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STUCK IN THE JAM? CO2 EMISSIONS AND ENERGY INTENSITY IN MEXICO

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Stuck in the jam?

CO_2 Emissions and Energy Intensity in Mexico

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Introduction

Global emissions of greenhouse gases (GHG) have been accelerating in recent decades. Moreover, since the year 2000 global emissions have been growing far more rapidly than the worst scenarios projected by the Intergovernmental Panel on Climate Change (IPCC) (Rogner et al., 2007, Raupach, et al., 2007). This growth has been driven by the expansion of activity in the world economy and the reversal of earlier declining trends in both the energy intensity of gross domestic product and the carbon intensity of energy (measured respectively, as energy consumption per unit of gross domestic product and the CO_2 emissions per unit of total primary energy supply). According to the last report of the Intergovernmental Panel on Climate Change (IPCC), during the period 1970 to 2004 global emissions have risen as the combined effect of global income growth (77%) and global population growth (69%), which have surpassed the general decrease in energy intensity of GDP (-33%) and the almost null reduction in carbon intensity of energy (-2%). In other words, “declining carbon and energy intensities have been unable

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to offset income effects and population growth” at a global scale, rising consequently carbon emissions (Rogner et al., 2007, p. 107).

Developing countries account for a considerable share of the increase in emissions in the last years, a share as high as 70% of emissions growth in 2004. The surge of GHG emissions in large developing economies like China and India reflects the extent to which declining energy intensities have been offset by increasing carbon intensities and rapid economic growth. Such a pattern of rising carbon intensities has been attributed the acceleration of coal-based electricity generation and a rapidly growing transport sector fuelled by oil (Rogner, et al., 2007). However, the asymmetries in terms of per capita income, per capita emissions, and per capita energy-use among countries remain strongly significant. Moreover, developing countries are responsible of only 23% of global cumulative emissions since 1750 (Raupach, et al., 2007).

These trends suggest two major issues. First, that the changing structure of growth in the global economy has a large impact on the scale of annual emissions. Developing countries’ scale of impact is large and growing, despite their modest gains in per capita income. Second, that technical change directly linked to the emissions intensity of economic growth has not been fast enough, and more importantly, has proceed on the wrong direction. The implications of these coupled developments are even more disturbing considering that both the physical processes and the economic choices relevant for climate change have such long-lasting effects that they can be treated as irreversible (Schmalensee, 1998).

This paper examines the pattern of GHG emissions in Mexico, having the above discussion as a framework. In the first section, it reviews the literature on the so-called environmental Kuznets curve hypothesis, as applied to the relationship between economic growth and GHG emissions. In section 2, we describe Mexico's CO_2 emission's historical path and its component factors. In section 3, the trends and sectoral features of energy intensity are analyzed and explained. Section 4 focuses on emissions derived from energy use in the energy-producing and industrial sectors. Section 5 discusses the results and concludes.

EKC and GHG emission paths

The relationship between economic growth and GHG emissions has been examined by relying on the environmental Kusnetz curve hypothesis (Holtz-Eakin and Selden, 1992; Moomaw and Tullis, 1994; Cole et al., 1997; Moomaw and Unruh, 1997 and 1998; Schmalensee et al. 1998; de Bruyn et al., 1998; Sun, 1999; Dijkgraaf and Vollebergh, 2001; Harbaugh, et al. 2002; Matrínez-Zarzoso and Bengochea-Morancho, 2004).

Environmental Kuznets curve predicts, or more accurately, assumes, an inverted U-shaped curve relating emissions to GDP. It was originally formulated by Grossman and Krueger (1991) and presented in the context of the discussion on trade and the environment (see also Grossman and Krueger, 1995). Simply stated, the hypothesis asserts that the environmental impact of economic growth increases with income up to a maximum level and decline afterwards. In other words, as societies satisfy their basic needs, and education and health standards rise, they become more willing to spend parts of their income in protecting the environment. At the same time, and due to technological leapfrogging and imitation, developing countries should exhibit “lower” EKC curves and smaller income thresholds (Dasgupta, et al. 2003).

As argued in Dasgupta et al (2003), an environmental Kuznets curve (EKC) can result as income increases in a society if four conditions are satisfied: 1) the marginal utility of consumption is constant or falling; 2) the dis-utility of pollution is rising; 3) the marginal damage of pollution is rising; and 4) the marginal cost of abating pollution is rising. Some of this conditions may simply be absent, the environment could be emitting the wrong signals (for example, distorting the marginal damage of pollution). Property rights and externalities: if the agent experiencing the damage of pollution and the agent who benefits from pollution are not the same one, pollution need not curbe with income, even if the other two conditions are fulfilled. The hypothesis’ postulate is presented without an attempt to measure its internal workings; for example, a consequent inquiry on measuring some of the underlying utility functions. Rather, applications have focused on estimating income levels at which “turning points” take place. Evidence on a decreasing relationship between measured impacts and income growth through cross-sectional analysis has been argued, perhaps far too quickly, for promoting policy stakes like trade and investment liberalization (see for example the comment by Baker, 2003).

The EKC hypothesis faces challenges from both empirical evidence and theoretical narrowness. Clearly, it is nowhere implied that dis-engaging economic growth from CO_2 emissions is an automatic consequence of growth (Arrow et. al. 1995). Despite punctual warnings by the original authors, the hypothesis has sometimes been argued to encompass aggregated environmental impact; however, this implies building a consistent measure pf multidimensional environmental impact (Nadal, 2006), an obstacle that impedes, for the moment, an consistent testing of the hypothesis. The aggregation problem reveals itself at the spatial level, if one considers that environmental damage could be curbing at some place while increasing somewhere else, due to a “passing the buck” mechanism (Rothman, 1998). This is particularly the case when the intended environmental impact to be examined is of a global effect.

