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# How Feasible are Emissions Intensity Targets for China, India, and Other Developing Countries? An Econometric Analysis

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# How Feasible are Emissions Intensity Targets for China, India, and Other Developing Countries?

# **An Econometric Analysis**

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#### **Abstract:**

Several developing economies have announced carbon emissions targets for 2020 as part of the negotiating process for a post-Kyoto climate policy regime. China's and India's commitments are framed as reductions in the emissions intensity of the economy of 40-45% and 20-25% respectively from 2005 to 2020. Yet the emissions intensity of the Chinese economy fell 8% from the end of 1999 to the end of 2008, while India's emissions intensity declined by about 14%. How feasible are the proposed reductions in emissions intensity for China and India, and how do they compare with the targeted reductions in the US and the EU? In this paper, we use a stochastic frontier model of energy intensity to decompose energy intensity in China, India and other major developing economies into input and output mix, climate, and scale effects, and a residual technology variable. We then evaluate how feasible various targeted reductions below business as usual trajectories would be, assessing what they would imply in terms of changes in the pace of technology adoption or changes in the fuel mix towards lower carbon fuels, and comparing these required changes to historical performance. We find that China is likely to need to adopt ambitious carbon mitigation policies in order to achieve its stated target, and that its targeted reductions in emissions intensity are on par with those implicit in the US and EU targets. India's target is less ambitious, but may nevertheless require some dedicated policy action.

Key Words: carbon emissions, climate change, developing countries, projections

**JEL Codes:** O13, Q54, Q56, Q58

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#### Introduction

Several developing economies including China, India, Brazil, Indonesia, Mexico, and South Africa have announced voluntary carbon emissions targets as part of the negotiating process for a post-Kyoto climate policy regime. The majority of developing country target commitments to date are framed as divergences from business-as-usual (BAU) trajectories to 2020 (the assumed levels of which are yet to be defined). However, the targets put forth by China and India – the most important developing countries in the climate talks – are framed as reductions in the emissions intensity of their economies (CO<sub>2</sub> per unit of GDP) over time: for China, a 40-45% reduction from 2005 to 2020 (Xinhua, 2009), and for India a 20-25% reduction over the same period (Dasgupta and Sethi, 2009). China also has a goal of ensuring the share of renewable and nuclear energy in total energy use is 15% by 2020 (Xinhua, 2009). It stands to reason that other developing countries might follow China's and India's example and define their commitments in terms of emissions intensity of their economies, at least for fossil fuel use. Intensity targets have often been criticised because they can be used to obfuscate the fact that a targeted reduction in intensity can mean a continued increase in absolute levels, but they have valuable properties in managing economic uncertainty, and focus the target formulation on structural and technological change, taking out GDP growth which is not a policy variable (Jotzo and Pezzey 2007).

The energy intensity (aggregate energy use per unit of GDP) of the Chinese economy was essentially unchanged from 2000 to 2007 (Figure 1), after a long period of declining energy intensity that started with the economic opening of the late 1970s came to an end in the late 1990s. Energy intensity has fallen by 10% from 2005 to 2008. China has a commitment in place to reduce the energy intensity of its economy by 20% from 2005 to 2010 (NDRC 2006). Meanwhile, the carbon intensity of energy supply (carbon/energy use) has increased since the year 2000, leading to an overall *increase* in emissions intensity of China's economy over the first half of the 2000s (Garnaut, Jotzo, and Howes, 2008) and a 8% fall in emissions intensity from the end of 1999 to the end of 2008 (our data).

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<sup>&</sup>lt;sup>1</sup> According to IEA data primary electricity and biomass accounted for 12% of Chinese energy consumption in 2007. The IEA World Energy Outlook 2007, however, projects this falling to 11% in 2020 according to our linear interpolation of their 2015 and 2030 forecasts. Therefore, this goal implies doubling primary electricity production compared to business as usual from 4% to 8%.

India shows a different pattern of change over time (Figure 2). While the energy intensity of the Indian economy has declined over time though at a slower pace than China's energy intensity the carbon intensity of energy supply has risen substantially, more than offsetting the improved energy intensity until the mid to late 1990s. This is due to a pronounced shift of fuel mix towards coal and away from biomass to coal and other fossil fuels. From 1971 to 1997 emissions intensity rose by 42%. From then till 2008 there was, however, a decline of 20% in emissions intensity as the decline in energy intensity accelerated.

