26.65	-10.25	-19.17	4.622	23.71	-3.485	-22.31
2020M11	-0.807	774.49	-2.349	129.19	1.69	167.88	-1.165	38.45	-0.013	34.07	5.766	16.36	-2.787	5.65	-16.153	-60.44	4.918	-5.47
2020M12	3.214	-98.61	3.108	-0.07	1.037	-91.42	28.36	21.32	3.624	1.82	-0.23	67.88	-2.948	2.80	17.91	155.43	-4.336	4.20

Source: created by the authors

Table A1
Monthly growth of manufacturing sales (VM) and number of infections (EE) in the states of Mexico during 2020 (In percentages), cont.

	Nuevo León		Oaxaca		Puebla		Querétaro		Quintana Roo		San Luis Potosí		Sinaloa		Sonora		Tabasco	
Period	VM	EE	VM	EE	VM	EE	VM	EE	VM	EE	VM	EE	VM	EE	VM	EE	VM	EE
2020M01	-1.511	15.87	0.267	-26.26	17.174	-49.81	6.488	-2.88	1.438	12.77	-2.314	5.10	-2.39	27.70	16.829	-11.70	-8.268	-18.98
2020M02	3.58	-24.72	-10.772	37.34	-9.773	7.97	0.301	-27.08	3.714	-30.96	17.719	-24.40	4.412	-1.13	-3.176	18.85	2.898	11.12
2020M03	4.878	36.41	-15.059	-7.74	4.732	106.56	-0.938	34.78	-8.137	123.73	6.803	13.95	1.009	37.97	-21.185	10.84	-3.201	25.00
2020M04	-33.655	-6.87	-22.633	11.83	-71.958	110.41	-31.782	-1.57	-2.202	468.82	-49.099	-15.15	4.09	78.90	-26.19	15.36	1.772	655.60
2020M05	-2.777	239.00	16.556	755.76	-26.701	383.51	-10.218	552.76	-1.113	79.92	-17.246	414.58	-5.749	217.34	-7.789	561.14	0.668	353.42
2020M06	36.512	228.21	17.306	99.22	75.522	111.77	49.264	1.01	-1.963	21.65	96.392	101.70	3.839	26.00	63.599	122.94	4.181	40.48
2020M07	2.987	101.39	-8.593	11.77	178.527	9.18	14.045	50.92	12.062	65.30	31.158	157.15	2.056	-13.95	34.844	37.00	1.354	50.81
2020M08	2.999	22.42	41.543	-22.01	2.432	-9.11	-2.299	98.01	- 30.023	-38.62	0.924	47.35	-1.455	1.07	-59.663	-49.03	2.691	-23.58
2020M09	4.542	-23.77	-1.778	-7.72	1.376	-53.11	1.682	-26.99	25.54	-39.13	0.204	-53.09	4.22	-39.50	42.777	-35.88	3.546	-60.45
2020M10	2.908	17.83	-2.542	16.74	0.378	10.00	0.246	77.86	- 13.016	-0.98	-3.362	17.36	-4.163	10.55	14.797	344.67	-1.587	-20.20
2020M11	-0.865	34.23	-11.406	-6.40	-5.173	21.27	0.431	121.04	22.88	-2.58	0.506	30.56	-4.775	3.86	13.929	-47.59	-4.623	53.96
2020M12	3.155	-19.69	9.218	-3.70	4.504	45.15	3.444	-10.07	-3.715	10.89	2.344	-35.17	9.943	-30.67	-1.566	4.71	-1.954	77.50

Source: created by the authors

http://dx.doi.org/10.22201/fca.24488410e.2021.3576

Table A1
Monthly growth of manufacturing sales (VM) and number of infections (EE) in the states of Mexico during 2020 (In percentages), cont.