Tisdell (2001) points at two central implications of the EKC hypothesis that make it especially unsuitable for examining the relationship GHG-emissions and economic growth. First, the EKC curve represents a function yielding average pollution; as long as marginal pollution is positive beyond the turning point, total pollution will continue to increase, even if at a slower rate. Second, the argument assumes that pollution is not cumulative or that its impacts are reversible. As is the case with GHG and their global warming effects, rising temperatures and GHG concentration are subjected to strong positive-feedback effects, and may not decline after a critical pollution threshold is exceeded. Once that threshold is exceeded, income may sharply depress and economic growth be reversed. In the worst scenario, economic production declines after that threshold is reached while aggregate impact increases at the same time.

Empirical evidence against an EKC for GHG emissions is on the other hand solid. EKC does not match for individual countries, great heterogeneity. Both Moomaw and Tullis (1994) and Schmalensee et al. (1998) found that cross-sectionally CO_2 rises with income per capita, and that even when some countries show an inverted-U path there exist many different development paths. Individual country heterogeneity has been confirmed in de Bruyn, van den Bergh and Opschoor (1998), Dijkgraaf and Vollebergh

(2001), Roca and Alcantara (2001), Friedl and Getzner (2002), and Huang et al. (2008). Cole et al (1997) found that "EKCs exist only for local air pollutants, whilst indicators with a more global, or indirect, environmental impact either increase monotonically with income or else have high turning points with large standard errors." The encompassing review by Stern (1998) noted that the evidence on an inverted-U relationship between emissions applied only to a small group of measures of environmental impact like suspended particles and SO_2. In general, thorough panel data analysis has shown that rebound effects and N-shaped relationships are ubiquitous (Moomaw and Unruh, 1997; Martínez-Zarzoso and Bengochea-Morancho, 2004), and that good curve fits does not necessarily imply future behaviour (Moomaw and Unruh, 1997).

With the salient exception of Moomaw and Unruh (1998) most EKC studies tend to ignore growth theory. They argue that while the notion that economic growth proceeds by stages is a key notion behind EKC, it is not certain that it "is a deterministic process that all countries must pass through" (p. 222). The approach compares countries with very different resource endowments, different income levels, and different patterns of product-technology specialization relying on a key assumption of "income determinism". Moomaw and Unruh use non-linear dynamic analysis to track EKC evidence on the transition to lower levels of CO_2 per capita in set of countries: "these transitions occur over a broad range of income levels and, somewhat surprisingly, the transitions are found to occur abruptly and co-temporally. They do not appear to be the result of endogenous changes in income growth, but instead result from rapid, co-temporal historical events and responses to external shocks." This way, "CO_2 emissions trajectories appear to be exhibiting behavior that could be called punctuated equilibrium."

The EKC is based on a growth theory that assumes international convergence and infinitesimally continuous, exogenous technical change (Nelson, 1981). At the same time, the evidence on international convergence shows a great deal of heterogeneity of long run growth paths (Baumol, 1986; Baumol, Blackman and Wolff, 1994). In turn, countries' growth path depends on a handful of factors (Mankiw, Romer, and Weil, 1992), among which the most important are innovation and structural change (Dosi, Pavitt, and Soete, 1990; Fagerberg, 1994). This underlying diversity and the relevance of conditional technical change, also questions the EKC hypothesis that developing countries would tend to show lower emission-to-growth curves. Can countries get trapped in low-growth traps with high carbon intensity? This conclusion has been suggested in a path-breaking study on the relationship between trade and the environment in Mexico (Gallagher, 2004). This author found that the hypothetical "turning point" of the emissions Kuznets curve for Mexico would be sliding away beyond the $5,000 1995-USD per capita threshold level found in cross-sectional studies. Trade liberalization would had been related to small income rise, while environmental degradation had advanced persistently.

In the following of this paper we show how the case of Mexico exemplifies, against evidence from developed countries and transition economies, that emission paths lock-in to determined levels of emissions when development stagnates. In our opinion, this reinforces the notion that emission's factors should be analyzed from a broader point of view, beyond reduced-form, aggregated functions.

The path of CO_2 emissions

Mexico contributes to 1.8% of the global GHG emissions with about 670 million tons of carbon equivalent every year. Current trends are somewhat disquieting: after experiencing a decreasing trend between 1989 and 2000, Mexico's energy and emission intensities increased in 2003 and 2004 (INE-SEMARNAT, 2006; SENER, 2006). The emissions level will easily double by 2030 at the current GDP growth rates; if more desirable growth rates were attained (5-6% a year) emissions could easily double in only 10 years (Masera and Sheinbaum, 2004).

Mexico's pattern of CO_2 emissions from energy-use in the second half of the 20th century expresses clearly the transition into a pattern of intensive use of fossil energy. According to Marland, et al. (2007) emission intensity had progressed geometrically during the 20th century, doubling between 1950 and 1970 (from 0.3 to 0.58 tons of CO2), and then doubling again between 1970 and 1982 (from 0.58 to 1.82). Therefore, examining the trend from the 1970 on tracks the most acute period of growth in emissions intensity.[1]

Emissions increase in Mexico since 1970 surpassed population and income growth by a factor of 2. Though impressive, this volume increase was not strongly different from the increase in OECD countries with similar income levels in the early 1970's.[2] The index

[1] The series by Marland, Boden, and Andres (200/) accounts only for a handful of GHG emissions' sources. Sheinbaum, Rodríguez and Robles (1999) estimated much higher GHG emissions derived from energy use, but the growth trend in their series is slower. Despite the point-accuracy of this latter estimate, the time-consistency of Marland et al (2007) makes it more suitable for analyzing the time trend.

[2] We use this set of countries mainly for reasons of data availability and homogeneity.

volume of total emissions in Mexico (1971=100) reached 385.6 in 2004, 497.6 in Turkey, 400 in Portugal, 272 in Spain and 186 in Ireland.

It is possible to decompose Mexico's emissions level into its constituent components. Using the Kaya identity. This type of analysis has been used in IPCC and other studies for decomposing historical trends in emission's factors (Kaya, 1990). Kaya identity is a gross simplification of a complex bundle of factors. It aggregates data from highly heterogeneous phenomena; separates functions which pertain together; conceals the nature of relationships among factors. For example, while there is undoubtedly a tight relationship between the carbon content of energy and energy efficiency, this relationship may not be constant in time due to a mixture of strictly technical issues changes in the relative importance of activities. All these caveats should be acknowledge in using it as an analysis tool.

