# What are the Driving Forces of Carbon Intensity Changes in East Asia Pacific Emerging Countries?

Miguel Rodríguez[1] & Yolanda Pena-Boquete[2]

*Dpt. Economía Aplicada, Universidade de Vigo*

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**Resumen.** There is a growing political interest on carbon intensity targets, as long as they are the basis for policies and pledges from relevant developing countries and policy designs in developed countries like EU. There are socioeconomic reasons in support of them but some drawbacks as well. This paper develops a comprehensive econometric study on the main drivers of national emissions intensity in East Asia emerging countries. They represent a noteworthy case study according to their pivotal position in global economic growth and remarkable trends in energy intensity. A notable contribution of this paper is to deviate from common practice in the empirical literature by including labour productivity and employment rates instead of per capita GDP in order to shed more light on the mechanism behind the main drivers on carbon intensity. Surprisingly, labour productivity is the main responsible of major carbon intensity reductions in countries like China.

Clasificación Código JEL: Q43; Q54; O13; O44.

Keywords:

Contact: [1]*miguel.r@uvigo.es ;* webs.uvigo.es/miguel.r ; researchgate.net/profile/Miguel_Rodriguez26

[2]*y.penaboquete@uvigo.es*

Tlf & Fax: 986812505; Facultade Empresariais e Turismo, 32004 Ourense.

Rede Research Group: http://rede.uvigo.es/

## 1. Introducción.

The Copenhagen Accord (UNFCCC 2009) probably delivered the first international commitment from some development countries in order to take action against climate change. Accordingly, developed and developing countries have notify to the UNFCCC Parties their emission pledges in the form of quantified economy-wide emissions targets for 2020. These communications include autonomous national mitigation actions to cut greenhouse gas emissions (i.e., EU 20%-30% compared to 1990), emissions intensity (i.e., China 40%-45% compared to 2005) or emissions relative to baseline (i.e., South Korea 30%).

The national targets have no legally binding status and therefore they are voluntary in nature. Many developed countries conditioned their pledges to the implementation of comparable efforts by other developed countries as well as fully commensurate actions by advanced and major emitting developing countries. Similarly, many developing countries conditioned the implementation of national mitigation actions according to the principles and provisions of the UNFCCC (in particular Article 4, paragraph 7)[1].

There are socioeconomic reasons in support of intensity targets: uncertainty governance, right incentives for enhanced efficiency, compatibility with economic development, etc. But there are also some drawbacks. It is in this framework politicians and researches should examine national emission intensity targets already in place or foreseeable in the near future both in developing a developed countries (i.e. latest European statements on intensity targets). For instance, the EU commissioned in 2014 an assessment on progress made towards reaching Horizon 2020 targets which will review also whether intensity targets or absolute targets or a hybrid of the two “represents a better benchmark upon which to frame a 2030 objective” (European Commission, 2014). Hence, there is a growing political interest on carbon intensity targets, as

[1] United Nations Framework Convention on Climate Change, article 4, paragraph 7: “The extent to which developing country Parties will effectively implement their commitments under the Convention will depend on the effective implementation by developed country Parties of their commitments under the Convention related to financial resources and transfer of technology and will take fully into account that economic and social development and poverty eradication are the first and overriding priorities of the developing country Parties.”

long as they are the basis for policies and pledges from relevant developing countries and policy designs in developed countries.

In this paper, we conduct a comprehensive econometric study on the main drivers of national emissions intensity in East Asia and Pacific emerging countries. We focus our attention on this region because the East Asia and Pacific region still presents one of the highest carbon intensity values despite of showing one of the highest cumulative reduction rates in carbon intensity in the world from 1990 to 2011. The simultaneity of both trends make worth to pay attention to this regional case in order to rise valuable lessons. Besides, BRICS countries and particularly China gained a prominent presence in the Climate Change international talks. These facts, coupled with the evidence that "the center of gravity of the global energy system is shifting towards Asia" according to the International Energy Agency (IEA, 2013) has motivated our regional interest in this piece of research.

The main contributions of this paper are twofold. First, it enlarges the empirical evidence as long as there are few studies concerned on this issue and most of them performed index decomposition studies. Second, we explain carbon intensity values based on the energy and economic performance of countries as well as some idiosyncratic national circumstances. The novelty in this piece of research is to deviate from common practice in the empirical literature by including labour productivity and employment rates instead of per capita GDP in order to shed more light on the mechanism behind the main drivers on carbon intensity.

According to our results, the huge improvement in China carbon intensity since the nineties is mainly due to labour productivity developments and not so much to energy efficiency improvements. Next section will review some results on carbon intensity as a political tool. Section 3 provides a survey of the empirical literature. Section 4 will provide a description of data and some preliminary empirical evidence whereas section 5 describes the methodology. Following we show the main results and policy implications. Finally section 7 summarize the main conclusions.

