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Contaduría y Administración

Accounting & Management

Contaduría y Administración 65 (5), Especial COVID-19, 2020, 1-19

Structural vulnerability of the Mexican economy before the crisis induced by the COVID-19 pandemic

La vulnerabilidad estructural de la economía mexicana ante la crisis derivada de la pandemia COVID-19

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Received August 22, 2020; accepted September 10, 2020
Available online August 17, 2022

Abstract

The paper assesses the structural fragility of Mexico's economy at the outbreak of the Covid-19 sanitary crisis. Following Chenery and Watanabe (1956), Rasmussen (1963) and Laumas (1976), indexes of both backward and forward linkages of the manufacturing industrial sector are estimated. The empirical analysis revealed that the economy's vulnerability at the moment the pandemic stroke the country is rooted in the latter's high technological dependence, the domestic industrial sector's weak linkages and, last but no least, Mexico's highly concentrated exports in the world economy. These very same structural features will, ceteris paribus, also determine the velocity, timing, and strength of the recovery from the crisis and the convergence to the path the economy exhibited prior to the Covid-19 shock.

JEL Code: I18, L5, L6, O470
Keywords: public health; regulation and industrial policy; manufacturing; economic growth and productivity

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

http://dx.doi.org/10.22201/fca.24488410e.2020.3026

Resumen

En el presente artículo realizamos un diagnóstico de la fragilidad estructural de la economía mexicana en el momento en que ocurrió el impacto de la crisis de salud Covid-19. Con la metodología de Chenery y Watanabe (1956), Rasmussen (1963) y Laumas (1976) estimamos índices de eslabonamientos hacia atrás y hacia adelante del sector industrial manufacturero. El análisis empírico revela que la dependencia tecnológica, los débiles eslabonamientos productivos de este sector y la alta concentración de nuestras exportaciones en el mercado mundial, condicionaron la vulnerabilidad de la economía ante la irrupción de la pandemia y, ceteris paribus, determinarán el ritmo, vigor y tiempos de la recuperación cíclica y del retorno de la economía a la trayectoria de desarrollo previa al choque de la crisis sanitaria.

Código JEL: I18, L5, L6, O470
Palabras clave: salud pública; regulación y política industrial; manufacturas; crecimiento económico y productividad

Introduction

The world is suffering from the scourge of a health crisis whose adverse economic effects are unprecedented in magnitude and nature. The United Nations Conference on Trade and Development (UNCTAD) forecasts that foreign direct investment flows will decline by 40% in 2020 and 5% to 10% in 2021 (UNCTAD, 2020a). No one doubts that the world economy will contract drastically. The manufacturing sector, services, global trade chains, financial markets (bonds and credit), and commodity prices have collapsed (the Brent crude oil price has fallen by more than 60%).

The negative effects on developing countries have been greater than in industrialized nations. For example, between February 21 and March 24, 2020, net portfolio capital flows (bonds and equities) from emerging economies to leading financial markets amounted to USD 59 billion, more than double the figure for the Great Financial Crisis of 2008. The spread of government debt bonds in these countries has increased, and their currencies have depreciated (UNCTAD, 2020b).

The Covid-19 health crisis emerged when Latin American economies presented accentuated macroeconomic vulnerability: from 2010-to 2019, the region's Gross Domestic Product (GDP) growth rate fell from 6% to 0.2%, the weakest performance since 1950 (CEPAL, 2020). In the case of Mexico, the forecast is of an annual aggregate contraction of -9% in 2020. Meanwhile, in April-June 2020, GDP contracted by 53.2%, industrial production (manufacturing, construction) fell by 65.9%, agriculture by 9.6%, and formal employment fell by 3.5% in annualized terms (Cañas & Smith, 2020); exports decreased by 21.1% between May 2019 and May 2020; between December 2019 and August 2020 the peso depreciated by 14.7%. As a compensatory reaction, the Bank of Mexico reduced its benchmark interest rate (by 50 base points) to 5%.

http://dx.doi.org/10.22201/fca.24488410e.2020.3026

The main objective and contribution of this article are twofold. On the one hand, it makes a diagnosis of the conditions of Mexico's economic structure, the production linkages by degree of technological intensity, and the value added of the key sectors of the economy at the time when the Covid-19 health crisis broke out, causing an unprecedented supply and demand shock in the national economy. On the other hand, several economic policy guidelines that should constitute the fundamental levers for cyclical recovery and sustained growth are inferred based on this analysis. This research makes heuristic use of the essentials of Hirschman's (1958) unbalanced growth strategy, Chenery and Watanabe's (1956) productive linkages analysis, Rasmussen (1963), and Laumas (1976).