Results for each component are shown in graph 2 as index numbers based in 1971. As commented above, the volume of emissions doubled between 1971 and 1981. Orders of magnitude reveal the nature of growth in the direction of fossilization. Shortly stated, and increase of 50% I income per capita would have relied on increasing the level of emissions by a factor of 2.5-3. Population growth diminished steadily in those consecutive decades. CO2 intensity of the energy mix has remained more or less constant during the whole period. Income per capita remained stagnated from 1982 to 1997, growing only slowly afterwards, while energy intensity of the economy clearly curbed about 1989. In consequence, it can be stated that the slight curbing trend in total emissions is driven, in the first place, by diminishing energy intensity, and to a smaller degree by slower population and by economic stagnation. This result confirms that of

Sun (1999), who shows that for the period 1971 and 1995, in most countries relative changes in energy intensity are much stronger than changes in the CO_2 intensity of primary energy.

[Graph 1 about here]

Observing closely Mexico's trajectory shows that the country's trajectory oscillated back and forth between income levels during the period 1981-1999. However, during these two "lost decades" of economic growth, the per capita emission rate did not diminish proportionately. With fairly steady emission rates and population increasing, total emission volume accumulated at inertial speed while income per capita oscillated around a short range of income levels. Huang et al. (2008) found that the relative CO_2 emissions' path for economies in transition exhibits a "hockey-stick" shape, as a result of the economic collapse that these countries experienced during the early 1990's. Graph 1 shows that such a path occurred as well in Mexico during the crisis period 1982-1987, but then emissions were catapulted again as a result of even moderate income growth rates.

The critical observation is that while economic growth seems clearly geared to growing emissions (even if at decreasing rates), within close ranges of per capita income instability, emissions are independent from economic growth. The emissions pattern shows signs of irreversibility along the growth path.

[Graph 2 about here]

Both a technical response and huge structural adjustment took place in Mexico between those lost decades. Technology up-grading and de-industrialization coexist with surging energy-intensive imports. This makes trends shakier than presumed simply by observing the trend in energy efficiency. This is what we question in this paper.

3. Energy Use

Graph 3 shows the long-term trend of energy-intensity in Mexico. In general terms, this curve exhibits an inverted-U shape along the period 1965-2004, peaking in 1989 and with a weak rebound in the last 2 years of the series. Total energy consumption in the country rise 6-fold in the period from 1,200 to 7,000 petajoules. According to OECD data, primary energy supply per capita increased from 0.87 tonnes of oil equivalent (t.o.e.) a year in 1971 to 1.65 in 2005, just about the world's average. Energy use per capita is 7.91 t.o.e. in the US, 3.89 in the EU-25, 1.24 in China, 1.11 in Brazil and 0.53 in India (OECD, 2007).

The decreasing trend in energy intensity of the Mexican economy is not the product of a single factor, but rather the compound result of various overlapping processes. First, Between 1965 and 1981 the annual growth rate of energy consumption grew faster that that of GDP (7.6% and 6.7% a year, respectively). Growth in both indicators stagnated during the eighties. Between 1989 and 2004, however, economic growth was much slower compared to previous decades (2.7% annual average), but larger than that of energy demand (1.8%). By the 1980's most of the energy-intensive industries in mining, energy-producing and manufacturing had already been deployed.

[Graph 3 about here]

This means that energy-demand per additional unit of output in the industrial sector would have started to fall from that date on, as activities with smaller energy-output ratios increased their share in new investments. Increase in the relative weight of the service sector may also likely impact negatively energy intensity for the economy as a whole. Second, after the 1982 crisis the economy entered a low-speed growth trajectory, compared to that of the previous decades. Growth of per capita GDP fell from 3.2 per cent a year between 1965 and 1982 to 0.7 per cent a year between 1982 and 2004.[3] This has prevented demand to be channeled into more energy-intensive consumption patterns. Third, the economy's liberalization process that took place since the 1980's and a context of a constrained domestic demand both increased market competition and financial stringency. This triggered a multitude of structural and technical changes operating at different levels throughout the productive sector, that plausibly induced, both directly and indirectly, rationalization of energy use. Aguayo and Gallagher (2005) showed that most of the reduction in energy intensity since 1989 can be accounted for by changes in the manufacturing sector, and that energy savings are a result of structural, technical, and trade effects. Finally, organized institutional efforts, like the creation of the National Commission for Energy Savings (CONAE, for its name in Spanish) and the Fund for Electric Energy Saving (FIDE) were also instrumental in attaining energy savings.

[3] Other Latin American countries experienced a similar trend. Between 1982 and 2004, per capita income growth (measured in constant US dollars PPP) in Argentina and Brazil reached 0.7 and 1.0 per cent a year respectively. This figure contrast strongly with countries that held similar wealth levels in the 1960's like Ireland (6.3), Spain (3.3) and Portugal (3.1), and even more with emerging Asian economies like those of India (5.0), Singapore (5.6), South Korea (7.8) and China (11.5). Source: author's calculations based on *UNCTAD Handbook of Statistics*, 2005.

Graph 4 shows sectoral trends in energy intensity for the same periods. Relative energy use in the energy and industrial sectors is given by the sectors energy consumption per unit of the sector GDP. Due to the pervasiveness of transport, its intensity is calculated as the sector's energy use per unit of total GDP.

[Graph 4 about here]

We distinguish two periods in the time path of energy intensity at the sectoral level. First, in the period that runs from 1965 to the mid 1980's, total energy intensity increases strongly as an effect of industrialization and urbanization, which reflects in rising intensity in industry and transport. Along this period there is a simultaneous increase in the energy efficiency in the energy producing sector. Plausibly, this last effect is a result of economies in energy use, development and rationalization of the energy infrastructure of energy production and distribution, as well as from technological advance in national energy firms. Energy efficiency in the energy producing sector accompanied the transition to an energy-intensive development pattern, relatively offsetting the impact on energy resources from the other productive sectors. Upstream efficiency gains in the production of fuels and electricity prevented the economy to reach higher intensity levels as it integrated energy-intensive activities.

