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Patterns of TFP growth in Mexico: 1991–2011

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ABSTRACT

We review the behavior total factor productivity (TFP) growth in the Mexican economy during the period 1991–2011 using a new data set recently published by INEGI. Our analysis shows that TFP has had a negative contribution to output growth, although its traditional positive link with output growth is still present. The data also indicate that TFP growth in Mexico is highly concentrated and unstable, as there is just a handful of industrial branches that at any given moment account for most of the TFP growth observed, but that rarely remain at the top over time. The patterns identified here – low growth, concentration, and unsteadiness of TFP – are in accordance with what has been found using other data sets for the Mexican economy, and also with those that have been reported for other economies at different levels of aggregation.

1. Introduction

In a recent paper, Jorgenson and Vu (2012) sustain that the world economy will experience a massive reconfiguration that will translate into a New Economic Order by 2020. In this new order, the authors claim, "China will displace the U.S. as the world's leading economy and India will overtake Japan. This will shift the balance of the G20 from the leading industrialized economies of the G7 to the emerging economies, especially China and India (Jorgenson & Vu, 2012)." Interestingly, in that description of the future international configuration, Mexico receives very little attention, something that perhaps may be understood in terms of the low growth that the authors estimate for the Mexican

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economy for the current decade in their baseline scenario, and which results in Mexico being excluded out of the eight biggest economies of the world in 2020.

Such forecast invites one to ponder about what has been happening with the Mexican economy's growth fundamentals. Attempting to answer these questions is without a doubt a difficult task, since the study of the economic growth process continues to be as complex as controversial as ever, both from a theoretical as well as from an empirical point of view (Hulten, 2000). Considering the above, the current paper is modest in its scope as it only seeks to identify patterns in the Mexican growth process which may help to better understand its nature. In particular, we take advantage of a new growth accounting data set at the subsector level for the period 1991–2001 recently published by INEGI (the Spanish acronym for the National Institute of Statistics and Geography), where the relevance of these estimates arise from the fact that they come from the most recent and comprehensive effort in terms of data sources used so far in our country, and also because they are obtained through the KLEMS framework, a methodology that today is being adopted by renowned institutions to study the growth process in both developed and developing economies.

Our work reviews, first, the behavior of output and total factor productivity (TFP) growth in the Mexican economy during the period covered by this new data set (1991–2011), where it is shown that despite the fact that TFP has had a negative contribution to output growth, the traditional positive link between the two variables still holds. Then, we proceed to analyze how concentrated or dispersed productivity growth has been, and report that such growth has been highly concentrated and unstable, as there is just a handful of industrial branches that at any given moment account for most of the productivity growth, but that rarely remain at the top over time. The patterns identified here – low growth, concentration, and unsteadiness of TFP – are in accordance with what has been found using other data sets for the Mexican economy, and also with those that have been reported for other economies at different levels of aggregation.

The main implication of this poor, highly concentrated and unsteady performance of TFP in Mexico is that there is no "magic bullet" to solve our problem of anemic economic growth. The strategy, instead, will have to be wide-ranging and sustained.

The paper is organized as follows. In Section 2 we review briefly the Mexican KLEMS data; in Section 3 we look first at the link between output and productivity growth, and then we look at the concentration and resilience patterns of TFP growth; final comments are presented in Section 4.

2. The KLEMS project for Mexico

Today is well established that economic growth stems from the increase in the use of inputs, as well as from increases in total factor productivity. Such statement has been traditionally summarized in the following growth equation:

$$\Delta Y = w\Delta L + \rho\Delta K + R \tag{1}$$

with "Y" representing real gross output,[1] "L" the employed labor force, "K" the real net capital stock, "w" the average real wage, and "ρ" the average real gross rate of return to capital.[2] This equation imputes to incremental labor the average real wage of existing labor, and to incremental capital the average real return of the existing capital stock. The last component, "R", was initially thought of as a coefficient of technical advance, but it was quickly recognized to be a composite of many different elements, such as economies of scale, unused capacity, improved ways of combining resources to produce goods and services, not just at the level of new machines or processes, but also by minor adjustments at the level of the factory, among others.

[1] There is disagreement about whether to use gross or net value added in these calculations. Growth theorists, for example, sustain that it is more adequate to exclude depreciation of fixed capital because "this is an intermediate cost that, like the consumption of raw materials and semi-finished goods, is excluded from the measure of final output. However, others, particularly those looking at the issue from the standpoint of production theory, prefer the gross measure because for them depreciation is part of the measure of the services of the primary factor-capital." (In Baumol & McLennan, 1985, p. 30). See also Pilat and Schreyer (2001). INEGI uses gross value added, and this is why we employ this concept in this paper.

[2] If Y is net real output, "r" should be the net-of-depreciation rate of return to capital.

Early growth accounting studies showed that about half of output growth was unaccounted for by the growth of inputs, an observation that led many economists to "attempt" to reduce the size of the residual. This research agenda quickly produced important advances by emphasizing the need to subtract from the residual the contribution stemming from increases in the quality of the inputs (labor, physical and human capital, intermediate inputs) as well as the contribution from research and development (R&D) (Griliches, 1979; Hulten, 2000; Jorgenson, 1986; Maddison, 1993). These efforts, in turn, were conducive to the development of a more microeconomic oriented view of the growth process in which the growth equation was rewritten as:

$$\Delta Y = \sum\nolimits_j w_j \Delta L_j + \sum\nolimits_i \rho_i \Delta K_i + R, \tag{2}$$

with "Y" representing once again real gross output, "w_j" the unit cost of labor of type "j", "ρ_i" the gross rate of return to capital of type "i", "$_{Lj}$" the labor of type "j", and "K_i" the net capital stock of type "i" (Harberger, 1992).

More recently, and thanks to the availability of new data, this more disaggregated growth accounting approach has been extended, once again, to include additional inputs besides capital and labor in the accounting of growth. The KLEMS approach goes along these lines, in the sense that in addition to capital (K) and labor (L) inputs, explicitly considers the contribution of three additional inputs: energy (E), raw materials (M), and services (S). Hence, the growth accounting equation now becomes:

$$\Delta Y = \sum\nolimits_j \rho_j \Delta K_j + \sum\nolimits_i w_j \Delta L_i + \sum\nolimits_m \gamma_m \Delta E_m + \sum\nolimits_n \varepsilon_n \Delta M_n + \sum\nolimits_p \tau_p \Delta S_p + R. \tag{3}$$

Therefore, the KLEMS methodology follows the old-fashioned growth accounting framework with the extra feature that inputs go beyond the traditional capital (K) and labor (L), to include also energy (E), raw materials (M) and services (S). Additionally, a lot of refinement is involved in the measurement of each of these five inputs within each sub-branch, and this is why the KLEMS project provides a lot of value to researchers.

In October 2013, INEGI released the results of its growth accounting "KLEMS" project for the Mexican economy which, according to the Institute, represents the most complete information generating effort on the subject which has so far been performed in Latin America. According to INEGI (2013), this effort – which was also sponsored by the OECD and CEPAL – seeks to integrate a statistical and analytical platform based on the North American Industrial Classification Code 2007 (NAICS2007) that allows regional and international comparisons of the contributions of capital (K), labor (L), energy (E), raw materials (M), and services (S), and total factor productivity (TFP) to output growth in the Mexican economy. The project provides growth accounting decompositions for 67 sub-branches from three sectors (primary, secondary and tertiary) at an annual frequency for the period 1991–2011, information that constitutes the basis of our study.

3. TFP and output growth in the Mexican economy

Given the refinements in the estimation of the sources of growth for Mexico provided by INEGI's KLEMS data set, we proceed here to investigate whether some postulates of the empirical literature on growth accounting still hold with this new data. In particular, we review first whether two traditional findings of the growth accounting literature hold, namely, (i) that TFP growth represents a significant component of output growth; and (ii) that changes in TFP growth are associated to changes in output growth. The relevance of looking into these patterns resides in that a variety of studies at different levels of aggregation show that higher rates of TFP growth are closely and positively related to output growth. After that, we move to investigate two other issues that are frequently overlooked in the traditional literature, but which are also quite relevant for a better understanding of the growth process. The first has to do with the concentration of TFP growth, while the second has to do with its resilience. Empirical evidence on these two issues is valuable since it helps determine whether productivity should be approached from an aggregate or from a microeconomic perspective.

3.1. The association between output and TFP growth

The relevance of TFP to account for output growth is one of the main tenets of the growth accounting literature. Indeed, in this literature it is common to find claims indicating, for instance, that "roughly half of cross-country differences in per capita income and growth are driven by differences in total factor productivity (TFP). . . Furthermore, much of the widening gap between rich and poor countries results not from differences in capital investment, but from differences in technological progress (Lederman, Maloney, and Serven, 2005)."