## 2. Carbon intensity as a political tool.

Some authors have advocated in favor of the adoption of emission intensity target by developing countries (usually an upper limit on $CO_2$ per GDP). According to Marschinski and Edenhofer (2010), there may be several reasons: it could facilitate the adoption of binding emission restrictions by developing countries as long as (i) they may be compatible with high economic growth, (ii) may contribute to the reduction of cost-uncertainty of any emission commitment and (iii) may introduce the right incentives for a low carbon economy development[2]. In any case, emissions intensity targets might be compatible with high emission growth levels.

Intensity targets have been criticized because its stringency depends on the national economic growth rate. Accordingly, intensity targets may become “meaningless” for those GDP growth rates exceeding previous expectations as long as might be achieved “with a little additional effort on emission reduction” (Vazhayil and Balasubramanian, 2010). Hence, some authors have raised doubts about some national intensity target announcements as long as it could represent just committing to business as usual[3].

Nevertheless Stern and Jotzo (2010) assert that intensity targets “have valuable properties in managing economic uncertainty and focus the target formulation on structural and technological change, rather than GDP growth, which itself is not a policy variable” despite that intensity targets “can be used to obfuscate the fact that a targeted reduction in intensity can mean a continued increase in absolute levels”.

From a different perspective, emissions relative to GDP may be a good proxy for valuing the national emission reduction potentials (Yi et al., 2011): more room for improvement may be available when emissions intensity is larger (through enhanced economic development, energy efficiency or greening the energy mix). In this context, Yi et al. (2011) sustain that differences on intensity values (and therefore differentiated intensity target commitments) may be displaying dissimilarities in emission reduction

[2] Marschinski and Edenhofer (2010) provides an excellent survey and discussion on these issues.
[3] Lu et al. (2013) provides an excellent survey and discussion on this issue for the particular case of China.

potentials. Actually, there is a concept developed by the OECD (2002) alongside to this perspective: the relative decoupling measure on carbon emissions. This measure can be estimated as the ratio of carbon intensity at the end and the beginning of the selected periods, so decoupling takes place when the ratio is lower than 1. That ratio may be use as a basic indicator intended to track single country performance in a cross-country comparison[4].

## 2. The survey.

Xu and Ang (2013) provide a nowadays survey for the relative contributions of key effects on changes in aggregate carbon intensity by reviewing 80 papers appearing in peer-reviewed journals from 1991 to 2012. Empirical studies are mainly concerned with the evolution of total emissions and only a few studies analise carbon intensity (they transformed the results from the literature into carbon intensity values in order to compile a database for comparative analysis).

However, there are technical reasons beyond political and socioeconomic support (presented above) that justify our interest on carbon intensity instead of absolute and per capita carbon emissions. For ease of exposition, the point raised in Ang (1994), where it vindicated the dominance of energy intensity in order to decompose the changes in aggregate energy consumption for industry, is translated here to the carbon intensity issue: in fast growing developing countries, the contribution from the scale effect is usually quite significant, often many times larger than the estimated structural and energy intensity effects, and that fact may become an inconvenient if your purpose is to study the impact of structural and intensity changes.

As pointed previously in the introduction, most literature performed index decomposition analysis. It usually identifies five main factors, namely the scale, structure, energy intensity, fuel mix, and carbon

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[4] Environmental decoupling is one of the main objectives of the OECD Environmental Strategy like for instance the Green Growth initiative and material flow analysis.

coefficient effects (carbon to energy ratios). Xu and Ang (2013) concluded that energy intensity “was the main contributor to reductions in aggregate carbon intensity in most countries”, both in developing and developed countries. The same result was reached for the industrial sector alone where “fuel switching towards clean energy sources was less prevalent in the developing countries” whereas the impact of structural change was also marginal.

For the particular case of Chinese carbon intensity, Fan et al. (2007) reached similar conclusions: “the overwhelming contributor to the decline of energy-related carbon intensity was the reduction in real energy intensity” whereas fossil fuel mix and renewable energy penetration played a minor role. That is in accordance with previous results in the literature (i.e., Wu et al., 2005 and 2006; Wang et al., 2005). Analogous results were reported more recently in Zhang et al. (2009) for our period of interest 1991–2006. They provide some information offering some possible explanations for the minor impact from fuel switching and structural changes. On the one hand, “although the coal share decreased steadily, it still is the leading energy supply, which has accounted for about 70% of the total energy demand”. On the other hand, the “industrial sector is the biggest contributor to energy consumption, which accounts for about 63.8–70.3% of total energy consumption”.

Accordingly, Steckel et al. (2011) concluded that [Chinese] policy measures to reduce emissions must concentrate on the reduction of “energy intensity and – in the long run – especially carbon intensity, while the effects due to growth of GDP and population are either hard to control, judged to be unavailable for political reasons, or face moral controversies”.