The hypothesis is that technological dependence, the weak production linkages of the Mexican manufacturing sector, and the high concentration of exports in the world market conditioned the vulnerability of the economy to the outbreak of the pandemic and, ceteris paribus, will also determine the speed, strength, and time of the cyclical recovery and the return of the economy to the development trajectory prior to the health crisis shock.

After this introduction, Hirschman's development strategy is discussed as a theoretical framework. The third part presents a brief review of the relevant empirical literature, and the fourth part presents the methodology and empirical analysis. The conclusion synthesizes the argument, summarizes the results, and discusses the policy implications of this research.

Theoretical framework

Hirschman (1958, p. 89, passim) suggests that investment should be oriented toward fixed capital stock (FCS), which includes public services such as health, communication and transportation, education, and infrastructure necessary for development. It is also necessary to identify the directly productive activities (DPA) in which, due to their greater impact on the economy, it will be more efficient to invest. Investment in FCS indirectly affects DPA; however, it may be more appropriate to invest directly in DPA due to their multiplier effects that will induce a subsequent sequence of more efficient investment decisions (Thirlwall, 2011, p. 325). The strategy proposed by the "unbalanced growth"[1] hypothesis is based on a structural analysis of the economy through the input-output model (IOM) to identify linkages in the production chain and to understand the interdependence between economic sectors (Chenery & Watanabe, 1956; Rasmussen, 1963). Thus, by establishing the backward and forward linkages, investment can be oriented

[1]Hirschman's model is a critique of the balanced growth model proposed by Rosenstein-Rodan (1943) and Nurkse (1953).

toward the productive activities (heavy and light industry, agriculture, exports, and import substitution) that have the greatest impact on total output.

Emerging industries require inputs that, since they are not produced locally, must be imported; however, some aspects can limit imports, such as the position of the balance of payments and the exchange rate. To understand the development process to be followed, it is necessary to analyze the structure of an economy through the IOM and the strategic sectors that have backward linkages (demand for inputs) and forward linkages (supply of inputs) since they accelerate the development of other sectors. Therefore, knowing the interdependence between sectors is an efficient tool to increase economic activity or, in the case of a depression such as the one induced by the Covid-19 crisis, to be able to orient recovery policies toward key industries.

The degree of industrialization is given by the relative participation of the size and type of industry that characterizes the economy in question. An economy with higher industry participation shows higher productivity, and its linkages promote development. Therefore, the higher the degree of industrial development, the greater the sectoral interdependence. Conversely, the primary sectors are independent and have fewer upstream and downstream linkages, so the primarization of the economy must be avoided.

Hirschman considers it important to determine the triangularization matrix of inter-industrial transactions to accelerate industrial growth by emphasizing the activities with the greatest backward linkages. Therefore, in the development strategy Hirschman (1958) proposed, it is crucial to identify the inter-industrial flows in the economy's input-output matrix because it is thus possible to identify the productive activities with the greatest potential for combined linkages. The main problem of non-industrialized countries is that they are characterized by insufficient interdependence between production sectors (cf. Thirlwall, 2011). This is either because their production structure is characterized by the predominance of primary activities with few backward linkages or because the trade liberalization that began in the late 1980s generated a high content of imported inputs in exports, which has fragmented the value chains.

Ros (2013, pp. 181-188) reinterprets Hirschman's unbalanced growth strategy by presenting a model with pecuniary externalities, elastic labor supply, increasing returns in the production of intermediate goods, and imperfect competition. This model has backward linkages between the modern industrial and intermediate goods sectors. Ros derives multiple long-run equilibria that depend on pecuniary externalities and capital accumulation. This, in turn, is a function of the rate of profit in the modern industrial sector. There is a critical value K* of the capital stock. If the capital stock is lower than K*, a recursive contraction of production will occur because the demand for intermediate goods is low, and the production costs of these intermediate inputs will be high. Thus, the profitability of capital in the modern industrial sector will decline. With this, the size of the industrial sector and the intermediate input sector will contract; the economy will move toward a low equilibrium in which the sectors of increasing returns (manufacturing and intermediate goods) will tend to disappear. And vice versa, if the value of the capital stock is greater than K*, the economy will move toward a high equilibrium. Ros's analysis dynamically presents the importance of economic growth of the linkages of the production chain in a dual economy. Suppose a sector of increasing returns contracts due to a supply and demand shock resulting from the Covid-19 health crisis. In that case, multiplier effects proportional to the backward and forward linkages of the production structure will be triggered.