However, over the years as more refinements have been gradually added to the growth accounting methodology, more studies have claimed that the relevance of TFP to account for output growth is not really as strong as it has been usually claimed. One example would be, precisely, Jorgenson and Vu (2010), who assert that "[p]roductivity growth accounted for less than 1/8 of world growth during 1989–1995; less than 1/5 in 1995–2000 and less than 3/8 in 2000–2004 and 2004–2008." Due to these contrasting views, in what follows we review the new Mexican data to determine how significant is the connection between TFP and output growth.

We start our review of Mexican productivity growth patterns by looking first at the breakdown of output growth for the whole economy provided by INEGI's KLEMS data set. The first panel of Table 1 shows the average annual rates of TFP and output growth, as well as the average annual contribution of inputs (K, L, E, M, S) to output growth.[3]

The first feature to observe from this data is the negative average contribution of TFP to output growth (−0.39 percent) for the period under study, a figure that implies that output growth, which averaged 3.58 percent, came entirely from the growth of inputs. In particular, the estimates show that around 44 percent of output growth came from "K" (0.44 = 1.58/3.58), followed by the contribution of "M" (32 percent), "S" (20 percent), "L" (12 percent) and "E" (3 percent) (see last line of second panel of Table 1).

Table 1 presents also the data divided in four sub-periods: 1991–1995, 1996–2000, 2001–2005, and 2006–2011. This breakdown shows that in all sub-periods the average contribution of all inputs (K, L, E, M, and S) to output growth was always positive, while that of TFP growth was positive only during the sub-period 1996–2000, when it posted an average annual rate of 1.11 percent, and implying that TFP growth accounted for only 15 percent of output growth. It is interesting to observe, however, that in the sub-period in which TFP growth was the highest (1.11 percent in 1996–2000), output growth also registered its highest rate (7.1 percent); and when TFP growth was the lowest (−0.93 percent, in 1991–1995), the rate of output growth was also the lowest (2.09 percent), suggesting that the widely known positive association between TFP and output growth is also present in this new Mexican economy's data set.

We also reviewed the association between TFP and output growth by sectors of economic activity (primary, secondary and tertiary[4]). Results are shown in Table 2, where we present the average data for the entire period, as well as for the aforementioned four sub-periods. A feature of the data presented here is that over the whole period (1991–2011) the secondary sector was the one which grew the most on average (3.87 percent); however, its TFP growth rate was still negative (−0.35 percent). In the primary and tertiary sectors average output growth was 1.6 and 3.5 percent, respectively; while TFP growth was −0.39 and −0.61 percent, respectively. Hence, the picture that emerges from Table 2 is that TFP growth tends to be *less* negative when output growth is higher, and *more* negative as output growth is lower, an attribute that is in accordance with the growth accounting literature.[5]

[3] The data in Table 1 are taken directly from INEGI, which estimate their average TFP growth for the whole economy as an average of the annual growth rates. In Appendix A, we compared these estimates with their weighted average measures, but results were essentially the same.

[4] See Appendix B for a description of the branches within each sector.

[5] It is convenient to emphasize here that the growth accounting literature usually reports a relationship in which more output growth tends to be associated with more TFP growth, since the latter usually turns out to be positive. This relationship is discussed, for instance, by Harberger (1994), who based on data from 96 countries for the period 1950–1987 reports that countries with higher output growth report higher TFP growth, not only in absolute terms, but also as a fraction of output growth. In our case, however, we do not just have low TFP growth, but we have negative TFP growth rates, and that is why we had to employ the terms "less negative" and "more negative". But a "positive" relationship is still there.

Table 1
Growth accounting for the Mexican economy 1991–2011.

Period	Output value	Capital services	Labor services	Energy	Materials	Services	Contribution of inputs	Total factor productivity
	Y (I)	*K* (II)	*L* (III)	*E* (IV)	*M* (V)	*S* (VI)	K + L + E + M + S (VII)	*TFP* (VIII)
Absolute contribution of inputs and TFP to output growth								
Annual arithmetic averages (%)								
1991–1995	2.09	1.28	0.47	0.06	0.83	0.38	3.03	−0.93
1996–2000	7.10	1.47	0.72	0.20	2.54	1.05	5.99	1.11
2001–2005	2.39	1.61	0.29	0.08	0.55	0.61	3.15	−0.76
2006–2011	2.88	1.90	0.26	0.04	0.79	0.76	3.76	−0.87
1991–2011	3.58	1.58	0.43	0.09	1.16	0.7	3.97	−0.39
Relative contribution of inputs and TFP to output growth								
Annual arithmetic averages (%)								
1991–1995	100	61.2	22.5	2.9	39.7	18.2	144.5	−44.5
1996–2000	100	20.7	10.1	2.8	35.8	14.8	84.2	15.6
2001–2005	100	67.4	12.1	3.3	23.0	25.5	131.4	−31.8
2006–2011	100	66.0	9.0	1.4	27.4	26.4	130.2	−30.2
1991–2011	100	44.1	12.0	2.5	32.4	19.6	110.6	−10.9

Source: Own estimates based on INEGI's KLEMS (2013) data.

Table 2
Growth accounting for the Mexican economy by sub-sectors 1991–2011. Average annual growth rates (%).

Period	Output value growth			Total factor productivity growth		
	Primary (I)	Secondary (II)	Tertiary (III)	Primary (IV)	Secondary (V)	Tertiary (VI)
1991–1995	1.08	2.17	2.14	−0.89	−0.61	−1.33
1996–2000	1.73	9.20	5.35	−0.80	1.08	0.78
2001–2005	2.12	1.92	2.99	0.32	−0.86	−0.82
2006–2011	1.47	2.45	3.52	−0.24	−0.89	−0.99
1991–2011	1.60	3.87	3.50	−0.39	−0.35	−0.61

Source: Own estimates based on INEGI's KLEMS (2013) data.

In order to support the results above regarding the link between output and TFP growth, we decided also to estimate simple correlation coefficients between these two variables for the whole period, as well as for each of the four sub-periods. The correlation using the data of all branches for the entire period reached 0.57; and by sub-periods the correlations spanned from 0.55 up to 0.71 (see column I, Table 3). When looking within each sector separately (columns II, III, and IV), all correlation coefficients remain positive and are higher on average than the ones reported in column I (take into consideration that the primary sector has only five sub-sectors).

The positive association between TFP and output growth can also be seen in Graphs 1–4. Graph 1 shows the association between average TFP and average output growth for all branches together, as well as by sector, for the whole period 1991–2011; while Graphs 2–5 present the same associations by sub-periods (1991–1995, 1996–2000, 2001–2005, and 2006–2011) for the whole economy, as well as for each sector.

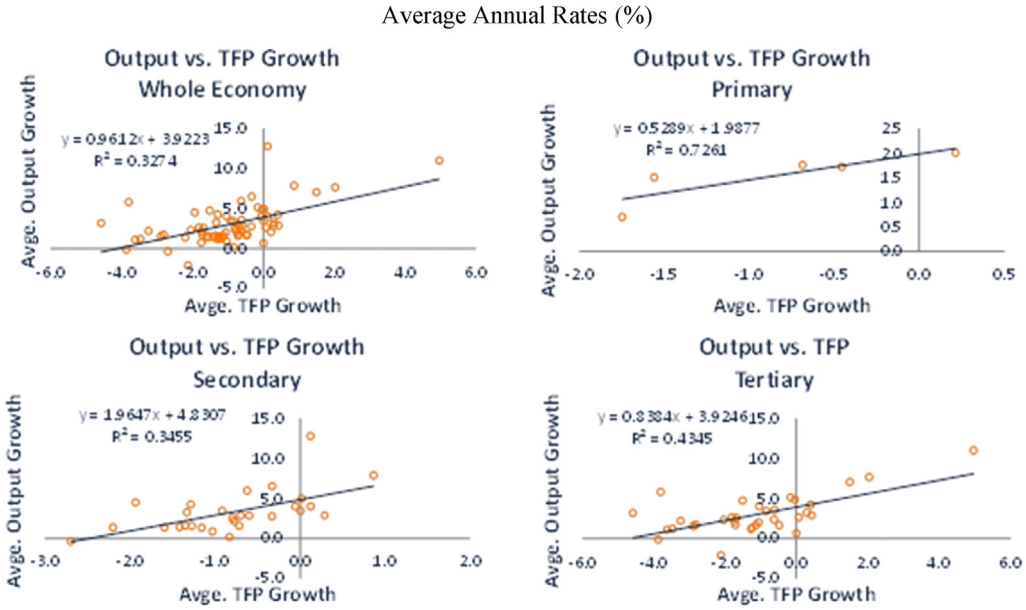
But having a positive association between TFP and output growth is not an indication on causation. Hence, we decided to perform simple Granger causality tests to investigate whether a line of causation between TFP and output growth could be identified. In a first attempt, we performed the tests using the annual growth rates as provided by INEGI. The tests were performed with 1, 2 and 3 lags for each of the 67 sub-sectors; with the results being presented in Table 4. The table presents cases in which output growth causes TFP growth, cases in which TFP growth causes output growth, cases in which causality runs in both directions; and cases in which there is no causality at all.