Second, from the mid 1980's these trends experience shifts in their trajectories. Efficiency gains in the energy sector shows signs of exhaustion, reducing significantly its growth rate. Energy intensity in the industrial and transport sectors peaks in the mid 1980's and early 1990's respectively. While energy efficiency gains show a strong diminishing trend in industry, the trend is much weaker in the transport sector. Finally, the three main sectors show a slight rebound effect from 2000 on, mainly due to economic stagnation.

4. Sectoral emissions

Differences en emission trends between the sectors can be tracked according to differences in their originating factors. In order to account for “structural” differences of emissions we map the trends of the components of the Kaya equation for both energy-producing and industry sectors. The following analysis is different from the one in section 1 in two aspects. First, it omits the population factor. With population growing at less that 2% in this short period of time, the population effect, though positive, would not deviate significantly the relevant trends. Second, unlike the decomposition analysis of section 1, GHG emissions in this section refer to CO_2, CH_4, and SO_2 sectoral aggregates in units of CO2 equivalent.[4] Data comes from the National Inventory of GHG Emissions (INE-SEMARNAT, 2002). The above mentioned caveats on this type of analysis must again be recalled.

Surge of emissions in the energy-producing sector is driven by expansion of scale without no significant reduction in either the carbon content of energy nor in the energy intensity of GDP.

[Graph 5 about here]

The calculation of the energy sector includes both oil extraction and refining as electricity generation. It is known that the latter has experienced important technical change (by substituting thermal generation with combined cycle) that comprised both a reduced carbon content of fuels and increased energy efficiency. However changes in the fuel mix between 1990 and 2003 yielded only minor reductions in emissions volumes. Direct emissions derived from energy consumption in the energy sector increased 49.8% between 1990 and 2003.[5] The share of major fuels in the energy sector changed substantially, with fuel-oil (*combustóleo*) decreasing from 53% to 33%, and natural gas and coal increasing from 29.9 to 49.6% and 5.0 to 13.4% respectively. This changes in the energy mix, however, represented a reduction of only 2.79% in terms of emission volumes. That is, if the fuel share in 1990 had remained constant throughout the period, total emissions from energy use in the energy sector would have been about 3% higher. Considering electricity generation alone, direct emissions from energy use increased 75.14% between 1990 and 2003, accumulating barely 3.7% of emissions savings derived from changes in the fuel mix.

In the next decade, further technical change in electricity generation will not provide significant direct reductions of emissions from changes in the fuel mix. According to planned investment of the Federal Commission of Electricity (CFE), the substitution of natural gas for fuel-oil will deepen between 2003 and 2013, changing their share in the industry's fuel mix from 37.6 to 52.2% and 36.2 to 17.5%, while keeping the relative consumption of coal constant. These changes would at most generate around 5% of emission abatement at each level of emissions. Clearly, since our estimation misses additional differences in emission factors between specific technologies, the ongoing

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[4] CH_4 and NO_2 equivalents according to their potential warming up to 100 years, converted by equivalence factors of 21 and 310, respectively.

[5] Emission values were calculated simply by adding up the volume of fuel consumption scaled by the corresponding emission factors specified in the IPCC guidelines (1996). IPCC; "Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories"; Reference Manual (Volume 3),: Table 1-1, p. 1.13. Figures of energy consumption come from the National Inventory of Emissions of Greenhouse gases (INE, 2006). Due to lack of information, we omit additional differences in emission by further differentiating among technologies that use the same fuels. This omission implies that our estimation should be considered an average with a significant dispersion.

changes in the technological profile in electricity generation will provide additional emission reductions both directly and indirectly (through energy efficiency). To put these trends in proportion one needs to consider that, according to most estimations, gross electricity generation will increase 70% between 2003 and 2013, and that an additional 30 to 40% increase in supply will be needed by 2030.[6]

It seems clear that the ongoing phase of technical change in electricity generation in Mexico, characterized by the penetration of natural gas as a main fuel is insufficient to draw the industry much closer to a level of emission stabilization by 2030. Of course, new combined cycle plants also deliver important emissions savings through increased generation efficiency; however, these efficiency savings, coupled with minor changes in absolute emissions per unit of energy produced will be unable to offset the scale effect of growing energy supply. Without major improvement in energy efficiency and a much stronger effort to adopt and deploy renewable energy sources, the energy sector will not be able to disengage growing emissions from economic growth in the next 2 or 3 decades in any significant way.

Graph 6 below shows the evolution of the physical and economic efficiency-ratios, measured respectively as the amount of energy consumed per unit of energy produced and as units of energy consumed per unit of economic output (in turn, measured as the energy sector's gross domestic product). Both ratios are expressed as index numbers with base in 1965, first year available in the time series.

[Graph 6 about here]

[6] See IEA (2002).

We identify two different periods. The first period starts in 1965 and ends between 1981-1983, and reflects the deployment in Mexico of a "modern" energy infrastructure based on oil and electricity and its development. In this period both measures of efficiency follow twin trajectories, showing a cycle of energy-intensity growth and rationalization that talk about the energy-consuming phase of construction of a modern energy base and a phase of adjustment and realization of both energy-saving opportunities and improvement of energy generation practices and technologies. While the effect of increasing international oil prices from 1973 on surely affects the economic efficiency ratio (as energy GDP includes a strong component of crude exports), this was firmly accompanied by increasing physical efficiency by about 30% from 1965, cutting relative energy use by a half from 1973-1983.