**4. The database and some preliminary empirical evidence.**

Our sample is a balanced panel for emerging countries in the East Asia world region during the period 1990-2011. It includes China, Indonesia, Republic of Korea, Malaysia, Philippines, Singapore, Taiwan and

Thailand. We have excluded previous years in order to avoid the structural changes taking place in the 70's in response to important oil market disruptions. As we mention in the introduction to this paper, any analysis performed on these countries is appealing as long as the global economy is shifting to a multipolar world thanks to this region enhanced income growth largely from greater internationalization and productivity.

The East Asia region displays one of the highest carbon intensity values despite showing one of the highest cumulative reductions in the world from 1990 to 2011 (see Table 1). In particular, this region decreased carbon intensity at an annual rate of 2.4% compared to the 1.9% of United States (note that inside this region, China decreased its carbon intensity by a 4.4%). Simultaneously, this region experienced important changes in labour productivity in such a way that cumulative annual growth rate is equal to 6.8% compared to the 1.7% of United States. In the particular case of China showed an even larger productivity growth rate up to 9.3% in the same period. Accordingly, in this paper we have merged data published in the "Global Energy & CO2 Data" by ENERDATA with data on economic national performance from the PENN World Table (PWT 8.0) published by the Centre for International Comparison at the University of Pennsylvania in order to investigate the relationship between both trends.

**Table 1: CO2 intensity[1] in selected regions**

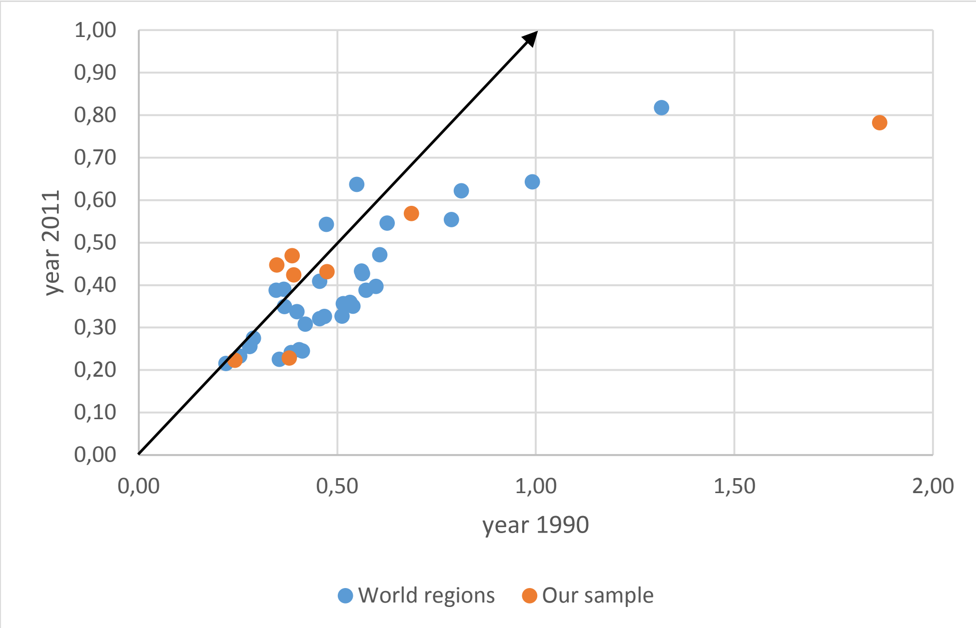
| | 1990 | 2011 | Variation % | Decoupling ratio |
|---|---|---|---|---|
| East Asia & Pacific (developing only) | 0,67 | 0,57 | -14,67 | 0,76 |
| Baltic countries | 0,57 | 0,32 | -28,22 | 0,71 |
| Latin America & Caribbean (developing on | 0,60 | 0,40 | -33,50 | 0,66 |
| Middle East & North Africa (developing o | 0,40 | 0,24 | -40,05 | 0,59 |
| South Asia | 0,41 | 0,41 | -0,49 | 0,98 |
| Sub-Saharan Africa (developing only) | 0,83 | 0,93 | 12,33 | 1,12 |
| Europe | 0,85 | 0,75 | -11,87 | 0,85 |
| Other devoloped countries | 1,02 | 1,18 | 15,26 | 1,16 |
| Our sample[2] | 3,44 | 1,59 | -53,69 | 0,46 |
| China | 4.43 | 1.86 | -58.06 | 0,42 |

Source: Enerdata and own calculations.

Notes: [1] kCO2/$ in constant US$ 20005 at purchasing power parities;

[2] weighted mean according to 2011 population.

**Figure 2: CO2 intensity[1] in selected regions (1990, 2011)**




Source: data from Enerdata.

Notes: [1] kCO2/$ in constant US$ 2005 at purchasing power parities.