The top panel of Table 4 shows that, considering one lag, there are more cases in which output growth causes TFP growth than the other way around; but when considering 2 and 3 lags, the figure is more balanced. For instance, with one lag there are only 4 cases in which causality runs from TFP to output growth, and 13 in which causality runs from output to TFP growth. The number of cases in which causality runs in both directions is 8, while the number of cases in which there is no causation at all is 42. Using 2 lags, however, we find 6 cases in which Granger causality goes from TFP to output growth, and only 5 cases in which output growth Granger causes TFP growth. The number in which Granger causality is seen in both directions is identified in 8 cases, while the number of cases in which there is no causality goes up to 48.

Table 3
TFP and output growth 1991–2011. Correlation coefficients.

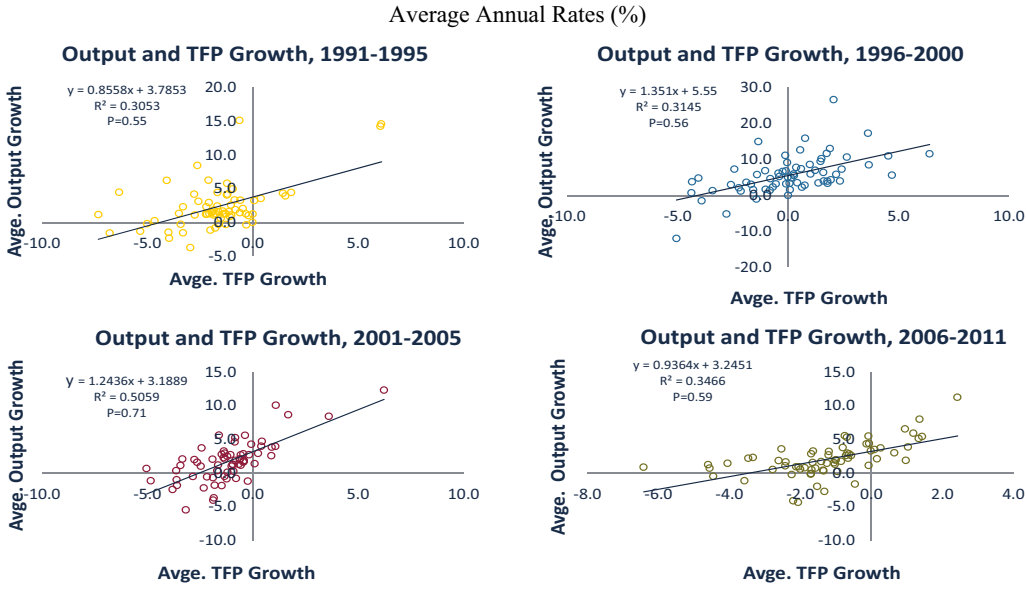
Period	All (I)	Primary (II)	Secondary (III)	Tertiary (IV)
1991–1995	0.55	0.81	0.27	0.69
1996–2000	0.56	0.90	0.61	0.59
2001–2005	0.71	0.97	0.68	0.81
2006–2011	0.59	0.80	0.68	0.59
1991–2011	**0.57**	**0.85**	**0.59**	**0.66**
n=	**67**	**5**	**28**	**34**

Source: Own estimates based on INEGI's KLEMS (2013) data.

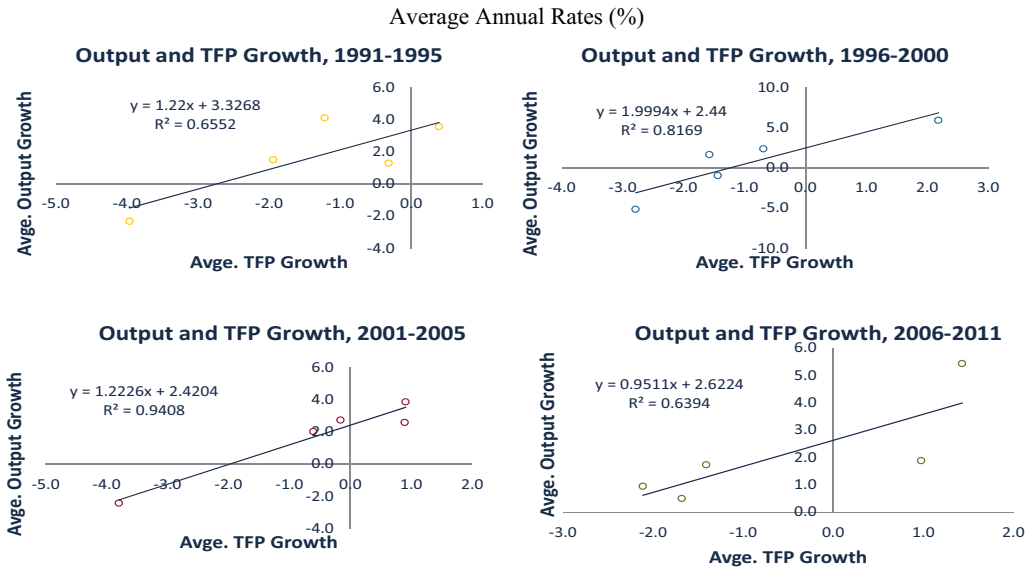


Graph 1. TFP and output growth 1991–2011: whole economy and sub-sectors.
Source: Own estimates based on INEGI's KLEMS (2013) data.

The bottom panel of Table 4 presents the Granger causality tests by sector when using 2 lags. The interesting feature of presenting the data this way is that reveals that most cases in which TFP growth Granger causes output growth are found in the secondary sector, while causality in the other direction is seen in a higher number in the tertiary sector.

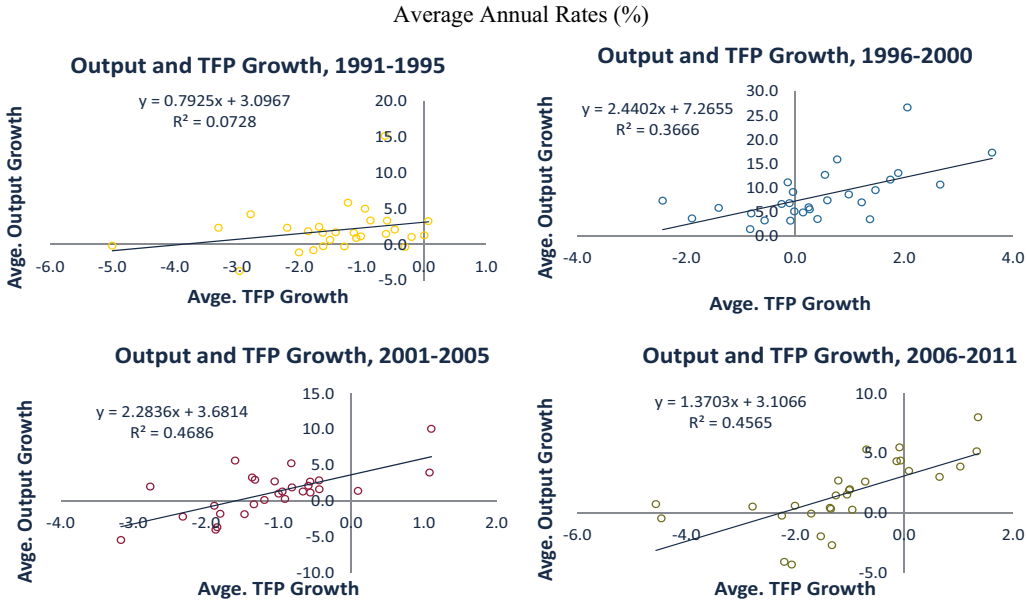


Graph 2. TFP and output growth by sub-periods: whole economy.