The second period expresses important shift in the structure of the energy use base. The trends of the coefficients now diverge, expressing on one hand a more or less averaged exhaustion of improvement possibilities in physical efficiency, and on the other stagnant levels of economic efficiency. This diverging trend is not only worrying despite expected high international prices in the medium and long terms, but precisely because of that. High international prices of oil have allowed Mexico to subsidized an increasingly inefficient pattern of exploitation and consumption of energy through surging crude-oil exports. This pattern is clearly not sustainable as the fossil-fuel reserves approach exhaustion: the country will be left out to grab whatever resources there are to finance heavy amounts of energy to be consumed in very inefficient ways, and without the "cash cow" of cheap crude exports.

Graph 7 shows that the trends in GHG emissions and their factors in the industrial sector follow a significantly different and moderately more optimistic pattern of change. Emissions in the industrial sector include all CO_2, CH_4, and NO_2 emissions from energy use as well as emissions from industrial processes. The total volume of sectoral emissions in the industry sector increased around 18% between 1990 and 2000, with a 10% decrease between that last year and 2003 due mainly to economic stagnation. Provided that the carbon content of the energy supply shows a slightly increasing trend, it seems clear that improvements in energy efficiency of about 30% during the period buffered the impact of activity growth (40 to 50%).

[Graph 7 about here]

The emissions' trend of this sector is then one of moderate increase in the GHG intensity of industrial activity. This trend expresses a technical pattern of development in which, first, a the fuel mix of energy is persistent, and second, growing energy efficiency almost compensates the emissions effect of economic growth. Such a technical patterns seems to respond to one in which there are no major technological changes occurring at the level of the carbon intensity of core industrial production technologies, and that efficiency gains are attained mainly through incremental technical progress in energy efficiency. Such a process would find its limits on the investment cycle and market barriers to capacity growth, since the absorption of new core technologies depends on capital turnover rates. However, there is room for energy saving in small scale changes. What about other changes in terms of the relative changes among energy intensive industries?

[Graph 8 about here]

Graph 8 shows how the evolution of energy efficiency at the sectoral level is a combination of both industry level efficiency gains and changes in the relative sizes of industry. Total changes in energy intensity during the period 1988-2004 would have a technology component of about 75%, and a scale component of about 20%. That is, about a fifth of the reduction of energy efficiency comes from more intensive industries loosing relative importance in favor of less energy intensive ones. A more detailed analysis, shows that most of the scale or composition effect can be attributed to the collapse of the petrochemical industry in Mexico since the late eighties (confirming the results by Aguayo and Gallagher, 2005).

Finally, comparing these two latter graphs, it seems evident that efficiency gains are also closely related to cycles of investment and capacity expansion; the slowing of economic and market growth since the year 2000 would have prevented Mexican industry from attaining subsequent gains in energy efficiency. How solid is reading about the pattern of development, as well as its finer-grain causes is something that clearly demands further research at the industry-, and plant-level.

Discussion

We have shown that the path of increasing GHG volume of emissions in Mexico slowed down from 1982 onwards, as a combined result of economic stagnation and moderate gains in energy efficiency. This way, the national trajectory is one in which the rate of emissions per unit of income remains constant for a long period during which, income growth remains also constant. Retarding growth, however, does not reduce the country's contribution to the stock of GHG concentrations. At some level of industrial development, environmental impact is not reversible, and its effects accumulate whether there is development or not.

Analysis of trends at the sectoral level show that the pattern of GHG emissions of the industrial and energy generating sectors in Mexico show strong inertial features regarding the carbon content of energy. At the same time, energy efficiency seems to have slowed down, reaching a plateau where further gains would depend on more profound technological and structural changes.

We have argued that the EKC approach can be misleading for assessing barriers to disengaging emissions from economic growth. It is of the outmost importance to turn attention to two issues ignored by reduced-form representations of that relationships. The first is the positive probability that large segments of economic activity get lock-in to high-carbon technical choices, creating large costs and weak opportunities for switching investment flows into low carbon energy technologies and efficient reversal of CO_2-sinks depletion. Income growth has been built on a technological platform that sinks investments into high-carbon technological systems, generating multiple sources of lock-in and vested interests (including, but maybe not among the largest, the type of organizational inertia commented by Unruh, 2000).

Second, we cannot stress enough the fact that an EKC approach also ignores the dangerous possibility for adaptation costs in developing countries to absorb out funds otherwise available for mitigation-oriented investments. There is wide consensus and a large likelihood that the negative impacts of climate change will be suffered earlier and stronger in developing countries (UNFCC, 2007). This means that, in a scenario where some dangerous impacts of climate change cannot be avoided, highly vulnerable developing countries will be facing increasing adaptation costs with increasing difficulties to mobilize efforts and resources to mitigation. Due to the inertial features of average temperatures, it is unlikely that in such a scenario these countries could even turn to swapping economic growth for emissions reductions, the most likely result would be that of large scale social failure in responding to climate change impact.