Table 2 summarise the main descriptive statistics.[5] Our data database includes eight countries showing quite different levels of carbon intensity during the period (from 0.22 to 1.86 tons per thousands of US$2005 as showed in Figure 1). That might be the result of somewhat different economic structures as a result of:

(i) divergent weights of manufacturing sectors in either the GDP (ranging from 14% to the 52%)

(ii) divergent industrial energy consumption per worker (from 0.16 to 3.13 toe/worker)

(iii) dissimilarities in the productivity levels (from 1.96 to 92.19 thousand $ per worker)

(iv) and dissimilarities in global employment rates (from 33.80 to 60.03).

[5] Details about the variables definitions are showed in the Appendix.

There are also some other idiosyncratic variations like for instance very different degrees of urbanization (26.44% to 100.00%) and as a result unalike residential energy consumption per capita (from 0.07 to 0.42 toe per capita). Differences in the energy mix profile represent also a relevant explicative variable, where we found important variations among countries in e) the energy carbon factor (from 1.91 to 11.80 tons/toe) and f) the electricity generation carbon factor (ranging from 353.5 to 1017.58).

**Table 3: Descriptive Statistics**

| Variable | Obs. | Mean | Sts dev. | Min. | Max. |
|---|---|---|---|---|---|
| Carbon intensity (Tons/thousands $2005 ppp) | 176 | 0.52 | 0.28 | 0.22 | 1.86 |
| Energy carbon factor (tons/toe) | 176 | 4.15 | 1.71 | 1.91 | 11.80 |
| Labour Productivity(thousands $2005 ppp) | 176 | 25.67 | 22.96 | 1.96 | 92.19 |
| Global Employment rate (%) | 176 | 46.50 | 7.49 | 33.80 | 60.03 |
| Industrial energy consumption (toe) per worker | 176 | 1.07 | 0.79 | 0.16 | 3.13 |
| Residential energy consumption (toe) per capita | 176 | 0.19 | 0.08 | 0.07 | 0.42 |
| Oil Dubai index Spot price ($/bbl) | 176 | 40.23 | 30.56 | 12.16 | 106.33 |
| Urbanization rate (%) | 176 | 56.97 | 22.14 | 26.44 | 100.00 |
| Electricity carbon factor (gCO2/kWh) | 176 | 619.02 | 156.60 | 353.57 | 1017.58 |
| Industrialization rate (%) | 176 | 28.31 | 8.00 | 13.66 | 51.81 |

Source: own elaboration. Note: GDP values in US$ at constant purchasing power parity (2005).

In advance to our econometric study, let us proceed first with an index decomposition analysis IDA performed on carbon intensity based on the Logarithmic Mean Divisa Index. The LMDI (Ang and Choi, 1997) is an index approach based on the nonparametric character of Divisa methods by using log mean weights, resulting in exact decompositions (without residuals). This method would be preferable to conventional methods (Laspeyres (LASP) or Shapley / Sun (S / S)…) in those periods where the data experienced significant changes, otherwise conventional methods will result in important residuals.

Carbon intensity (C/GDP) could be decomposed in two factors: the energy carbon factor (C/E) and de energy intensity (E/GDP):

$$\frac{C}{GDP} = \left(\frac{C}{E}\right)\cdot\left(\frac{E}{GDP}\right) \qquad \text{i.e. } CI = CE\cdot EI$$

accordingly, any change in carbon intensity may be decomposed as follows:

$$\Delta CI = CI_t - CI_{t-1} = CE_t EI_t - CE_{t-1} EI_{t-1}$$

and by means of the logarithmic mean weighting scheme, this can be further decomposed as:

$$\Delta C = \Delta C_{CE-effect} + \Delta C_{EI-effect}$$

$$\Delta C_{CE-effect} = L(C_t, C_{t-1}) \ln\left(CE_t / CE_{t-1}\right)$$

$$\Delta C_{EI-effect} = L(C_t, C_{t-1}) \ln\left(EI_t / EI_{t-1}\right)$$

where $L(x,y) = (x-y)/\ln(x/y)$

As we can see in Table 3, according to this simple decomposition we may conclude that the energy carbon factor had a positive contribution to the increase of carbon intensity for all countries but Singapore. However, this effect has been compensated by a negative contribution of the energy intensity, hence reducing carbon intensity during this period. Some authors have extend that decomposition in order to assessing the importance of economic development (per capita GDP) on carbon emission. For instance according to the Kaya identity Wang et al. (2005) and Davidsdottir et al. (2011) breakdown energy intensity between two new factors, energy per capita ($E_{PC}$) and the inverse of per capita GDP ($GDP^{-1}pc$) as follows:

$$\frac{C}{GDP} = \left(\frac{C}{E}\right)\cdot\left(\frac{E}{POP}\right)\cdot\left(\frac{POP}{GDP}\right)$$

This second decomposition may give us more insights on the evolution of the carbon intensity (see Table 3). After applying the same logarithmic mean weighting scheme, results disclose economic development as the main driver of carbon intensity reductions whereas energy per capita in addition to the energy carbon factor had contributed to the increase of carbon intensity.