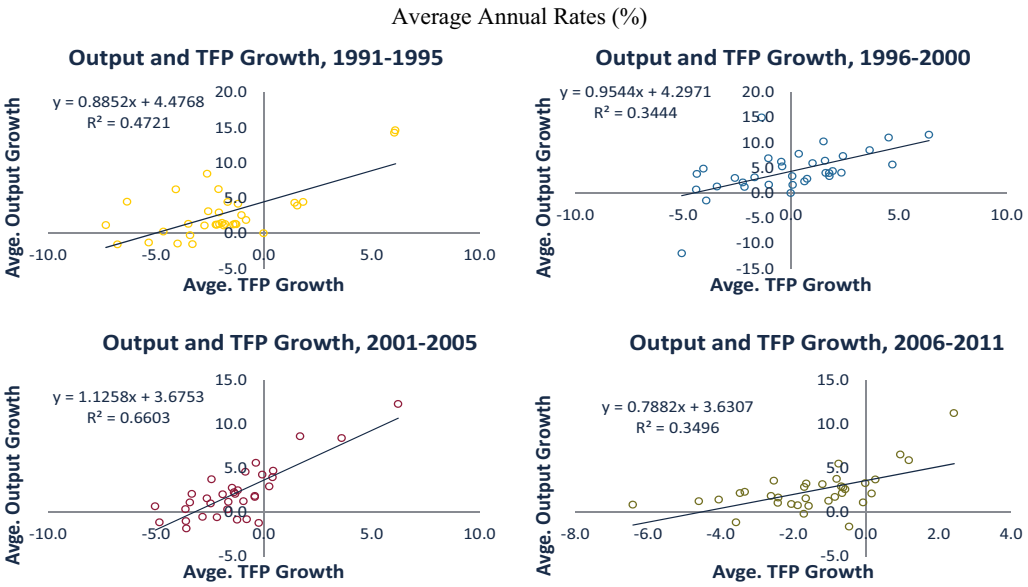


Graph 3. TFP and output growth by sub-periods: primary sector.
Source: Own estimates based on INEGI's KLEMS (2013) data.

We tried other data specifications in an attempt to uncover a stronger connection between TFP and output growth. Hence, we considered using moving averages for the series of TFP and output growth under the argument that probably more stable relationships could be identified if we looked at data smoothed this way. The top panel of Table 5 presents the results of Granger causality tests for the 2, 3,



Graph 4. TFP and output growth by sub-periods: secondary sector.



Graph 5. TFP and output growth by sub-periods: tertiary sector.
Source: Own estimates based on INEGI's KLEMS (2013) data.

Table 4
TPG growth vs. output growth 1991–2011.

Granger causality tests				
Lags included	Output causes TFP	TFP causes output	Granger causality in both directions	No Granger causality in either direction
1 lag	13	4	8	42
2 lags	5	6	8	48
3 lags	6	4	7	50
Granger causality test by subsector (2 lags included), 1991–2011				
Sector	Output causes TFP	TFP causes output	Granger causality in both directions	No Granger causality in either direction
1. Primary	0	1	1	3
2. Secondary	1	3	1	23
2.1. Manufacturing	0	2	1	18
3. Tertiary	4	2	6	22
Total	5	6	8	48

Source: Own estimates based on INEGI's KLEMS (2013) data.

and 4 year moving averages of TFP and output growth.[6] We present the results of the tests using only 2 lags since it was under this specification that we obtained the best results. Notice, however, that even under this specification the number of cases in which we were not able to identify causation in either direction was still quite large: 5 cases out 67 cases under moving averages of 2 years, 33 out of 67 under moving averages of 3 years, and 41 out of 67 moving averages of 4 years. This evidence suggests that even though there is a clear positive association between the two variables, their causality is not clear.

[6] We did not try more lags since we only have 20 observations for each sub-sector.

Table 5
TFP growth vs. output growth 1991–2011.

Granger causality tests				
2 lags included	Output causes TFP	TFP causes output	Granger causality in both directions	No Granger causality in either direction
Moving average MA(3)	12	9	13	33
Moving average MA(4)	5	12	9	41
Granger causality test by subsector (2 lags included-MA(3)), 1991–2011				
Sector	Output causes TFP	TFP causes output	Granger causality in both directions	No Granger causality in either direction
1. Primary	0	0	1	4
2. Secondary	4	5	3	16
2.1. Manufacturing	2	3	3	13
3. Tertiary	8	4	9	13
Total	12	9	13	33

Source: Own estimates based on INEGI's KLEMS (2013) data.

It is not hard to think of a variety of factors that may account for this lack of causality. For instance, it is possible that growth in demand in any given sector may lead some firms in that sector to increase simultaneously their use of capacity and their profitability, and this fact may lead them to gradually adopt new methods to escalate their production in order to take advantage of the surging demand. In this case, output increases precede productivity growth. But also a slower demand growth may lead some firms to reduce production costs, thus leading them to become more productive. For instance, lower output growth may lead firms to become more productive if they want to survive in that harsher environment. In other words, higher as well as lower output growth may generate incentives to increase productivity. And it is also possible that in any given sector an invention could translate into more output with the same amount of inputs (K, L, E, M, S), which would be reflected in higher productivity.

The examples above are useful in that they illustrate how difficult it is to establish a clear direction of causality between TFP and output growth, and therefore help us understand why we should not be surprised by the results in Table 5.

In summary, in this section we have seen that in the Mexican economy output and TFP growth are positively correlated, but the evidence that TFP growth causes output growth, or the other way around, is not very strong.

3.2. Concentration and persistence of TFP growth in Mexico

> "The grand design that emerges ... is that: (i) a small-to-modest fraction of industries can account for 100 percent of aggregate real cost reduction in a period; (ii) the complementary fraction of industries contains winners and losers, the TFP contributions of which cancel each other; and (iii) the losers are a very important part of the picture most of the time."
> Harberger (1998), p.10

Other dimensions of the Mexican productivity growth process we revise here relate to its concentration and persistence.[7] These two features are interesting to look at since they may be compared with the view implied by aggregate models of economic growth. For instance, aggregate neoclassical and endogenous growth models convey the view of economic growth as being smooth, uniform and steady, and more importantly, stemming from a few general forces. Some practitioners, however, assert that is not the case and propose instead that productivity growth tends to be a quite uneven

[7] We will explain below what we mean precisely by concentration and persistence.

and unsteady process at all levels of aggregation, and emphasize that this feature stems from the fact that productivity and output growth derive from a vast array of forces that makes no sense to try to model them.

Using the Mexican data, we look first at the concentration patterns of TFP growth for the Mexican economy by constructing "sunset-sunrise" diagrams as proposed by Harberger (1998); next, we review the persistence of the growth process by looking at the distribution of leader and laggard sectors across different time periods. As we will see, the Mexican data suggests, not surprisingly, that productivity growth is highly concentrated and highly unsteady.

3.2.1. Concentration of TFP growth in the Mexican economy 1991–2011

We start this subsection by reviewing first the construction and interpretation of the "sunset-sunrise" diagrams, for they are the tool we will employ here to look at the concentration patterns of productivity growth. These diagrams simply contrast how much of the productivity growth for an aggregate (i.e., the total economy, a given sector, or sub-sector, etc.) during any given period, is accounted for a given fraction of the economic units for which we have information to construct the corresponding aggregate. For instance, if we had data on all sectors (firms) of a given economy (sector), a "sunset-sunrise" diagram would tell us which fraction of the sectors (firms) would account for all of the TFP growth registered in that economy (sector).

The construction of a sunset-sunrise diagram follows the next steps:

1. Arrange economic units (sectors, industries, or firms) in descending order according to their average TFP growth rates for the period.
2. Obtain the dollar value of real cost reductions for the period for each economic unit (in our case, the economic units are sub-sectors). This dollar value is simply the result from multiplying each unit's average TFP growth for the period, times its initial value added.
3. Calculate the cumulative sum of real cost reductions from step (2) and plot it against its cumulative initial real value added.
4. Scale the vertical axis according to the metric decided upon for the rates or TFP increase and the horizontal axis so as to add up to 100 percent.