As already discussed, the recession induced by the Covid-19 health crisis has required governments worldwide to implement massive fiscal and monetary programs to stabilize financial, goods, and labor markets to avoid a prolonged economic depression. Hirschman's development strategy (1958, pp. 201-204) includes two government functions: unbalancing and equilibrating. Anti-recession programs are an expression of the equilibrating function, which aims to prevent the spread of the crisis.

Literature review

The origin of the conception of the economy as a set of interrelationships and interdependencies dates to the second half of the 18th century. François Quesnay analyzed the importance of the circular flow of productive activities and their interdependence in the economy[2]. Based on the law of nature, the physiocrats considered agriculture to be the source of wealth, which generated the net product of the economy. In his Tableau Économique of 1758, Quesnay devised a diagram representing income and products among the sectors of the economy. However, in his system, manufacturing is not a productive sector[3].

In turn, Wassily W. Leontief (1936) developed a closed economy model in which each sector is identified with the final commodity it produces; thus, everything produced is used as an input. Capital coefficients are assumed to be fixed to determine changes in output and investment. Later, Leontief (1941) presented an input-output model that merges the general equilibrium approach with microeconomic analysis and Keynesian macroeconomics. The differential equations comprising the input-output model (IOM) include coefficients of intermediate inputs where final demand is determined exogenously. Later, Leontief (1966, 1986) formulated an IOM through a structure based on the interdependencies existing in the economy. In this way, empirical data serves as a guide for economic policy. The model is classified

[2]In the 17th century, Sir William Petty had already envisioned that the production, distribution, and disposition of wealth in a nation are interconnected and should be accounted for.
[3]The critical algebraic formulation of this argument is due to the French engineer Achille Nicholas Isnard (1871), who defines production as a circular flow and considers surplus value as available wealth (Kurz and Salvadori, 2000).

http://dx.doi.org/10.22201/fca.24488410e.2020.3026

by sector; each sector is characterized by the final product even though it may use several inputs for its production. In this IOM, the technical coefficient measures the combination of inputs required, and the value added refers to the difference between revenues (unit price) and costs per unit produced. Thus, the Leontief inverse matrix includes all sectors of the economy that can measure the direct and indirect effects of changes in supply or demand on final demand[4].

Rasmussen (1963), Chenery and Watanabe (1956), and Hirschman (1958), in turn, propose various methods for calculating sectoral linkages that determine final demand and identify the importance of sectors in the economy. Two types of linkages are distinguished: backward linkages, when inputs from other sectors induce their development, and forward linkages, which provide inputs for other sectors. Rasmussen states that it is better to invest in them to expand the economy by identifying the key sectors. This creates synergies that lead to increased investment, lower costs, and the elimination of bottlenecks to boost production. Unlike the primary sector, industry is characterized by both types of linkages. In the same vein, Chenery and Watanabe propose a methodology to identify the direct effect of sectors on the economy and a sectoral typology: non-manufacturing and manufacturing production with an intermediate and final destination.

In Mexico, the National Institute of Statistics and Geography (INEGI) prepares the input-output matrix based on the system of national accounts; the most recent one was published in 2018 with the base year 2013. Based on the various INEGI input-output matrices, some models have applied regional input-output analysis (Spanish: Matriz de Insumo-Producto Regional, MIPR) with emphasis on the northern border states of Tamaulipas, Sinaloa, Baja California, Coahuila, Chihuahua, and Nuevo Leon (Fuentes, 2003; Chapa et al., 2009; Alvarado et al., 2019; Vera & Langle, 2019), which register export-oriented manufacturing activity[5]. The northern border states are closely related to trade dynamics with the United States, inducing positive employment effects.

In these MIPRs, the regional impact of industry, product multipliers, and value added are analyzed to identify the strategic sectors mentioned above to guide public policies and strengthen regions, municipalities, and states (Flegg et al., 1995)[6]. In general terms, studies have found that the share of the tertiary sector (transportation and administrative services) in total output is greater than that of industry.

[4]The matrix can demonstrate the relationship between the supply and use of products, or else the production of industries and the demand for the production of industries (Sistema de Cuentas Nacionales de México, INEGI, p. 29, 2018).

[5]According to the Report of the Bank of Mexico on Regional Economies, the country is divided into four zones: north, north-central, central, and southern; most studies focus on the northern border zone due to its strong export-oriented industrial sector.

[6]This analysis is used to obtain an estimator of the percentage of production coefficients corresponding to the region under study.

Additionally, some subsectors in the manufacturing sector present backward and forward linkages, and because of their greater contribution to value added, they are strategic in the economy.