**Table 4: LMDI decomposition of changes in carbon intensity (1990-2011)**

| Country | Changes in carbon intensity | Decomposition 1 | | Decomposition 2 | | | Decomposition 3 | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | CO2/E | E/GDP | CO2/E | E/P | P/GDP | CO2/E | E/P | L/GDP | P/L |
| China | -1.13 | 0.29 | -1.42 | 0.29 | 0.72 | -2.14 | 0.29 | 0.72 | -2.09 | -0.05 |
| Indonesia | 0.06 | 0.16 | -0.1 | 0.16 | 0.2 | -0.3 | 0.16 | 0.2 | -0.27 | -0.03 |
| Korea | -0.06 | 0.06 | -0.12 | 0.06 | 0.31 | -0.43 | 0.06 | 0.31 | -0.36 | -0.08 |
| Malaysia | 0.08 | 0.12 | -0.04 | 0.12 | 0.27 | -0.31 | 0.12 | 0.27 | -0.26 | -0.05 |
| Philippines | -0.02 | 0.14 | -0.16 | 0.14 | -0.06 | -0.1 | 0.14 | -0.06 | -0.08 | -0.02 |
| Singapore | -0.15 | -0.25 | 0.1 | -0.25 | 0.33 | -0.23 | -0.25 | 0.33 | -0.19 | -0.04 |
| Thailand | 0.09 | 0.08 | 0 | 0.08 | 0.27 | -0.27 | 0.08 | 0.27 | -0.24 | -0.03 |
| Taiwan | -0.1 | 0.16 | -0.26 | 0.16 | 0.35 | -0.61 | 0.16 | 0.35 | -0.52 | -0.08 |

Source: own calculations.

As we have pointed out previously in this paper, our main hypothesis is that labour productivity played an important role in the evolution of the carbon intensity in these countries. Accordingly, we would like to include that variable into the decomposition analysis as a first approximation for revealing its importance in the following way:

$$\frac{C}{GDP} = \left(\frac{C}{E}\right) \cdot \left(\frac{E}{POP}\right) \cdot \left(\frac{L}{GDP}\right) \cdot \left(\frac{POP}{L}\right)$$

This third decomposition approach let us further breakdown energy intensity among three elements: energy per capita ($E_{PC}$), the inverse of productivity and global employment rate. As a result, the energy carbon factor and energy per capita show a positive contribution to the evolution of carbon intensity whereas the reversal effect stands for both the inverse of labour productivity and global the employment rate. Although these two last factors show a negative contribution to the evolution of the carbon intensity from 1990 to 2011, it is clear that the factor driving the lessening of carbon intensity in the East Asia and Pacific region was the improvement in labour productivity.

## 5. Methodology.

In this paper, we would like to go further than the decomposition technics in order to get a deep understanding on the main drivers of the carbon intensity. Our aim is to conduct an econometric analysis to explain *carbon intensity* ( $CI_{it}$ ) on a vector of factors ( $X'_{it}$ ) as follows:

$$\ln(CI_{it}) = \beta_1 + B_2 \ln(X'_{it}) + u_{it}\,;\; i = 1,...,N; t = 1,...,T$$

We will assume that the residual $u_{it}$ follows a one-way error component model, $u_{it} = \mu_i + \upsilon_{it}$

where $\mu_i \sim$ IID $(0,\sigma^2_\mu)$ and $\upsilon_{it} \sim$ IID $(0,\sigma^2_\upsilon)$, independent of each other and among themselves.

The selection of variables affecting carbon intensity was based on the previous index decomposition analysis and a survey of the economic literature.[6] It is well known that income per capita or economic development, represented by GDP per capita, is one important factor explaining carbon intensity (Wang, et al., 2005; Davidsdottir et al., 2011). However, as we point out before, our hypothesis lay on the importance of the productive aspects. GDP growth is a combination of both extensive (increased use of resources) and intensive (increased productivity) growth. Due to the lack of data, we will try to capture those elements by making use of labour market variables. In particular, we include *productivity* and *employment rates* as proxies for the level and performance of the economic activity in all our model specifications to shed more light on the mechanism behind the GDP evolution influencing carbon intensity.

Energy consumption is another important variable explaining carbon intensity. Nevertheless, researches should take care of some national idiosyncratic like for instance the energy mix (conditioned by geography and political commitments), and the social and economic structure of the country. In order to account for the energy mix we include the *energy carbon factor,* (tonsCO2/toe from total energy final consumption minus

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[6] We analyzed a full cross-correlation matrix of each potential independent variable to prevent multicolinearity. None of the covariates included simultaneously in any of our equations exhibit a highly significant correlation.

non-energy uses) plus *CO2 emissions of the electricity production* (gCO2/kWh), so these variables will be smaller as the countries uses more low carbon energy sources (renewables, nuclear, natural gas).