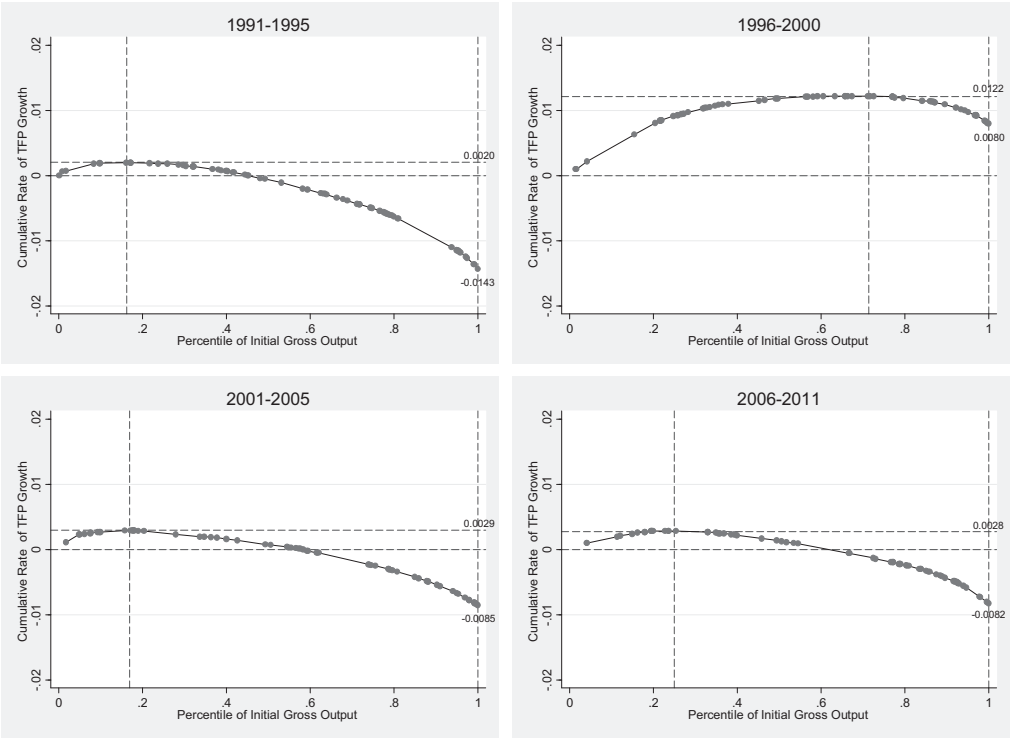
Based on the above, if we obtain a graph that resembles a 45° straight line, we would be finding evidence of a uniform (in terms of having firms reporting the same rate of productivity growth), although not necessarily and evenly distributed productivity growth process. On the other hand, if non-linear patterns are observed, this would suggest that productivity growth tends to be unevenly distributed and, perhaps, concentrated.

We computed "sunset-sunrise" diagrams for the sub-periods 1991–1995, 1996–2000, 2001–2005 and 2006–2011 using all sub-sectors of the economy together (Graph 6), and then we performed the same exercise within each sector (Graphs 7–9). The first feature to notice out of these graphs is that they are far from resembling 45° straight lines, implying that productivity growth in Mexico, as in many other countries, has not been uniformly distributed. To appreciate this feature, look at, for instance, period 1991–1995 in Graph 6. There we have that TFP growth was positive in only 18 percent of the sub-sectors (as measured by their accumulated gross output); while the remaining sub-sectors (82 percent) reported zero or negative TFP growth. If the sub-sectors with nil or negative contributions had not been present, the average TFP growth of the Mexican economy for the 1991–1995 period would have been 0.2 percent, instead of the −1.4 finally reported.

It is worth mentioning that the message here may have been anticipated from Graphs 1–5, where it was shown that just a small (large) number of sub-sectors were in the positive (negative) quadrant of TFP growth. However, Graphs 6–9 are more compelling since they tell us right away if during any given period TFP growth is being explained by a relatively small or large number of economic units, with that size being measured in terms of the initial value added of the corresponding economic units.

3.2.2. Persistence of TFP growth in Mexico

The previous section showed evidence that productivity growth in Mexico has been highly concentrated, a feature that is in accordance with existing empirical literature on the matter (e.g., Harberger,



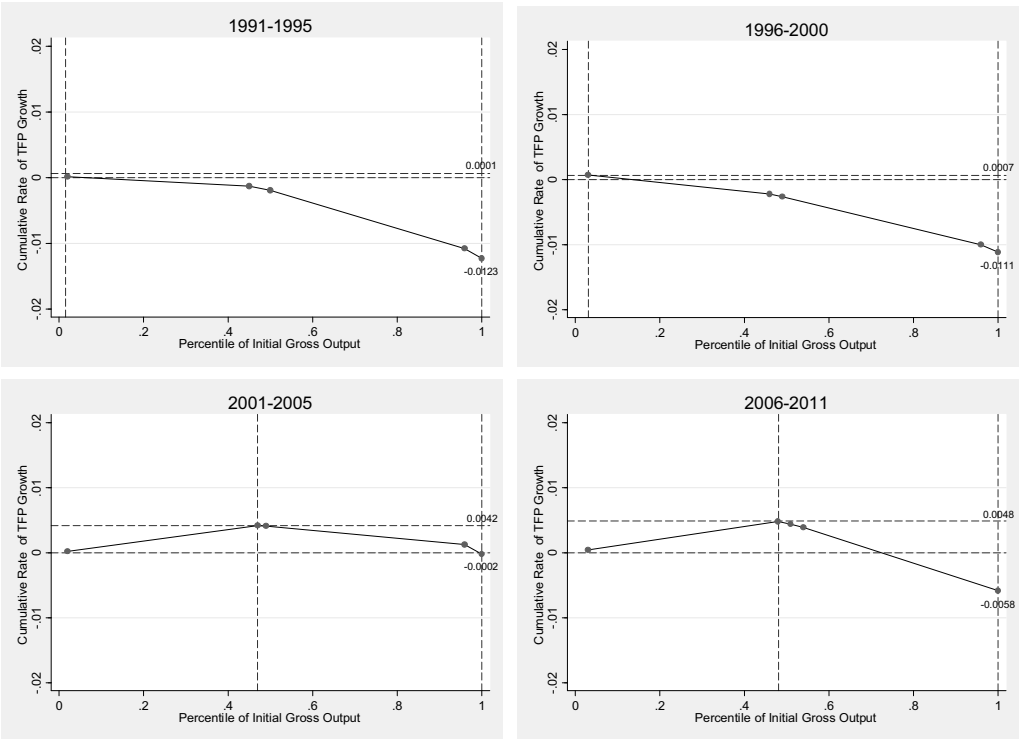
Graph 6. TFP growth profile in the Mexican economy (67 subsectors).

1998; Torre, 2000). A question remains, however, about how persistent this process is. In particular, the question we would like to answer here is the following: Do high-performing (winner) and low-performing (loser) sectors in the Mexican economy tend to be the same along the time period covered?

Although the answer may seem an obvious "no", the truth is that there is no evidence looking at this feature yet simply because the data for the period was not available. We will see next that productivity growth in Mexico is unstable across time in terms of which industries will be at the top, and which at the bottom of the distribution.

To tackle the issue, we ordered sub-sectors from high to low based on their average productivity growth in the four sub-periods (1991–1995, 1996–2000, 2001–2005, and 2006–2011). Then, we chose for each sub-period the 8 sub-sectors with the highest average TFP growth, the 8 with the middle, and the 8 with the lowest average TFP growth (these sub-sectors are shown in Table 6).[8] Finally, we compared how many sub-sectors remained within each group from one sub-period to the next. Here, we will refer that there exists "high persistence" when the same or a significant fraction of sub-sectors tend to remain within each sub-group across time; and by "low persistence" that sub-sectors do not tend to remain within each sub-group. According to Table 6, among the *top 8*, only 2 sub-sectors repeat between sub-periods I and II (491&492, and 517&518), 2 between sub-periods II and III (517&518 and 237) and 3 between sub-periods III and IV (52, 112 and 517&518). Also notice that just one sector remains within the top 8 in all sub-periods (517&518). The corresponding numbers for the sub-sectors in the *middle 8* are 1, 0, and 1, respectively. In this group, we did not find a single sub-sector that remained in the middle of the distribution through the whole period, although there

[8] We recognize that choosing 8 subsectors was rather arbitrary. However, the conclusions are the same for different group sizes.