There is also evidence of industrial concentration in the border region and other central states, but this concentration is detached from the local economy (Vera & Langle, op. cit.). Although there is an intersectoral linkage as heavy manufacturing is a voracious market for inputs, these inputs are not of local origin. Therefore, strengthening domestic industry requires identifying, through input-output analysis, the production chains and local input supplies needed to reduce dependence on imported inputs (the role of intermediate goods analyzed by Ros (2013) in his interpretation of Hirschman's (1958) unbalanced growth)), and thus avoid bottlenecks in final production.

Quantitative analysis

Background and macroeconomic effects of the health crisis: Some stylized facts

The specialized literature recognizes that the transition to the open economy model sought, among other things, to: eliminate the macroeconomic imbalances accumulated during the substitutive industrialization phase; reduce economic and financial sensitivity to external shocks; position the manufacturing sector as the engine of economic activity, leveraged on increased competitiveness and productivity; and achieve high and sustained GDP growth rates.

Although the operation of this model has helped the Mexican economy to reach a stage of macroeconomic stability, contain price volatility, and fiscal consolidation, it also constitutes a period of clear divergences. On the one hand, the stagnation of economic activity, productivity, and capital formation, which, given the concomitant flagrant social inequality, fiscal crisis of the State, and reduction of public spending on health and education, determined the vulnerability of the economy and the low-income social classes to the shock of the Covid-19 health crisis. On the other hand, the rapid growth of international trade and capital flows. Given these vicissitudes, some questions arise. How do productive/commercial specialization characteristics affect the consolidation of production chains? How does the health shock restrict the long-term economic growth path and the performance of the manufacturing sector? Moreover, how should macroeconomic policy operate to promote economic recovery in the face of the recession induced by the Covid-19 health crisis? Table 1 provides an overview of the evolution of the Mexican economy over the last three decades, including the recent phase of the outbreak of the health crisis.

http://dx.doi.org/10.22201/fca.24488410e.2020.3026

Table 1
Mexico: economic activity, investment, and trade

Indicator	1990-2000	2000-2010	2010-2018	2018-2019	First-quarter 2020	Second-quarter 2020
GDP /1	3.5	1.5	2.7	-0.3	-1.4	-18.9
Primary activities /1	1.6	1.7	2.4	0.4	1.4	-0.7
Secondary activities /1	3.2	0.5	1.2	-1.7	-2.9	-26.0
Tertiary activities /1	3.8	2.0	3.4	0.2	-0.7	-15.6
Inflation /1	18.3	4.7	4.0	3.6	3.4	2.8
Household consumption /1	4.3	1.8	2.8	0.7	-0.7	-23.7
Government revenues /1	1.6	4.7	3.0	1.5	-10.9	-6.9
Government spending /1	1.2	5.5	2.6	0.0	19.0	-7.7
Total debt /1	-3.6	6.1	7.6	2.0	9.9	11.9
Gross fixed investment /1	3.8	1.7	2.2	-5.1	-9.3	-38.2
Savings /1	3.1	2.3	3.2	-6.6	-11.4	-
Staff employed /1/2	2.3	0.6	1.6	2.4	-0.6	-
Labor productivity /1/2	1.2	0.8	1.0	-2.6	-3.4	-
Exports /1/3	11.1	3.5	5.6	1.4	1.7	-37.9
Imports /1/3	12.0	2.9	5.0	-0.9	-3.4	-34.2

1/average annual growth rate; 2/ The information on employed personnel for the first quarter of 2020 is taken from ENOE statistics; 3/ The data corresponds to the period from the first quarter of 1993 to the first quarter of 2020; the second-quarter figures use the U.S. GDP deflator.
Source: created by the authors with information from INEGI, Banxico, and Federal Reserve Bank

The manufacturing sector represents the pillar of the Mexican economy's trade exchanges since, according to INEGI data, between 1990 and 2018, its activity supported 80.3% of the country's total exports, in addition to accounting for 19.1% of the employed personnel, 20.5% of gross capital formation, and 48.8% of foreign direct investment (FDI) inflows. However, this sector presents dissimilar results. On the one hand, there was a systematic decrease in its share of the national value added (18.3%) and, on the other hand, there was a persistent contraction in productivity (0.3% annual average). It is important to note that, despite the rapid growth of export activity and the high demand for imports (90.1%), the reduced contribution of domestic value added in manufacturing exports outlines a synthesis of this bifurcation since it indicates the dependent nature of the industrialization process followed by the national economy on imported intermediate inputs and technology. It is a model based on the consolidation of export platforms and specialization in intermediate stages of the value chains.