Moreover, not only productive aspects are important to explain national carbon intensity levels as long as the residential sector will play an important role. Thus, we distinguish between the energy consumption from both the residential sector and the industrial sector in order to account for the social and economic structure. For this purpose, we include in all specification the *residential energy consumption per capita* and the *industrial energy consumption per worker* plus the *weight of the manufacturing sector* on GDP (according to the literature, carbon intensity may diminish as a result of a shift from manufacturing sectors towards service sectors which typically exhibit lower energy intensity).

We also account for additional variables that has been point out in the literature. Urban areas typically show higher degree of energy consumption. Socioeconomic changes leading to increasing *Urbanization rates* could lead to an increase of energy consumption and ceteris paribus increasing carbon intensity. Finally, the International Energy Agency (IEA) highlighted that energy intensity –and thus carbon intensity– is lower in countries with relatively higher energy prices evolution. Accordingly, we include in our econometric exercise the *Dubai spot price* for oil because this is the main international index for the East Asian countries (coal represents also a relevant primary energy, in particular for China, but prices for coal an oil exhibit a strong correlation and therefore it was omitted in our analysis). Supplementary analysis also included squared terms for key variables (productivity, employment rate and energy consumption) in order to account for second order relationships.

We have used Haussmann test to check whether fixed or random effects was the better estimator for the econometric specification. Based on our results, the fixed effects model revealed as the statistically stronger model for our analysis. The fixed effect approach will allow us to account for national idiosyncratic characteristics like for instance economic and political regime or climate and geographic conditions that are invariable in our period of analysis. Moreover, we include year dummies and country-trends in order to account for common shocks and country-specific tendencies (i.e. technological developments, etc.).

The models were also subject to the Augmented Dickey Fuller test statistic (Dickey Fuller, 1979; Stock and Watson, 2003), the modified Wald test for group-wise heteroscedasticity and the Wooldridge test serial correlation (Breusch and Pagan, 1979). Since the tests detect the presence of heteroscedasticity and serial correlation we employ a two-stages fixed effects with standard errors robust to serial correlation and heteroskedasticity.

## 6. Results and policy implications.

Table 4 shows the results from different specifications to explain carbon intensity. It shows that economic performance it is important to explain the evolution of the carbon intensity rate. In particular, the coefficient of labour productivity[7] appears to be negative and significant, i.e. and increase in productivity tend to reduce the carbon intensity rate. This result is in line with Davidsdottir et al. (2011) where the economic performance (measured as the per capita GDP) is an important factor to explain carbon intensity. However, they do not take into account the role of productivity in the development process. The global employment rate turns to be not significant for most of the equations. This result is also consistent with Davidsdottir et al. (2011) using a similar variable as labour intensity, which appears also to be not significant. Variables taking into account the energy mix as the Industrial energy consumption per worker and energy carbon factor appear to have a positive and significant coefficient.

[7] Although, in the decomposition analysis we have included the inverse of the productivity and of the employment rate, in the econometric analysis we use the variables directly since we consider in make easier the results interpretation.

**Table 5: Results for Carbon intensity**

| | | | | |
|---|---|---|---|---|
| Productivity | -0.892*** | -1.020** | -1.451*** | -1.987*** |
| Global Employment rate | -0.096 | -0.540* | -0.106 | -0.213 |
| Industrial energy consumption per worker | 0.485*** | 0.294 | 0.539*** | 0.241** |
| Residential energy consumption per capita | 0.059 | 0.008 | 0.135 | 0.658 |
| Energy carbon factor | 1.186*** | | 1.352*** | |
| Spot price of Dubai | | -0.065 | | -0.114*** |
| Urbanization rate | | 0.894 | | 0.326 |
| Electricity carbon factor | | 0.263* | | 0.347** |
| Industrialization rate | | -0.077 | | 0.081 |
| Productivity (squared) | | | 0.100* | 0.196** |
| Ind. energy cons. per worker (squared) | | | 0.095*** | -0.013 |
| Resid. energy cons. per capita (squared) | | | 0.039 | 0.215 |
| Constant | 0.733 | -0.695 | 0.375 | 0.756 |
| Observation | 176 | 176 | 176 | 176 |
| Adjusted R2 (within model) | 0.93 | 0.86 | 0.96 | 0.88 |
| [a] Year dummies significance (F-test) | 0.80 | 2.04 | 12.55*** | 4.60*** |
| [b] Country trends significance (F-test) | 14119.18*** | 90.13*** | 118.15*** | 414.38*** |

Legend: * p<.1; **p<.05; *** p<.01. Note: all variables expressed in logarithms. Year dummies and country trends included. [a] F test statistics with corresponding p-value in parentheses for the joint significance of the country-trends. [b] F test statistics with corresponding p-value in parentheses for the joint significance

In line with Robaina-Alves and Moutinho (2014), both energy intensity of industry and carbonization of the energy mix will increase the national carbon intensity. Moreover, they highlight the role of the fossil fuels and the differences among sectors. Because of that reason, we try to take into account the structural changes by the industrialization rate variable, but finally it turns to be not significant in order to explain changes in carbon intensity across countries and along the period being analysed.