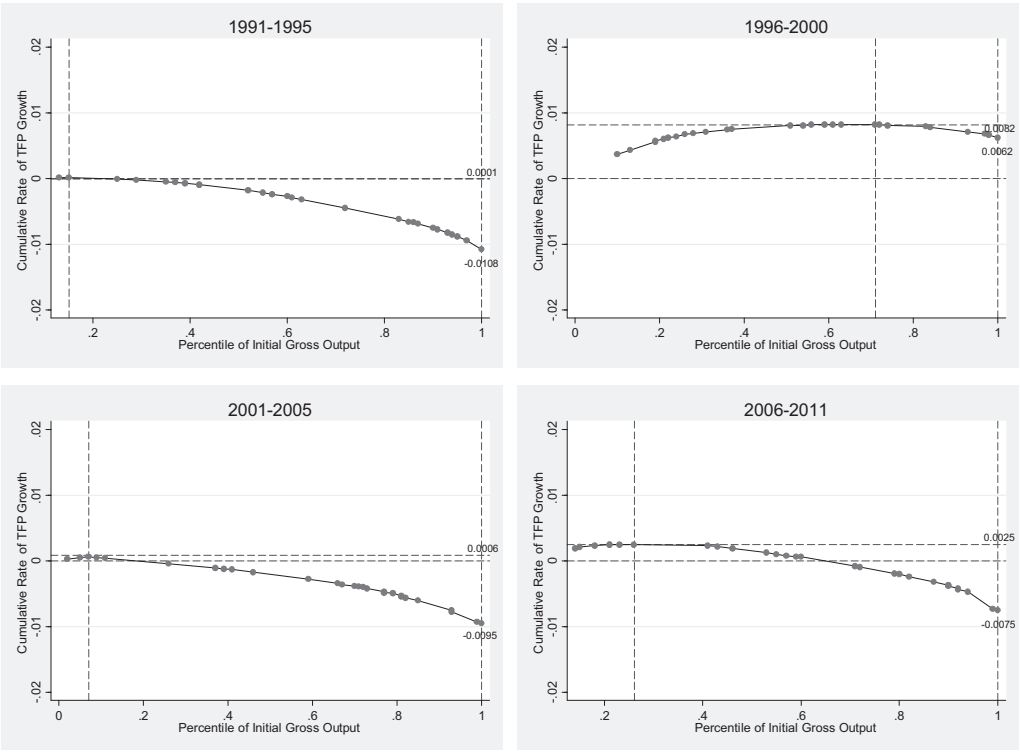
Graph 7. TFP growth profile in the Mexican primary sector.

are 2 sub-sectors that appear 3 times (sub-sectors 322 and 326, see figures in bold in the same Table). Finally, in the *bottom 8* group, the figures are 4, 2, and 4, suggesting that it seems more difficult to get out of the group of laggards than remaining at the top.

Table 7, on the other hand, presents the same exercise as above within each of the three sectors of the Mexican economy (primary, secondary and tertiary).

In this case, since the number of sub-sectors varies within each sector (there are only 5 in the primary sector, 28 in the secondary, and 34 in the tertiary), we chose to select the top performer, the middle performer and the worst performer in the primary sector; the top 5, the middle 5, and the bottom 5 performers in the secondary sector; and the top 6, the middle 6, and the bottom 6 performers in the tertiary sector. The exercise was performed comparing five and ten year periods. In these cases, there are no clear patterns of persistence, except for that of the bottom 6 in the tertiary sector, where we can see that the number of sub-sectors that remain there between sub-periods I-II, II-III, and III-IV are 4, 1, and 4, respectively. These results tend to indicate that TFP growth is not persistent, based on the definition we adopted here.

Finally, we also computed rank correlation coefficients between sub-periods of 5 and 10 years within the three sectors, as well as for the entire economy, in an attempt to confirm the low level of persistence of TFP growth identified Tables 6 and 7. Results are shown in Table 8. The table presents the rank correlation coefficients within each sector in columns I (primary), II (secondary), and III (tertiary); while column IV presents the estimates using all sub-groups together. According to the table, the rankings between sub-periods 1991–2000 and 2001–2011 produce correlation coefficients for the primary, secondary, and tertiary sectors of 0.30, 0.41 and 0.43, respectively; while that for the whole economy reaches 0.38. When working with 5 year sub-periods, the results show once again more persistence in the tertiary sector since two out of three coefficients are above 0.50, while in the primary and secondary sectors the highest coefficient reaches 0.43 (secondary sector, 1996–2000 vs.



Graph 8. TFP growth profile in the Mexican secondary sector.

2001–2005). Hence, it seems fair to conclude that the picture that emerges from this section is one in which top performers struggle to remain at the top, while a greater fraction of losers tends to have a hard time getting out of that group, with the latter being especially clearer in the tertiary sector.

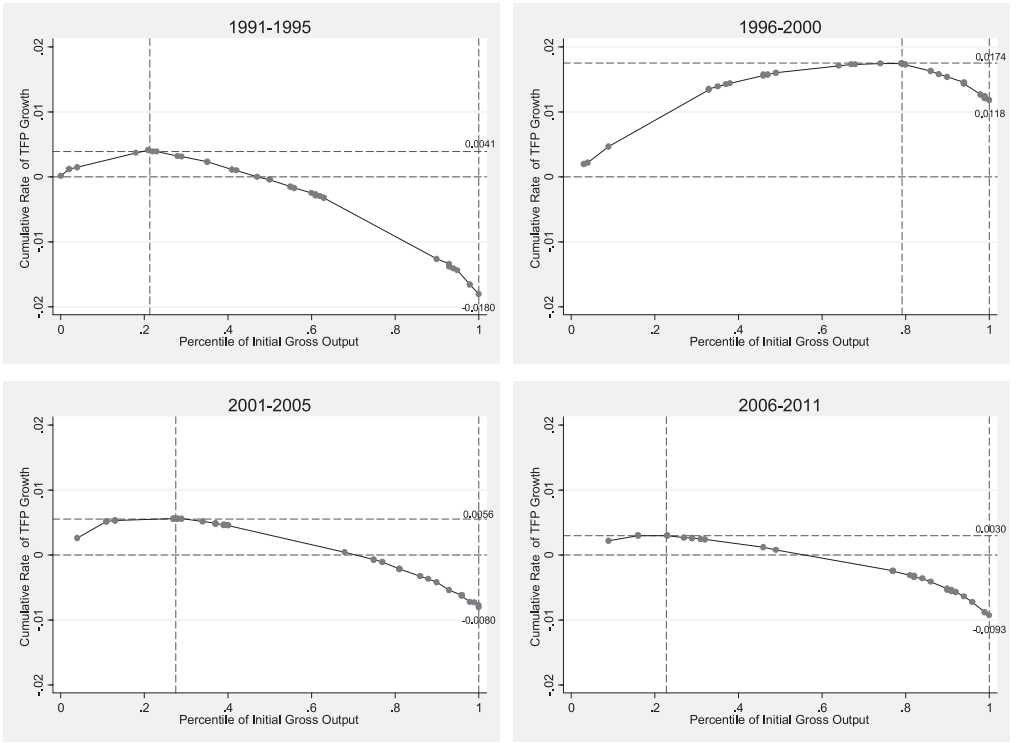
3.2.3. A few words on NAFTA, China and the patterns of TFP growth in Mexico

In the last two decades there have been two significant events for the Mexican economy. The first was the signing of the North American Free Trade Agreement (NAFTA) in 1993, which came into effect in 1994; the second was China's accession to the World Trade Organization (WTO) in 2001. Given the significance of these two events, a few words are deserved on whether they could have had an impact on Mexico's TFP growth during the period that we have been covering in this study.

NAFTA, once it went into effect in January 1994, was hoped to increase Mexican productivity as the removal of tariff and non-tariff barriers would increase competition and foreign investment, favor the adoption of new technologies, and induce a better allocation and utilization of internal resources. The agreement, in fact, was seen as a strong supplement to the privatization of government owned enterprises, the deregulation of industry, the liberalization of foreign investment, and the initial unilateral trade liberalization efforts – via Mexico's accession to the General Agreement on Trade and Tariffs (GATT) – that had been implemented by the Mexican government since the mid 1980s.

Since TFP growth for the whole economy was performing poorly prior to 1994 – as we have seen in this work – one may expect that NAFTA's impact on Mexican productivity could have been more easily noticed. Table 1 shows, in fact, that TFP growth was the highest during the period 1996–2000.[9]

[9] If we had presented the average 1994–2000, the average TFP growth rate would have been lower due to its performance during the 1995 crisis, see Appendix A.



Graph 9. TFP growth in the Mexican tertiary sector.
Source: Own estimates using data from INEGI (2013).

However, it must be also noticed that even during this period, the average contribution of TFP growth to output growth reached just a meager 15 percent. In other words, the evidence from INEGI's KLEMS data indicates that TFP had a minor contribution to output growth, and that the lion's share of output growth during that period was accounted instead by M (36 percent) and K (21 percent). Results are similar even if we concentrate only in the primary and secondary sectors, which were the sectors most likely to have experienced the highest effects of NAFTA. In particular, the data in Table 2 imply that during the period 1996–2000, TFP in the primary sector had a negative contribution to output growth, while that of the secondary sector reached only 12 percent.

The poor performance of TFP growth in Mexico after NAFTA is not new, and it does not have an easy answer either. In fact, there is a vast amount of research attempting to explain the behavior of productivity and output growth in México after NAFTA. In this work however, will not be reviewed here (e.g., Amoroso, Chiquiar, Quella, & Ramos-Francia, 2008; Cabral & Mollick, 2011; De Hoyos & Iacovone, 2013; De León & Parra-De La Torre, 2011; Gutiérrez, 2005; Hanson, 2010; Ito, 2010; Kehoe & Ruhl, 2010; López-Córdova, 2002; Lopez-Cordova, 2012; Salgado & Bernal, 2007; Verhoogen, 2012; Weisbrot, Lefebvre, & Sammut, 2014).