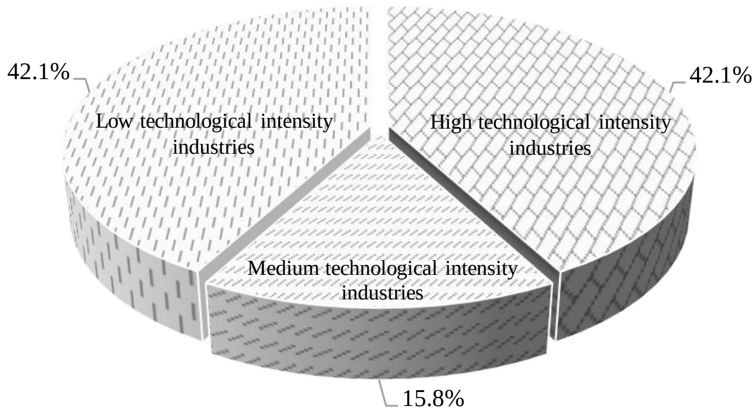

Figure 1. Industrial participation in the value added generated within the manufacturing sector. 1990-2019.
Source: created by the authors with information from INEGI and BANXICO

A significant part of the performance of the manufacturing sector is based on the dynamics of "high" technology-intensive industries (machinery and equipment, computers and electronics, automotive, electrical equipment, and chemicals), which account for 74.8% of exported production, 57.8% of total FDI received, and 61.0% of gross capital formation. Given these figures, it is incompatible, first, that productivity within the dynamic subsectors maintains a persistent contraction; second, there is low incorporation of highly skilled labor; third, there is a low contribution of domestic value-added to exports. The combination of these conditions could be an expression of the subordinate and inoperative role (for economic growth) of the manufacturing sector, especially the dynamic industries, in becoming a propelling factor of the national productive apparatus, the appearance of effective productivity gains associated with international trade, and the greater presence of transnational corporations (see Table 2).

http://dx.doi.org/10.22201/fca.24488410e.2020.3026

Table 2
Economic activity, productivity, and competitiveness
(average 1990-2019)

Concept	PTF1/	VA2/	FBCF2/	EA3/	EM3/	EB3/	FDI2/	X2/	M2/	VAX4/
Manufacturing Sector	-0.3	100.0	100.0	10.6	49.3	40.1	100.0	100.0	100.0	52.3
Low Technology										
Food industry	0.0	26.0	10.7	12.7	42.2	45.1	21.7	4.2	4.4	71.2
Textile industry	-0.9	5.4	1.9	3.3	41.0	55.8	2.0	3.6	3.8	56.2
Wood industry	-0.5	3.4	3.0	16.2	44.6	39.2	2.1	0.9	2.9	59.7
Oil industry	-1.8	3.5	5.1	30.5	52.4	17.1	0.1	1.5	6.0	75.9
Other industries	-1.1	3.7	3.8	8.9	43.8	47.3	2.7	3.8	3.0	62.8
Intermediate Technology										
Plastics industry	-1.2	2.8	3.8	9.2	55.7	35.1	4.5	2.0	4.5	54.2
Non-metallic minerals industry	-0.8	2.9	2.6	15.2	27.1	57.7	2.3	1.2	0.9	57.3
Base metal industry	-2.4	6.6	3.8	19.1	49.4	31.5	5.5	4.7	4.9	69.6
Metal products industry	-0.9	3.4	4.2	12.9	45.7	41.4	2.0	3.3	5.3	54.0
High Technology										
Chemical industry	-2.1	9.0	11.2	28.7	50.3	21.0	12.5	4.1	11.2	58.5
Machinery and equipment industry	-0.9	3.7	8.0	7.7	69.7	22.5	4.0	7.3	11.8	60.5
Computer equipment industry	0.2	10.0	8.0	8.1	64.0	27.8	8.1	23.9	20.6	39.6
Electrical appliance industry	-1.1	3.3	6.8	7.7	63.4	28.8	4.4	8.7	7.3	53.0
Automotive industry	-0.1	16.0	27.0	7.0	65.4	27.6	28.1	30.8	13.2	51.4

PTF: total factor productivity (1990-2018); VA: value added (1990-2018); EA, EM, and EB: employed population with high, middle, and basic education, respectively (1990-2018); FDI: foreign direct investment (1999-2019); X: exports (1993-2018); M: imports (1993-2018); VAX: domestic value added embodied in exports (2005-2015). 1/average annual growth rate; 2/ as a share of the total sector; 3/ as a share of total employed personnel in the subsector; 4/ value added embodied in exports as a share of gross exports.
Source: created by the authors with information from INEGI and the OECD

The health crisis facing the Mexican economy must not only be addressed in terms of its effects on the so-called macroeconomic fundamentals (inflation, fiscal deficit, debt), but it also requires the discussion, design, and operation of an economic policy framework that will enable a stable and efficient reactivation process to be achieved, given the structural characteristics of the national productive apparatus. The main undeniable stylized fact is that technological dependence, the weak production linkages of the manufacturing sector, and the high concentration of Mexican exports in the world market exacerbated the vulnerability of the Mexican economy to the impact of the Covid-19 crisis. Similarly, the distinguishing factors of this stylized fact will determine, ceteris paribus, the pace, vigor, and timing of the cyclical recovery and the return of the economy to the trajectory of development prior to the impact of the Covid-19 health crisis.