We also consider the hypothesis that as the population becomes wealthier, energy use may rise due to the purchase of new appliances, vehicles, etc…, increasing the per capita energy use. We use residential sector energy consumption per capita and the urbanization rate as a proxy of this effect and they both turn to be significant once we correct for correlation.

*6.1. Simulations*

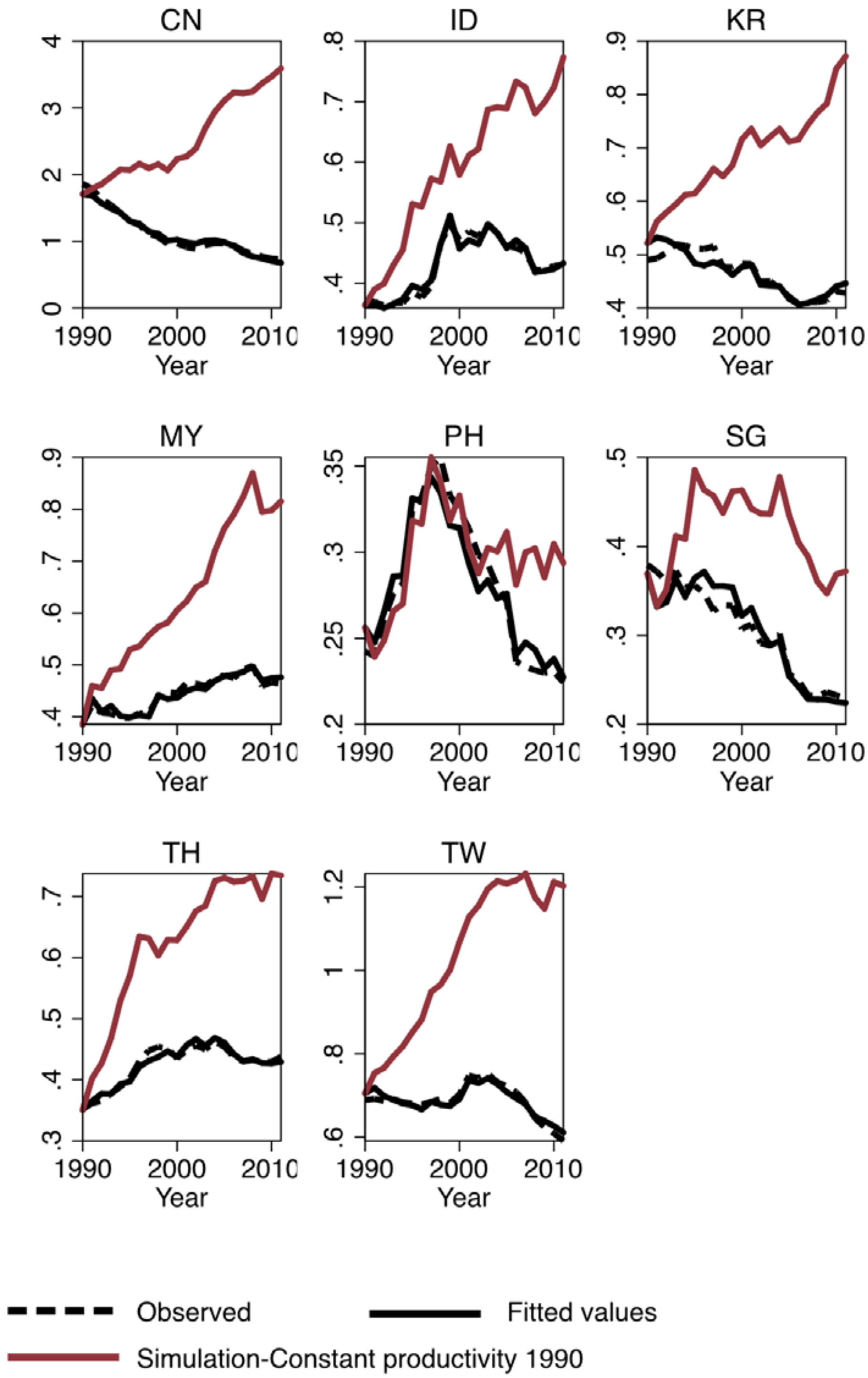
We use our model (first fixed effects model) to forecast how the carbon intensity will evolve if each country's productivity would remain constant with the values of 1990 during the whole period (Figure 2). Note that we also include the observed and the fitted values in Figure 2 in order to check the goodness of fit of our model to observed data. On the one hand, our model seems to adjust quite well the observed data for all countries. On the other hand, the simulation exercise shows that the carbon intensity would increase for all countries during 1990-2011 under the condition of constant productivity for the whole period.