Regarding the entrance of China to the WTO in 2001 and its effect on the Mexican economy, one may have expected that domestic firms had reacted to the more competitive domestic and international environment by increasing their productivity.[10] What we observe in the Mexican data, however, is

[10] This argument is proposed, for instance, by Bloom, Draca, and Van Reenen (2011), although their empirical work focuses in the effect of China's accession to the WTO on developed economies. The authors conclude that "Chinese trade stimulates faster technological change" (p.4). However, there is also abundant literature evaluating other channels through which China may have an impact on the economic performance of developing countries, and specifically on Latin American economies. See,

Table 6
Persistence of TFP growth in the Mexican economy 1991–2011.

	1991-1995 (I)	1996-2000 (II)	2001-2005 (III)	2006-2011 (IV)	1991-2000 (V)	2001-2011 (VI)
Top 8	491 & 492	**517 & 518**	**517 & 518**	52	517 & 518	518 & 518
	517 & 518	482	52	115	491 & 492	52
	721	484	493	336	721	112
	531	434	237	212	482	312
	722	336	312	**517 & 518**	484	115
	114	237	114	221	336	336
	311	491 & 492	112	112	531	237
	333	711	533 & 551	491 & 492	722	493
Middle 8	931	488	814	**326**	322	335
	322	327	212	485 & 489	493	326
	211, 213 & 486	**322**	**326**	**322**	316	323
	236	312	238	434	238	324
	326	611	337	222	313	482
	52	485 & 487	812	311	211, 213 & 486	222
	337	624	813	313	711	561 & 562
	323	316	339	236	326	327
Bottom 8	711	561 & 562	541	713	515 & 519	621
	813	115	811	532	814	713
	713	712	713	722	483	722
	237	713	722	621	813	515 & 519
	515 & 519	541	512	211, 213 & 486	713	211, 213 & 486
	541	814	113	321	622	321
	712	813	511	541	712	541
	622	483	515 & 519	511	541	511

Source: Own estimates based on INEGI's KLEMS (2013) data.

that the sector which could have been expected to respond the most as it faced Chinese competition more directly in both the domestic and external fronts, namely the secondary sector, showed negative rates of TFP growth during the periods 2001–2005 and 2006–2011 (see Table 2). Moreover, out of the 27 sub-sectors of the secondary sector, just 3 of them showed a positive average rate of TFP growth during the period 2001–2005, and only 5 during the period 2006–2011 (see Graph 8 and Table 9). Most of these sub-sectors, however, are not the ones facing, precisely, direct competition from China.[11]

for instance, Gallagher, Moreno-Brid, and Porzecanski (2008), Gallagher and Porzecanski (2008), Hanson and Robertson (2008), Lopez-Cordova, Micco, and Molina (2008), Uthar and Torres (2013).

[11] Of course, it is also possible that if China had been denied access to the WTO, Mexican TFP growth would have been lower, and instead of having only 3–5 sub-sectors in the secondary sector showing positive rates of TFP growth, probably all of them

Table 7
Persistence of TFP Growth in the Mexico, by Sector: 1991–2011.

Sector:		1991-1995 (I)	1996-2000 (II)	2001-2005 (III)	2006-2011 (IV)	1991-2000 (V)	2001-2011 (VI)
Primary	Top	114	113	114	115	112	112
	Middle	115	114	115	113	113	114
	Bottom	113	115	113	111	115	113
Secondary	Top 5	311	336	237	336	336	312
		333	237	312	212	334	336
		325	334	332	221	333	237
		324	314	333	312	314	212
		331	332	327	323	212	221
	Middle 5	332	313	325	332	325	339
		314	311	212	326	324	335
		335	327	326	322	322	326
		316	322	238	222	316	323
		322	312	337	311	238	324
	Bottom 5	315	325	315	315	237	314
		238	324	236	337	222	238
		321	323	323	238	321	315
		339	222	211, 213 & 486	211, 213 & 486	323	211, 213 & 486
		237	339	321	321	339	321
Tertiary	Top 6	491 & 492	517 & 518	517 & 518	52	517 & 518	517 & 518
		517 & 518	482	52	517 & 518	491 & 492	52
		721	484	493	491 & 492	721	493
		531	434	533 & 531	624	482	624
		722	491 & 492	482	711	484	491 & 492
		624	711	531	484	531	711
	Middle 6	481	531	814	622	811	488
		485 & 487	722	812	531	493	482
		811	488	813	485 & 487	711	561 & 562
		623	611	491 & 492	434	512	434
		611	485 & 487	481	813	485 & 487	813
		533 & 551	624	434	512	611	485 & 487
	Bottom 6	813	712	811	713	483	621
		713	713	713	532	813	713
		515 & 519	541	722	722	713	722
		541	814	512	621	622	515 & 519
		712	813	511	541	712	541
		622	483	515 & 519	511	541	511

Source: Own estimates based on INEGI's KLEMS (2013) data.

Thus, the evidence from NAFTA and China points toward a complex picture of productivity growth in Mexico, a picture in which internal, rather than external forces, might be playing a preponderant role in

would have shown negative rates. It is not the purpose of this paper, however, attempt to present the counterfactual, but simply illustrate that more competition from abroad has not translated into higher TFP growth in Mexico according to the INEGI estimates.

Table 8
Rank correlation coefficients for TFP 1991–2011.

	Primary (I)	Secondary (II)	Tertiary (III)	Total (IV)
1991–1995 vs 1991–1995	1	1	1	1
1991–1995 vs 1996–2000	−0.20	0.18	0.55	0.31
1996–2000 vs 2001–2005	−0.20	0.43	0.24	0.16
2001–2005 vs 2006–2011	0.10	0.42	0.54	0.50
1991–2000 vs 2001–2011	0.30	0.41	0.43	0.38
n=	5	28	34	67

Source: Own estimates based on INEGI's KLEMS (2013) data.

Table 9
TFP growth in the Mexican secondary sector 2001–2011 TFP growth rates and relative shares.

Sector	2001–2005		Sector	2006–2011	
	Average TFP growth	Average relative weight		Average TFP growth	Average relative weight
Civil engineering construction works	0.0110	0.0307	Transportation equipment manufacturing	0.0136	0.1476
Beverage and tobacco industries	0.0108	0.0266	Metallic and nonmetallic ore mining, except oil and gas	0.0134	0.0118
Metal products manufacturing	0.0010	0.0229	Electric power generation, transmission and distribution	0.0104	0.0276
			Beverage and tobacco industries	0.0065	0.0285
			Printing and related industries	0.0009	0.0054
Machinery and equipment manufacturing	−0.0044	0.0166	Machinery and equipment manufacturing	−0.0006	0.0160
Nonmetallic mineral products manufacturing	−0.0044	0.0245	Civil engineering construction works	−0.0008	0.0393
Transportation equipment manufacturing	−0.0056	0.1437	Manufacturing of computer, communications, and measuring equipment	−0.0013	0.1693
Food industry	−0.0056	0.1153	Other manufacturing industries	−0.0069	0.0181
Paper industry	−0.0059	0.0187	Electric appliances	−0.0071	0.0342
Manufacturing of products derived from petroleum and coal	−0.0066	0.0272	Chemical industry	−0.0095	0.0644
Basic metal industry	−0.0081	0.0482	Metal products manufacturing	−0.0099	0.0220
Manufacturing of computer and communications	−0.0082	0.1299	Plastic and rubber industry	−0.0100	0.0211
Chemical industry	−0.0091	0.0711	Paper industry	−0.0105	0.0185
Metallic and nonmetallic ore mining, except oil and gas	−0.0095	0.0119	Water and gas supply through mains to final consumers	−0.0120	0.0022
Plastic and rubber industry	−0.0100	0.0228	Food industry	−0.0125	0.1086
Specialized construction works	−0.0105	0.0109	Textile inputs manufacturing, and textiles finishing	−0.0132	0.0072

Table 9 (*Continued*)

Sector	2001–2005		Sector	2006–2011	
	Average TFP growth	Average relative weight		Average TFP growth	Average relative weight
Furniture, mattresses and blinds manufacturing	−0.0119	0.0080	Construction	−0.0134	0.0680
Other manufacturing industries	−0.0132	0.0162	Leather and fur tanning and finishing, and manufacturing of leather	−0.0136	0.0080
Electric appliances	−0.0134	0.0354	Manufacturing of products derived from petroleum and coal	−0.0152	0.0232
Water and gas supply through mains to final consumers	−0.0136	0.0023	Basic metal industry	−0.0170	0.0434
Leather and fur tanning and finishing, and manufacturing of leather	−0.0147	0.0094	Nonmetallic mineral products manufacturing	−0.0200	0.0234
Electric power generation, transmission and distribution	−0.0160	0.0254	Textile products manufacturing, except apparel	−0.0206	0.0030
Textile products manufacturing, except apparel	−0.0180	0.0038	Apparel manufacturing	−0.0220	0.0137
Textile inputs manufacturing, and textiles finishing	−0.0184	0.0101	Furniture, mattresses and blinds manufacturing	−0.0224	0.0067
Apparel manufacturing	−0.0186	0.0203	Specialized construction works	−0.0278	0.0102
Construction	−0.0188	0.0745	Oil and gas extraction	−0.0445	0.0538
Printing and related industries	−0.0232	0.0055	Wood industry	−0.0455	0.0050
Oil and gas extraction	−0.0276	0.0618			
Wood industry	−0.0317	0.0063			

Source: Own estimates based on INEGI's KLEMS (2013) data.

containing its potential. The list of these possible internal factors is lengthy as the recent literature on the determinants of TFP and output growth in Mexico has been documenting.[10] Hence, the challenge of policy makers is to continue fighting to dilute the influence of such restraining factors in order to finally unleash the potential that the Mexican economy possesses.