Undoubtedly, the epidemiological crisis has caused serious economic and financial devastation. The most recent data indicate that the health containment strategy (lengthening of the contagion and death curve) caused a sharp decline in economic activity and deepened the economic recession in the secondary activity sectors (especially construction and manufacturing) and the contraction of gross fixed investment. There is another significant impact in the sharp drop in private consumption since it reveals both the regression of the labor market (loss of employment, reduction of working hours, and, therefore, wages and salaries) and the consequent general decrease in household welfare.

On the other hand, in addition to the misalignment of public finances, the pandemic led to a significant savings contraction, exchange rate depreciation, and a substantial increase in debt. In addition to the structural problems of productivity and low competitiveness (due to product differentiation), these conditions will tend to restrict the GDP growth rate and induce an "L" shaped cyclical recovery in the long term.

The challenge for economic policymakers lies in projecting a critical short-medium-and long-term path that, in addition to addressing economic imbalances, will make it possible to promote market incentives aimed at boosting productivity, strengthening supply chains (Hirschmanian linkages), co-investment in R&D (applied and experimental), diversifying the origin/destination of international trade, strengthening strategic infrastructure and clean energies, as well as strengthening public spending on health and education.

Methodology and results

Input-output analysis is a useful tool for evaluating the interaction and interdependence between the different economic sectors of an economy. In this framework, the production linkage indices make possible the comparison and ranking of the dispersion or intersectoral drag effect. Thus, an optimal classification of the industrial network facilitates economic policy makers' decision-making to promote market incentives (fiscal, subsidies, infrastructure, or co-investment) or specific critical routes of cushioning, stabilization, and recovery from external shocks represented by the Covid-19 crisis.

For empirical purposes, this paper is based on the production chain indicators of Chenery and Watanabe (1956), Rasmussen (1963), and Laumas (1976), indicators that are consistent with Hirschman's (1958) development strategy. It aims to delineate the propulsive capacity and sensitivity of the productive network of the manufacturing sector to exogenous shocks.

In principle, Chenery and Watanabe (1956) break down the carrying capacity of a sector (subsector, branch, or class of activity) into two types of linkages: backward (EHA) and forward (EHD). Generically, they seek to measure the direct effect of a sector on the rest of the economy, combining both types of linkages.

By construction, the EHA quantifies the productivity interrelationship of a sector (subsector, branch, or class of activity) with the rest of the economy through the demand for intermediate inputs, that is:

$$\mathrm{EHA}_{j}^{CW} = \frac{\sum_{i=1}^{n} X_{ij}}{X_{j}} \tag{1}$$

Where $\sum_{i=1}^{n} X_{ij}$ represents the purchases of the i-th sector to the j-th sector; while X_j constitutes the value of the effective production of sector j. Meanwhile, the EHD presents the multiplier effect of a sector (subsector, branch, or class of activity) with the rest of the economy through its supply capacity, as follows:

$$\mathrm{EHD}_{i}^{CW} = \frac{\sum_{j=1}^{n} X_{ij}}{X_{i}} \tag{2}$$

In this equation, $\sum_{j=1}^{n} X_{ij}$ is the distribution of the product of the j-th sector to the i-th industry; while X_i represents the gross value of the production of sector i.

One problem with this procedure is that the sectoral classification is based solely on production and distribution relationships (direct effect) without considering each sector's structure and productive capacity.

In turn, Rasmussen (1963) analyzed the degree of interdependence between the sectors of an economy by calculating indicators of dispersion power and sectoral absorption. The former is associated with the multiplier effect exerted by the expansion of industry j. The latter is linked to the impact received by sector i, given the expansion of the production network, based on Leontief's inverse. Algebraically, the dispersion index of industry j (backward linkages) on industry i-th, in the face of an increase in final demand, is defined by:

$$EHA_j^R = \frac{\frac{1}{n}\sum_{i=1}^{n} b_{ij}}{\frac{1}{n^2}\sum_{i=1}^{n}\sum_{j=1}^{n} b_{ij}} \tag{3}$$

Where $\sum_{i=1}^{n} b_{ij}$ is the demand (total requirements) for intermediate inputs from the i-th sector to the j-th sector. As for the carry-over effect (dispersion sensitivity), it is expressed as:

$$EHD_i^R = \frac{\frac{1}{n}\sum_{j=1}^{n} b_{ij}}{\frac{1}{n^2}\sum_{i=1}^{n}\sum_{j=1}^{n} b_{ij}} \tag{4}$$

In this expression $\sum_{j=1}^{n} b_{ij}$ represents the quantity of production that sector i should generate to satisfy, ceteris paribus, one net unit of final demand of imports of the j-th industry.