Our results allow us to explain some disturbing conclusions from the empirical literature. For instance Wang, Chen and Zou (2005) found that China "has made a significant contribution to reducing global $CO_2$ emissions, especially since 1980" by comparing the total "theoretical decrease" of $CO_2$ emissions (according to the evolution on GDP and population) with the "total decrease". They realize that the 95% of Chinese contribution to curb global $CO_2$ emissions may be attributed to the energy intensity effect. In other words, without efforts for improving energy intensity "$CO_2$ emissions for China in 2000 would have been […] more than 50% higher than its actual emissions"[8].

What is the message for Chinese emissions and Climate Talks? We are now confident that the huge energy intensity effect in the past is probably the consequence of major improvements in Chinese labour productivity and that trend may last in the medium term. Therefore, national targets grounded on carbon intensity may be misleading for climate action. Countries experiencing great productivity gains may reap significant improvements on carbon intensity without significant achievements on energy and carbon efficiency.

[8] Similar conclusions for China may be found in Fan et al. (2007), Zhang et al. (2009).

**Figure 2. Observed and fitted carbon intensity.**



## 7. Conclusions.

There is a growing political interest on carbon intensity targets, as long as they are the basis for policies and pledges from relevant developing countries and policy designs in developed countries. There is no doubt that the accomplishment of emissions intensity targets is contingent to the relationship between emissions and output growth as well as the success of national mitigation actions (Lu, 2013). That relationship may be subject to micro and macroeconomic structural conditions as well as idiosyncratic national circumstances.

In this paper, we conduct a comprehensive econometric study on the main drivers of national emissions intensity in East Asia and Pacific emerging countries. We focus our attention on this region because the East Asia and Pacific region still presents one of the highest carbon intensity values despite of showing one of the highest cumulative reduction rates in carbon intensity in the world from 1990 to 2011. The simultaneity of both trends make worth to pay attention to this regional case in order to rise valuable lessons. Besides, BRICS countries and particularly China gained a prominent presence in the Climate Change international talks. These facts, coupled with the evidence that “the center of gravity of the global energy system is shifting towards Asia” according to the International Energy Agency (IEA, 2013) has motivated our regional interest in this piece of research.

The main contributions of this paper are twofold. First, it enlarges the empirical evidence as long as there are few studies concerned on this issue and most of them performed index decomposition studies. Second, we explain carbon intensity values based on the energy and economic performance of countries as well as some idiosyncratic national circumstances by applying fixed effects econometric techniques. The novelty in this piece of research is to deviate from common practice in the empirical literature by including labour productivity and employment rates instead of per capita GDP in order to shed more light on the mechanism behind the main drivers on carbon intensity.

We conclude that carbon intensity depends on both energy efficiency and primary factors productivity as well. Surprisingly, the last one is the main responsible of major carbon intensity reductions in countries like China. The paper shows that the carbon intensity would increase for all countries during 1990-2011 under the condition of constant productivity for the whole period. What is the message for Chinese emissions and Climate Talks? National targets grounded on carbon intensity may be misleading for climate action. Countries experiencing great productivity gains may reap significant improvements on carbon intensity without significant achievements on energy and carbon efficiency.

These results may be useful for policy analysis in other regions like EU (it is considering to launch new national targets on a carbon and energy intensity basis for 2035) and for Latin American countries (for any participation in climate action). In the particular case of the EU, those countries experiencing slower labour productivity improvements will burden inflated economic costs from intensity targets for carbon and energy consumption whereas the opposite stands for the other countries.

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## APPENDIX

Variables definition:

*Carbon intensity (CO2/GDP):* CO2 emissions from fuel combustion. (MtCO2) relative to GDP US$ at constant purchasing power parity (2005). M$05ppa. Metric tons per thousands of $

*Carbon emissions factor of energy (CO2/E):* CO2 emissions from fuel combustion. (MtCO2) relative to Total energy final consumption minus non energy uses (Mtoe)

Energy intensity (E/GDP): Total energy final consumption minus non energy uses (Mtoe) relative to GDP US$ at constant purchasing power parity (2005). M$05ppa

*Per capita energy (E/POP):* Total energy final consumption minus non energy uses (Mtoe) relative to Population (k)

*Per capita GDP (GDP/POP):* GDP US$ at constant purchasing power parity (2005). M$05ppa relative to Population (k)

*Productivity (GDP/L)*: GDP US$ at constant purchasing power parity (2005). M$05ppa relative Number of persons engaged (in millions)

*Global employment rate (L/POP):* Number of persons engaged (in millions) relative to Population (Millons)