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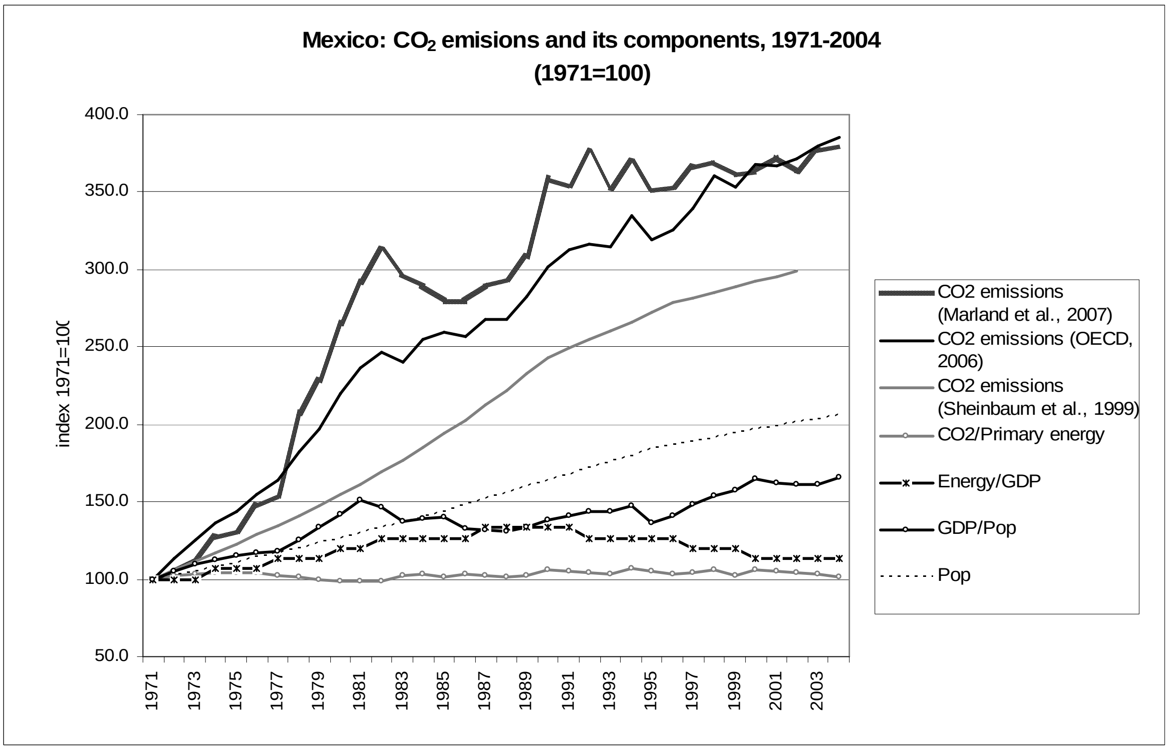
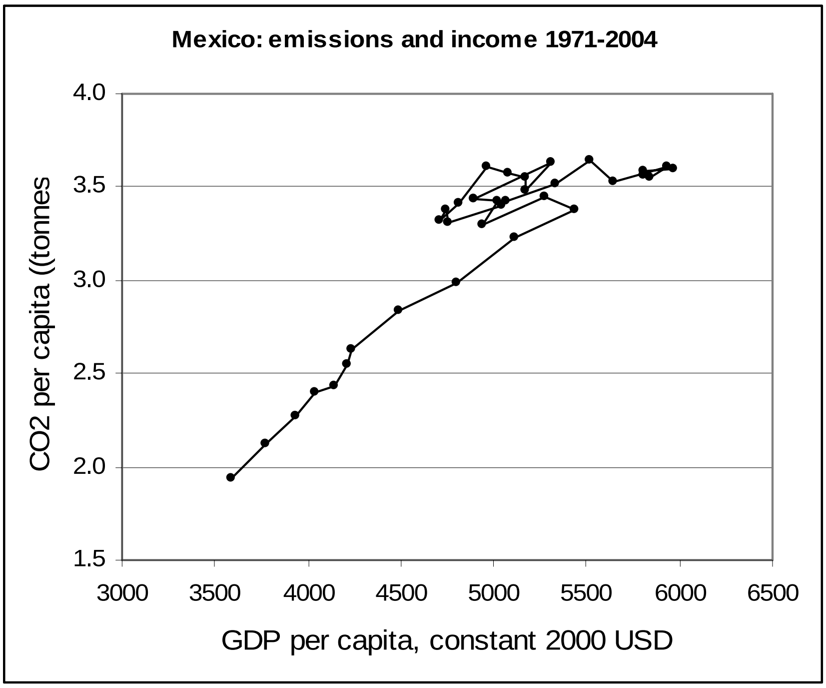
Graphs

Graph 1



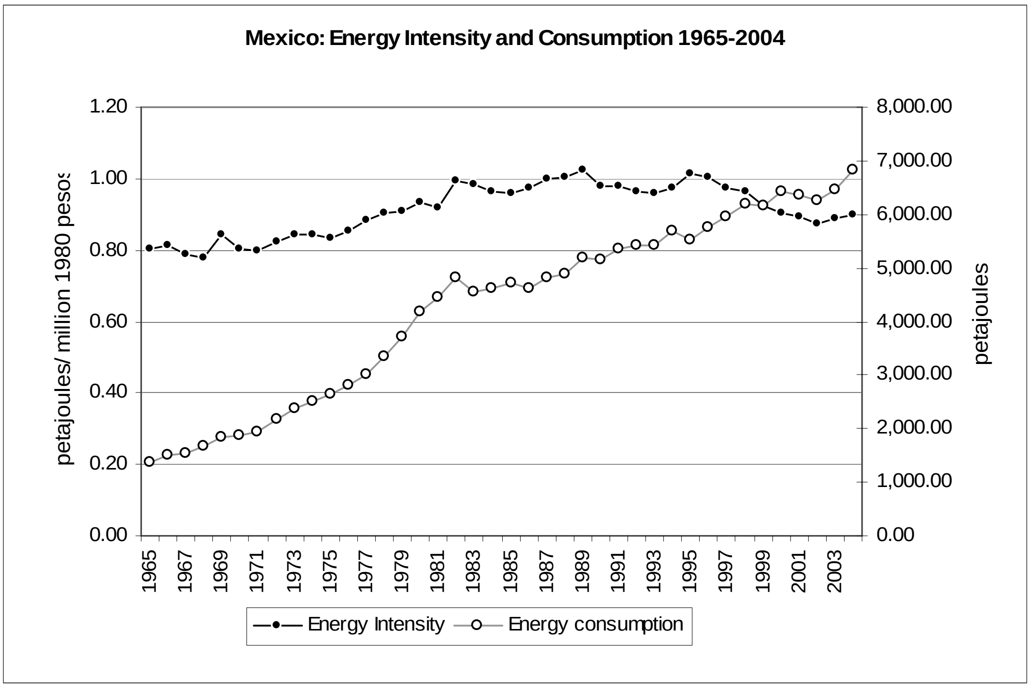
Source: Author's calculations. CO_2 emissions derived from energy use, indicated sources. Energy, GDP/Pop, and Pop: OECD (2007).