Unlike Rasmussen's unweighted index of total requirements, Laumas (1976) bases their proposal on the relative weight of an industry within the sectoral matrix and the degree of concentration of economic relations. In this way, they define the total backward linkages of a sector as:

$$EHA_j^L = \sum_{i=1}^{n} b_{ij}\frac{Y_j}{\sum_{i=1}^{n} Y_i} \tag{5}$$

This index measures the aggregate impact on the production of the i-th industry of an economy, given a variation in the final net demand for imports of sector j. In this expression, $\sum_{i=1}^{n} b_{ij}$ represents the elements of the matrix of total requirements (direct and indirect), which relates the production of each sector (subsector, branch, or class of activity) with the final net demand for imports; while $\frac{Y_j}{\sum_{i=1}^{n} Y_i}$ constitutes the relative weight of industry j in the total final net demand for imports.

On the other hand, the total forward linkages are expressed as follows:

$$\mathrm{EHD}_i^L = \sum_{j=1}^{n} b_{ij} \frac{\mathrm{VAB}_i}{\sum_{j=1}^{n} \mathrm{VAB}_j} \tag{6}$$

This specification quantifies the impact on the production of industry i (degree of dependence) in light of an expansion/decrease in the final net demand of imports of the j-th sector. Where $\frac{\mathrm{VAB}_i}{\sum_j^n \mathrm{VAB}_j}$ represents the share of sector i in total value added (primary inputs).

Cross-sectionally, industrial activities will be classified according to their dispersion and absorption power as: a) key industries, meaning those industries with high forward and backward linkages; b) base sectors, comprising industries with high forward and low backward linkages; c) driving industries, defined as those industries with low forward and high backward linkages; d) independent industries, meaning industries characterized by low backward and forward linkages (Cardenete, 2011; Schuschny, 2005).

Table (3) presents the values of the direct and total linkage indices, projected with data from the Input-Output Matrix (base 2013). For this purpose, this research considers 14 industrial aggregations, classified according to their technological intensity. The estimates present persistent structural heterogeneity and dissimilar degrees of productive integration in the manufacturing industrial chain. According to the results, the most significant linkage effects (dispersion and propulsion) are linked to the dynamics of the automotive and chemical industries and of the food and basic metals subsectors. The importance of the first two lies in the role they play in export production, the attraction of FDI, and the size of the capital investment generated, although discordant in the generation of added value, is comparatively similar to that generated in the food industry. Therefore, it is imperative to design and implement an industrial policy framework to consolidate backward linkage effects, which will make possible a strategic reduction in the participation of foreign value added in the production process and, therefore, increase product differentiation as a determinant of competitiveness.

Table 3
Direct and total linkages in the manufacturing sector

Subsector	Chenery and Watanabe			Rasmussen			Laumas		
	EHA	EHD	Classif.	EHA	EHD	Classif.	EHA	EHD	Classif.
Low Technology									
Food industry	0.4779	0.1157	SIM	1.1617	0.9672	SIM	5.7334	2.6892	SC
Textile industry	0.4341	0.2875	SIM	1.1096	0.8012	SIM	0.4020	0.1791	SIND
Wood industry	0.5122	0.6819	SC	1.1790	0.9639	SIM	0.2456	0.2117	SIND
Oil industry	0.5824	0.5992	SC	1.1525	3.1189	SC	2.6916	1.8307	SC
Other industries	0.3594	0.1147	SIM	1.0335	0.7586	SIND	0.8154	0.2409	SIND
Intermediate Technology									
Plastics industry	0.3871	0.4799	SC	1.0500	0.9774	SIM	0.8919	0.5190	SIND

http://dx.doi.org/10.22201/fca.24488410e.2020.3026

Non-metallic minerals industry	0.6105	0.7715	SC	1.2927	0.9620	SIM	0.4122	0.4791	SIND
Base metal industry	0.5376	0.5552	SC	1.2129	1.3441	SC	1.8929	1.7855	SC
Metal products industry	0.4818	0.4547	SC	1.1789	0.9763	SIM	1.2171	0.6513	SIM
High Technology									
Chemical industry	0.4558	0.4748	SC	1.0995	2.2726	SC	3.0186	4.6122	SC
Machinery and equipment industry	0.2971	0.0704	SIND	0.9691	0.7294	SIND	1.5357	0.5851	SIM
Computer equipment industry	0.1031	0.0188	SIND	0.7680	0.7423	SIND	4.3796	0.9859	SIM
Electrical appliance industry	0.3367	0.0977	SIND	1.0147	0.7541	SIM	1.8790	0.4265	SIM
Automotive industry	0.3685	0.1127	SIM	1.0339	0.9650	SIM	10.7813	3.1977	SC