4. Final comments

In this work we reviewed patterns of TFP growth for the Mexican economy during the period 1991–2011 based on a data set at the sub-sector level recently released by INEGI. Based on this new data, our analysis showed first that, despite the negative contribution of TFP to output growth for the period in consideration, the typical positive association between two variables is still present. Equally interesting was the finding that, notwithstanding the connection referred above, a clear direction of causality between TFP and output growth could not be pinpointed, suggesting that economic growth is a quite complex process.

The evidence on the complexity of the growth process was reinforced when we documented that TFP growth in Mexico, just as in many other experiences, has been highly concentrated and unstable, in the sense that in any given period just a handful of sub-sectors account for most of the productivity growth, but that rarely the same sectors remain at the top across time.

Finally, we reviewed up to what extent two important external shocks, namely, the signing of NAFTA and China's accession to the WTO, could have had on Mexico's TFP performance. Both of these

events were expected to increase productivity growth since they exposed Mexican producers to more intense competition, both in the internal as well as in the external markets. Our analysis of the data shows, however, that the behavior of TFP growth during the periods in which those shocks should have been expected to have an impact, was simply disappointing.

The fact that Mexico's new growth accounting data do not show a clear connection with the referred external shocks, invites one to propose that the reasons behind that poor productivity and output growth performance rest more on internal factors. Indeed, there is no doubt that few specialists would deny today that domestic restraints, such as monopolized markets, excessive regulations, low quality human capital, deficient public infrastructure, lack of economies of scale and scope, an inefficient tax system, among many others, are at the core of this poor growth experience. To the extent that these restraints are effectively abated, the potential to increase productivity and output growth in Mexico will be finally unleashed.

Acknowledgments

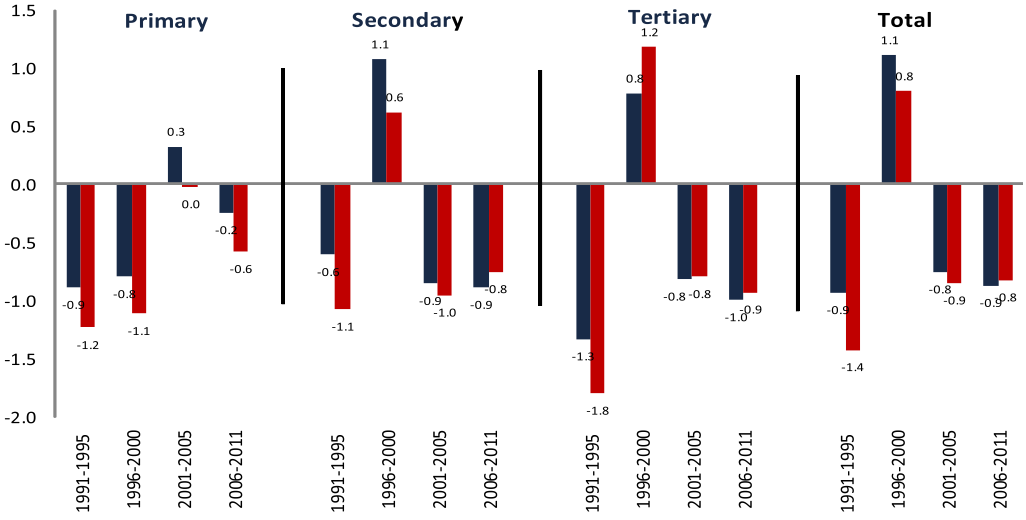
The authors would like to thank participants at the "China, Mexico and the U.S.: Opportunities for Trade and Growth" seminar held in Monterrey, Mexico, as well as to anonymous referees from Banco de Mexico and the North American Journal of Economics and Finance, for their valuable comments.

Appendix A.

Arithmetic vs. weighted averages of TFP growth: a comparison (%).

Period	Total factor productivity growth (arithmetic average)				Total factor productivity growth (weighted average)			
	Primary (I)	Secondary (II)	Tertiary (III)	Total (IV)	Primary (I)	Secondary (II)	Tertiary (III)	Total (IV)
1991–1995	−0.89	−0.61	−1.33	−0.93	−1.23	−1.08	−1.80	−1.43
1996–2000	−0.80	1.08	0.78	1.11	−1.11	0.62	1.18	0.80
2001–2005	0.32	−0.86	−0.82	−0.76	−0.02	−0.95	−0.80	−0.85
2006–2011	−0.24	−0.89	−0.99	−0.87	−0.58	−0.75	−0.93	−0.82

Source: Own estimates based on INEGI's KLEMS (2013) data.



Source: Own estimates based on INEGI's KLEMS (2013) data.

Appendix B.

Subsectors of the Mexican economy: by sector

NAIC2007 Code	
Primary sector	
111	Agriculture
112	Animal breeding and production
113	Forestry
114	Fishing, hunting and trapping
115	Services related to agricultural and forestry activities
Secondary sector	
211, 213 and 486	Oil and gas extraction, services related to mining and pipeline transportation
212	Metallic and nonmetallic ore mining, except oil and gas
221	Electric power generation, transmission and distribution[MÉX]
222	Water and gas supply through mains to final consumers[MÉX]
236	Construction
237	Civil engineering construction works
238	Specialized construction works
311	Food industry
312	Beverage and tobacco industries
313	Textile inputs manufacturing, and textiles finishing
314	Textile products manufacturing, except apparel
315	Apparel manufacturing
316	Leather and fur tanning and finishing, and manufacturing of leather, fur and allied materials products
321	Wood industry
322	Paper industry
323	Printing and related industries
324	Manufacturing of products derived from petroleum and coal
325	Chemical industry
326	Plastic and rubber industry
327	Nonmetallic mineral products manufacturing
331	Basic metal industry
332	Metal products manufacturing
333	Machinery and equipment manufacturing
334	Manufacturing of computer, communications, and measuring equipment, and other electronic equipment, components and appliances manufacturing
335	Electric appliances, accessories and electric power generation equipment manufacturing
336	Transportation equipment manufacturing
337	Furniture, mattresses and blinds manufacturing
339	Other manufacturing industries
Tertiary sector	
434	Wholesale trade of agricultural, forestry and industrial raw materials, and waste materials[MÉX]
481	Air transportation
482	Rail transportation
483	Water transportation
484	Freight truck transportation
485 and 487	Passenger transportation by road, except by rail and sightseeing transportation
488	Services related to transportation
491 and 492	Postal services and Courier and messenger services
493	Warehousing services
511	Newspaper, magazine, book, software and other materials publishing and integrated publishing/printing of these publications
512	Film and video industry, and sound recording industry
515 and 519	Radio and television and Other information services
517 and 518	Other telecommunications and Electronic data processing, hosting, and other related services
52	Financial and insurance services
531	Real estate services
532	Rental of tangible goods
533 and 551	Rental services of trademarks, patents and franchises and Head offices
541	Professional, scientific and technical services
561 and 562	Business support services Waste management and remediation services
611	Educational services

Appendix B (*Continued*)

621	Outpatient medical services and related services
622	Hospitals
623	Social assistance and health care residential facilities
624	Other social assistance services
711	Artistic, cultural and sporting services, and other related services
712	Museums, historical sites, zoos and similar institutions
713	Amusement services in recreational facilities and other recreational services
721	Temporary accommodation services
722	Food and beverage preparation services
811	Repair and maintenance services
812	Personal services
813	Associations and Organizations
814	Private households employing domestic personnel
931	Legislative, governmental and justice administration activities[MÉX]

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