	Tamaulipas		Tlaxcala		Veracruz		Yucatán		Zacatecas	
Period	VM	EE	VM	EE	VM	EE	VM	EE	VM	EE
2020M01	-4.406	6.05	-1.943	-6.53	1.309	-13.87	-2.124	25.28	6.807	0.11
2020M02	-5.676	-15.99	-0.051	-57.76	-3.911	-8.02	3.386	35.07	-0.716	-11.85
2020M03	1.743	32.23	2.68	109.25	5.329	28.84	-0.228	18.97	0.552	27.44
2020M04	-9.466	39.55	-36.943	338.24	-9.287	131.63	-1.612	135.14	-46.928	-27.95
2020M05	-4.798	244.46	-9.407	23.82	-16.505	538.33	-23.745	256.36	-5.089	106.98
2020M06	5.81	165.04	30.493	93.44	16.131	34.13	8.786	55.76	63.004	95.13
2020M07	8.901	93.09	24.172	166.26	-1.335	57.16	21.347	79.79	25.494	120.06
2020M08	0.358	-15.24	-1.038	-82.39	-6.23	-22.90	-7.168	4.88	-2.733	-72.97
2020M09	1.854	-50.65	12.129	-64.47	7.13	-43.59	1.335	-44.80	-0.905	-42.70
2020M10	1.148	-24.46	-7.543	710.09	0.185	-23.79	6.982	-3.35	0.955	203.91
2020M11	-2.019	29.07	-0.528	-75.76	2.431	-1.56	-0.848	1.12	2.65	-60.74
2020M12	-1.292	-22.83	5.345	238.22	3.332	-13.24	7.962	-24.38	-0.669	66.93

Source: created by the authors

http://dx.doi.org/10.22201/fca.24488410e.2021.3576

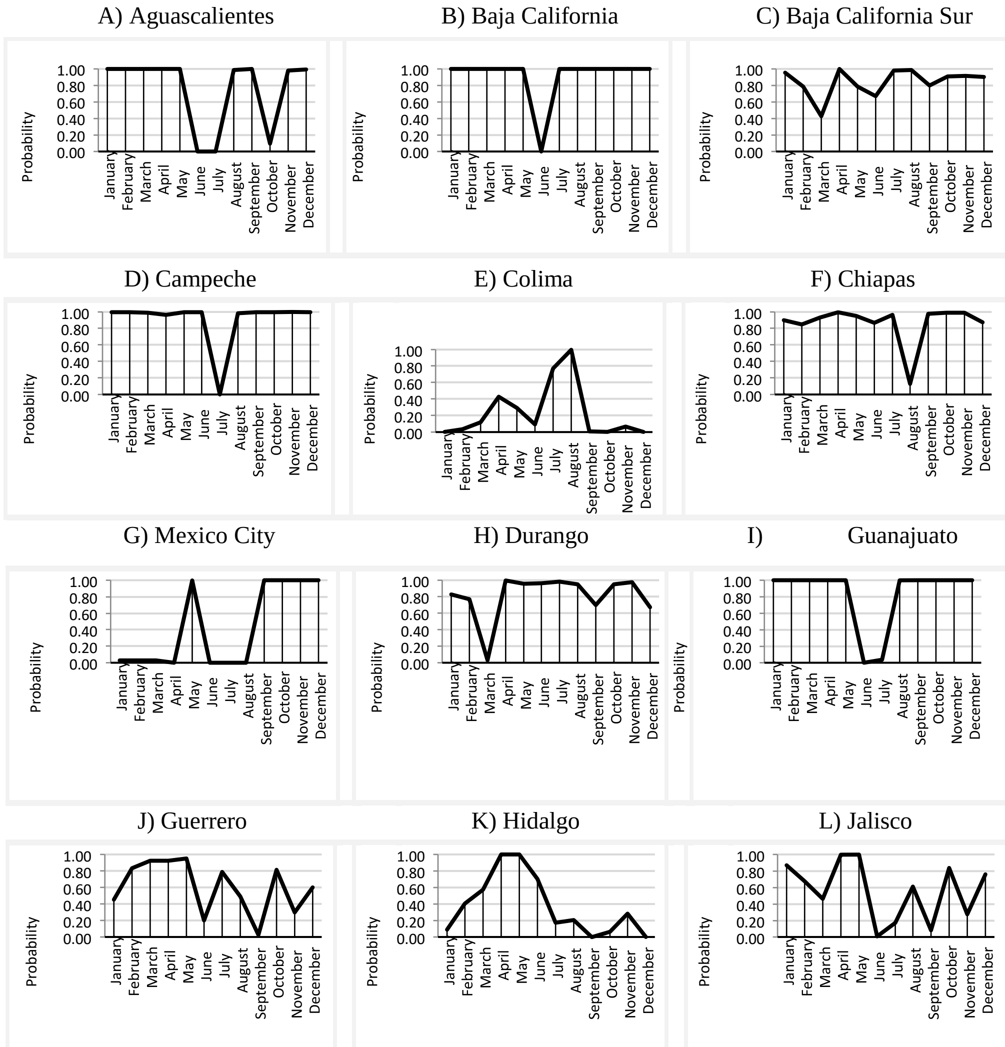

Figure A2. Probability distribution of manufacturing sales being in the slow-growth regime or in a contraction (St = 0) during 2020