SC: key sector; SIM: driving sector; SIND: independent sector; S.B.: base sector
Source: created by the authors with information from INEGI (MIP 2013)

Undoubtedly, a characteristic result is the degree of productive interdependence of the computer equipment industry since the estimates indicate a low or null dispersion capacity or productive absorption power. The relevance of these numerical fluctuations lies in the fact that almost 25% of the export activity of the manufacturing sector is due to this subsector, as well as the high content of imported inputs (foreign value added) in production. This environment is why export manufacturing is not a driving force of the national production system, despite the leverage in high technological intensity activities since the nature of this specialization pattern (outward industrialization or assembly/maquila model) significantly restricts productivity gains.

In the same line of reasoning, according to the estimation of the linkage indicators, the electrical appliances and machinery and equipment subsectors are established as industries with restricted consumption of intermediate inputs and production oriented to final demand (export). Therefore, they present a limited capacity to generate national value added and dynamize the economy.

The heterogeneity of technology-intensive industries in creating value added and generating inter-sectoral linkages and the loss of competitiveness reflect the inability of the manufacturing sector to establish itself as a core of development. Likewise, to the extent that the corporate strategies of transnational companies focus on the operation of export platforms, there is still a fragile diversification of international trade, combined with slow growth (contraction) in productivity and capital investment. These constitute a scenario that accentuates the vulnerability of the industrial sector and slows down the speed of convergence with the pre-crisis equilibrium trajectory in the face of external shocks.

Therefore, economic policy should constitute a significant (upward) turning point in reactivating employment, productivity, investment, and competitiveness, in the short term, through a defined vector of market incentives. In the medium and long term, industrial policy should strategically impact inter-sectoral linkages and promote a greater correlation between productivity and competitiveness based on technological innovation.

Conclusions

This research made a diagnosis of the structural conditions of the Mexican economy with the dual purpose of revealing the structural fragility of the manufacturing microeconomy and macroeconomy in the face of the impact of the Covid-19 health pandemic. To this end, the research heuristically uses the essential message of the development strategy formulated by Hirschman (1958), the production linkages indices proposed by Chenery and Watanabe (1956), Rasmussen (1963), and Laumas (1976), and data from the Mexican Input-Output Matrix (base 2013).

The typology of the production chain identified reveals a great heterogeneity of industries. Those of high technological intensity are not characterized by creating high value added and generating inter-sectoral linkages; as such, they are not champions of the competitiveness of the national industry. Thus, the high technological dependence of the manufacturing sector prevents it from establishing itself as a nucleus of autonomous development. Their character as export platforms for transnational corporations accentuates the vulnerability of the industrial sector and slows down the speed of convergence toward the equilibrium trajectory prior to external shocks.

The research results present a persistent structural heterogeneity and asymmetric degrees of production linkages in the industrial manufacturing network. The most significant linkage effects (dispersion and propulsion) are linked to the dynamics of a handful of industries (automotive, chemical, food and basic metals, computer equipment, electrical appliances, and machinery and equipment subsectors) with a meager generation of domestic value added. This pattern of specialization (outward industrialization or assembly/maquila model) significantly restricts productivity gains. It makes the economy vulnerable to disruptions in supply and demand chains resulting from shocks, such as the one induced by the Covid-19 pandemic.

Therefore, it is urgent to design and implement an economic policy to consolidate "backward" and "forward" production linkages to strategically reduce the share of foreign value added in the production process and, thus, increase product differentiation as a determinant of competitiveness. Industrial policy should increase inter-sectoral linkages and stimulate a greater correlation between productivity and competitiveness based on technological innovation.

Although the short-term economic policy will focus on containing the impact of the health crisis and stabilizing the macroeconomy, the long-term vision should focus on overcoming the structural fragility of the productive fabric. Governments and Central Banks in Europe and the United States have already been intervening with substantial and aggressive monetary and fiscal expansion (cf. Baldwin & Mauro, 2020). There is no reason the Mexican government should not do the same. However, in addition to stabilizing economic activity, it is imperative to induce structural change to integrate the linkages of industrial manufacturing production.

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