Graph 2



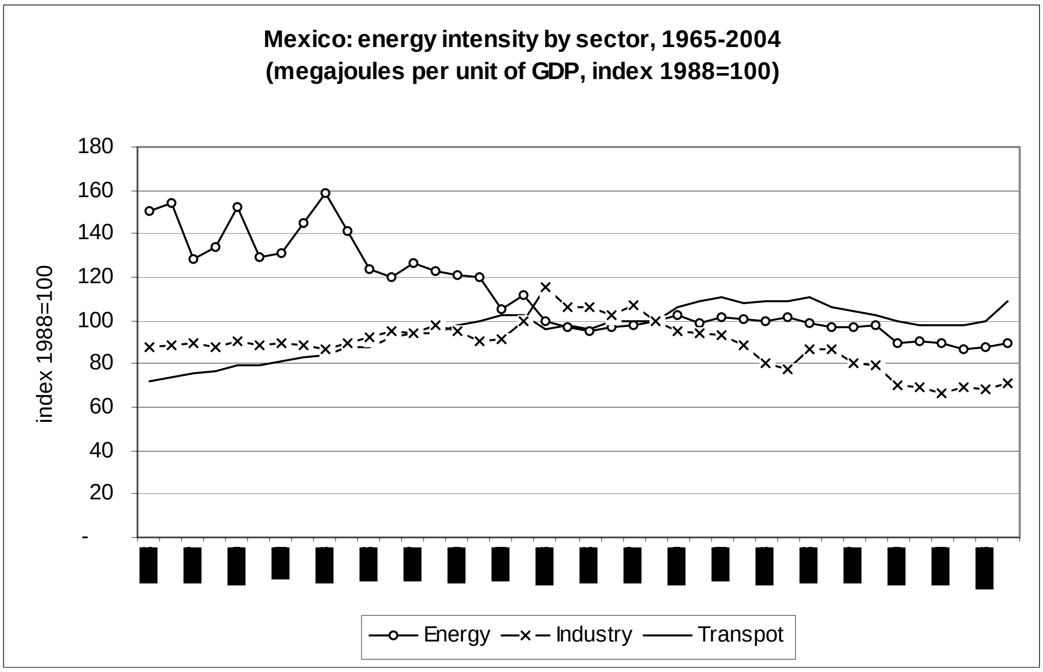
Source: Author's calculations, based on OECD (2007).

Graph 3



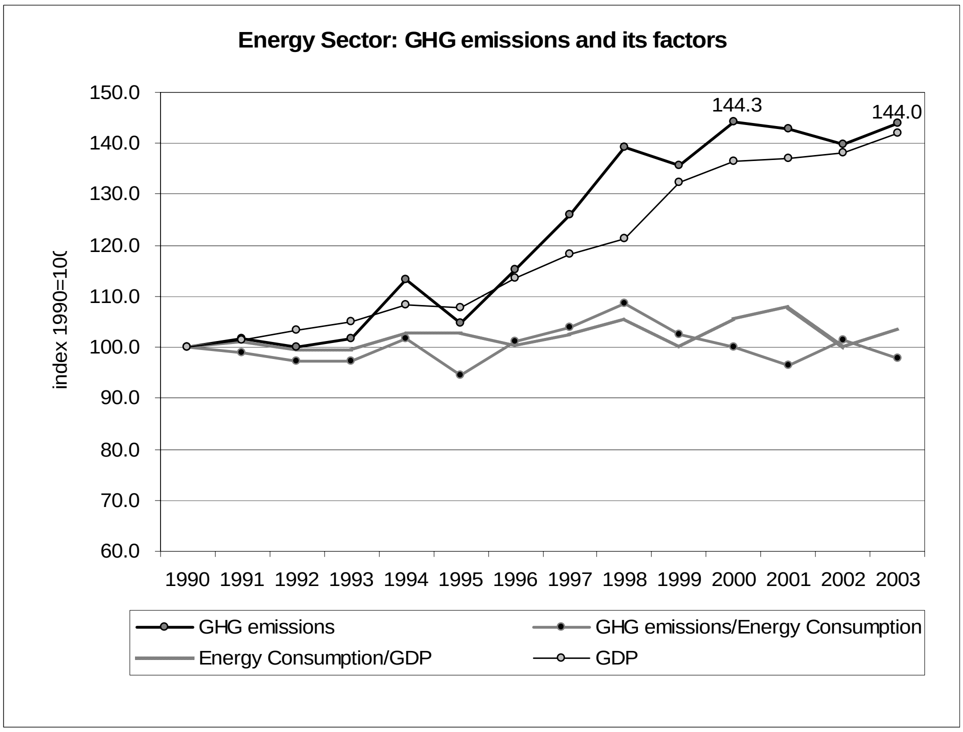
Source: OECD (2007)

Graph 4



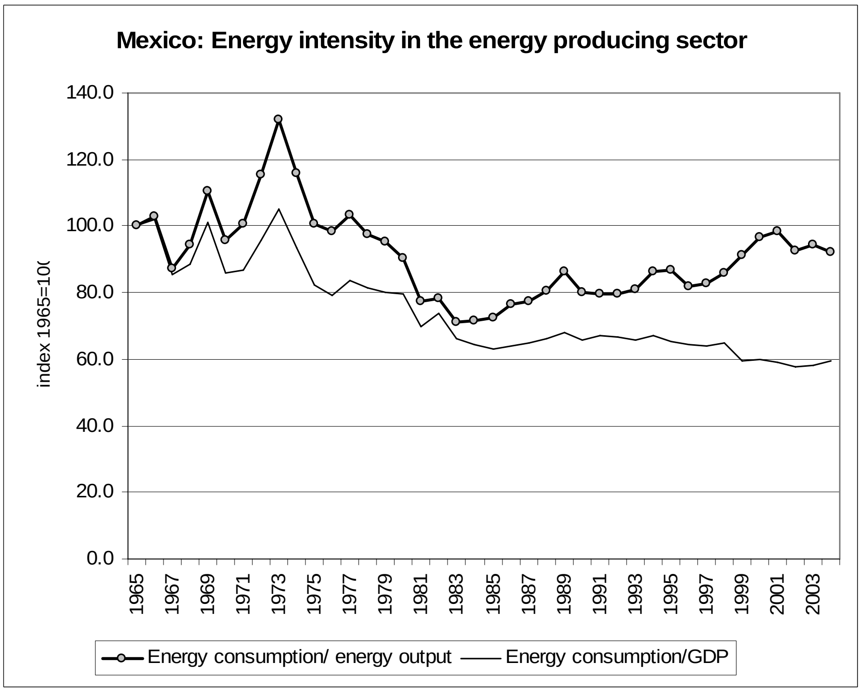
Source: Author’s own calculations. Based on INEGI, National Accounts (GDP); SENER, Energy Balances (energy consumption).