Source: Calculations by the authors

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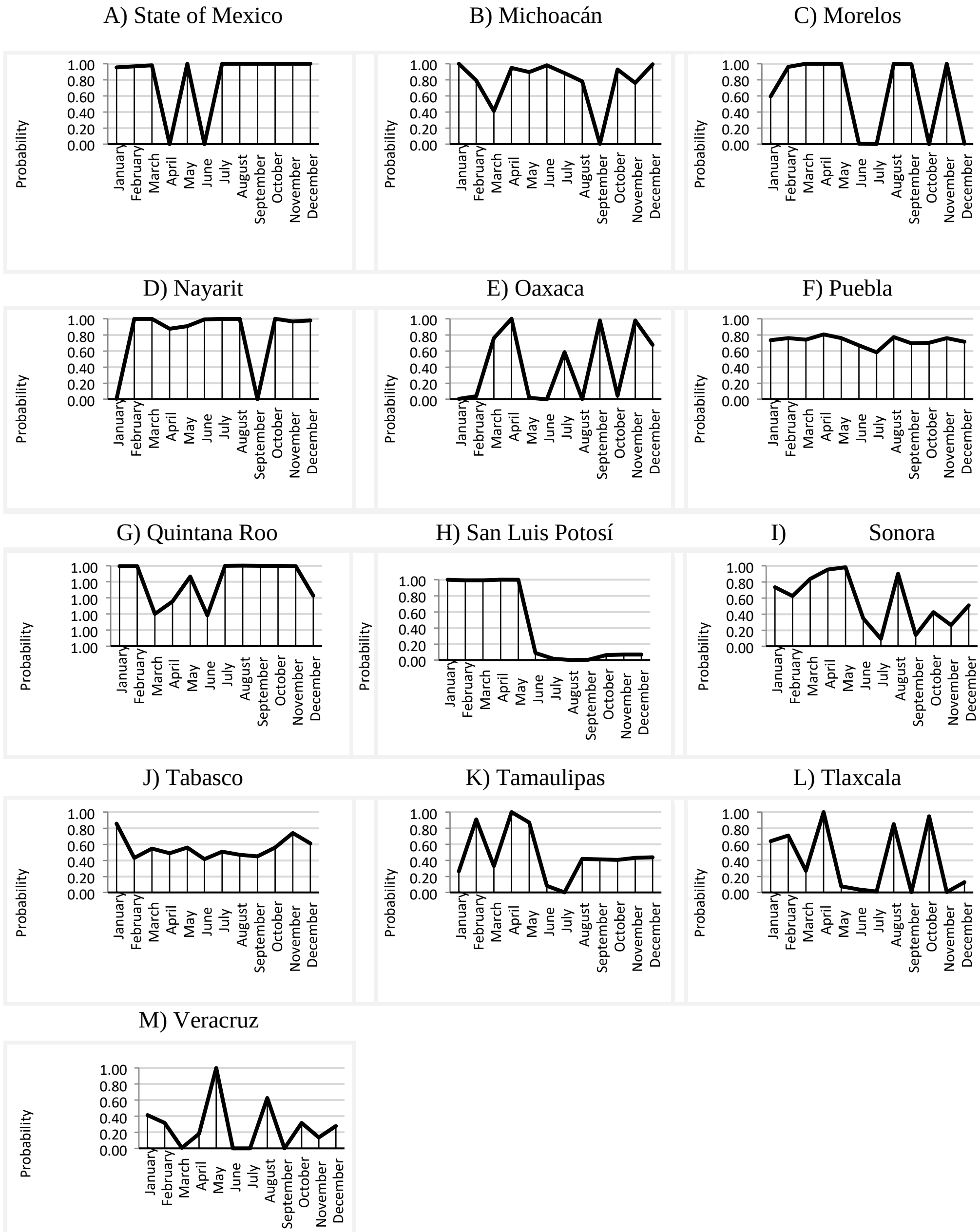

Figure A3. Probability distribution of manufacturing sales being in the slow-growth regime (St = 0) during 2020