Graph 5



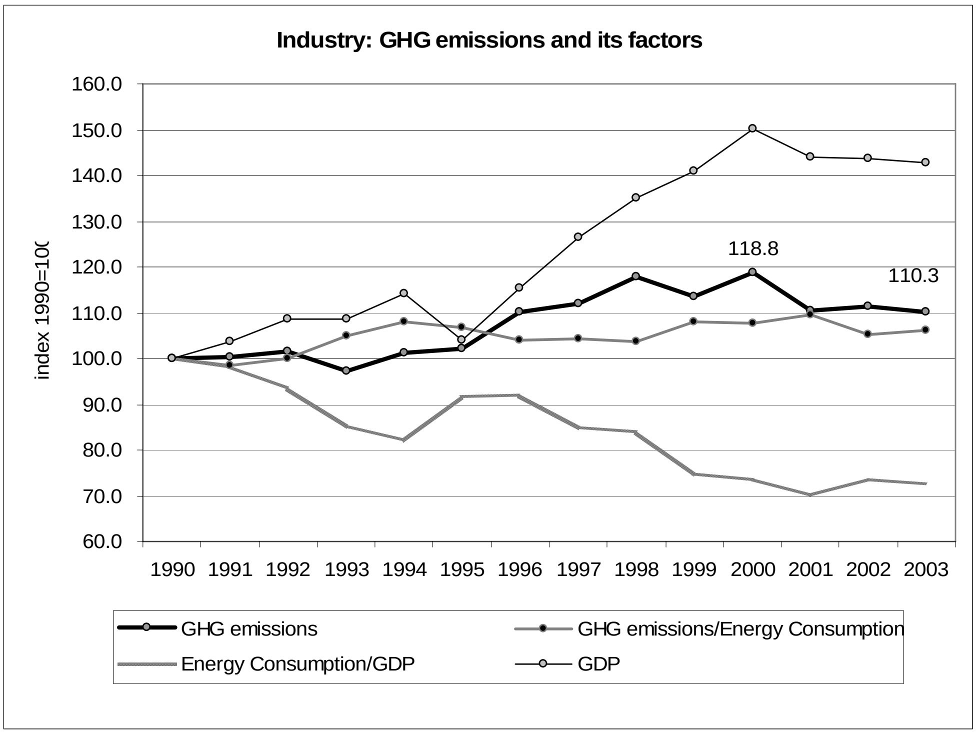
Source: Author's own calculations. Based on INEGI, National Accounts (GDP); SENER, Energy Balances (energy consumption); INE-SEMARNAT, Emissions Inventory (GHG emissions).

Graph 6



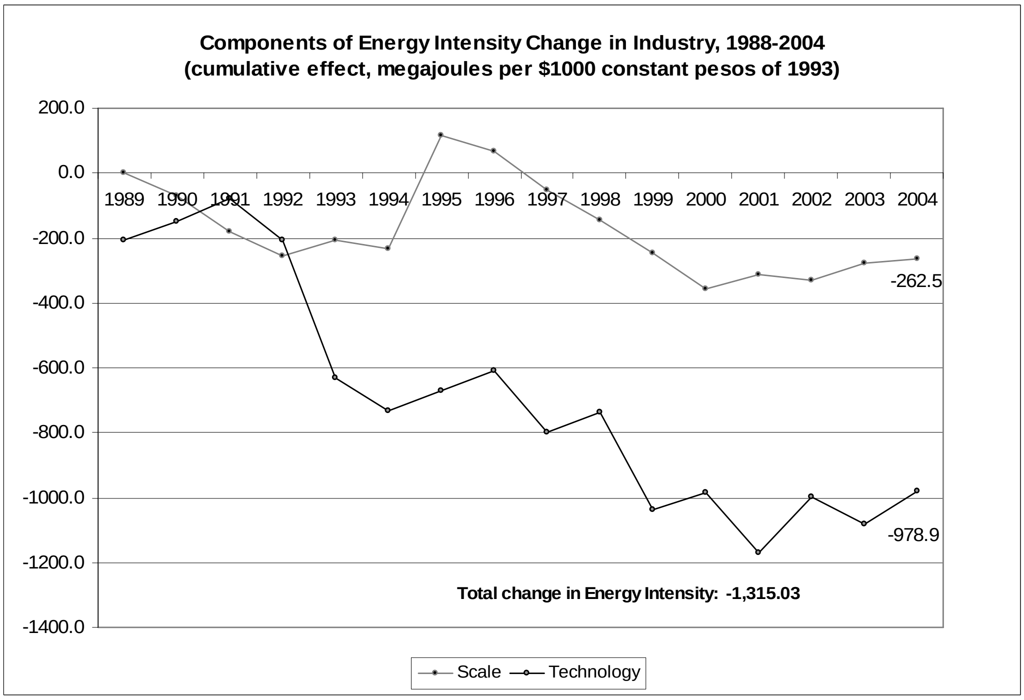
Source: Energy Balances, SENER 2007; National Accounts, INEGI.

Graph 7



Source: Author's own calculations. Based on: National Accounts, INEGI (GDP); Energy Balances, SENER (energy consumption); National Inventory of Emissions, INE-SEMARNAT (2002) (GHG emissions). GHG emissions include

Graph 8



Source: Author's calculations, following Aguayo and Gallagher (2005). Data is from: National Accounts, INEGI (GDP); Energy Balances, SENER (energy consumption)