How feasible are the proposed reductions in emissions intensity for China and India, and what magnitude of reductions might be feasible in other developing economies? While some analysts responded to China's announcement that it was just committing to business as usual, others argued that though China was likely to significantly reduce emissions intensity by 2020 in any case, the proclaimed target would require significant policy-driven action (Qiu, 2009). But the projections from the US EIA (Energy Information Administration, 2009), the International Energy Agency (International Energy Agency, 2009), and China's Energy Research Institute (see Jing, 2009) that underlie the various claims all assume very significant policy actions that are hard to construe as BAU trajectories (Carraro and Tavoni, 2010).

In this paper, we use a stochastic frontier model of energy intensity to decompose energy intensity in a number of major developing economies into input and output mix, and climate effects, and a residual technology variable. We then evaluate what business as usual trajectories of energy intensity might be, and how feasible various reductions to 2020 would be. We then assess what given reductions in emissions intensity would imply in terms of changes in the pace of technology adoption and/or changes in the fuel mix towards lower carbon fuels. We compare these required changes to our own business as usual (BAU) projections based on recent historical trends.

The paper is organized as follows. The next two sections detail our methods and data. These are followed by the BAU projection and a discussion comparing the BAU projection to the announced targets, a discussion of alternative policy scenarios, a comparison of developed and developing country targets, and finally a conclusion.

#### **Methods**

This section provides a basic description of our model, which will be described in more detail in an accompanying working paper (Stern, 2010). In that paper, one of the authors, Stern, develops a stochastic frontier model of energy intensity for estimation using a global panel data set. The model is estimated using a cross-section of 85 countries. Observations on each variable in each country are averages over the period 1971-2007. The model is given by:

$$\ln \frac{E_i}{Y_i} = -\alpha_0 - \alpha_W W_i - \sum_{j=2}^5 \beta_j e_{ji} + \sum_{k=2}^4 \gamma_k y_{ki} + \ln u_i + \ln v_i$$

$$\ln u_i \sim N^+ \left( \Gamma \mathbf{z}_i, \sigma_u^2 \right)$$

$$\ln v_i \sim N \left( 0, \sigma_{v_i}^2 \right)$$
(1)

where:

the  $e_j$  are the shares in total energy use, E, in country i of the five energy vectors,  $E_j$ : Coal, oil, natural gas, biomass, and primary electricity;

Y is GDP. There are four industrial sectors,  $y_k$ : Agriculture, Mining and utilities, manufacturing, and services;

W is average winter temperature.

The coefficients for oil and manufacturing are set to zero.

v is a normally distributed random error term with heteroskedastic variance that is assumed to be proportional to the inverse of GDP. This error is assumed to represent measurement error. u is taken to represent the state of energy efficiency technology in country i, u is a one sided error term whose mean is a linear function of a vector of additional explanatory variables,  $\mathbf{z}$ , that explain the differences among countries in the average level of technology. The vector  $\mathbf{z}$  contains the following variables:

lnTFP: Total factor productivity calculated as: lnTFP = lnY - 0.3lnK - 0.7lnH,

InPPP: Ratio of exchange rate to purchasing power parity exchange rate,

Openness: Ratio of exports and imports to GDP,

Corruption: Transparency International's Corruption Perception Index,

Energy Reserves/GDP: Size of energy reserves relative to GDP

A dummy variable for Protestant Europe derived from the World Values Survey and a dummy for current and former Communist states.

Lower levels of *u* imply higher energy efficiency.

The model is estimated via a maximum likelihood procedure (Kumbhakar *et al.*, 1991; Hadri et al., 2003). Estimation of the model using the "between estimator" – estimation on a cross-section of means has some advantages and disadvantages. Stern (2009) provides a detailed discussion. Among the advantages are that it does not impose any structure on the evolution of the state of technology over time or on short-run dynamics associated with capital investment etc. The state of technology in each year in each country can be derived in two steps as follows. First a residual series is computed according to:

$$\ln \hat{u}_{it} = \ln \frac{E_{it}}{Y_{it}} + \hat{\alpha}_0 + \hat{\alpha}_W W_i + \sum_{j=2}^5 \hat{\beta}_j e_{jit} - \sum_{k=2}^4 \hat{\gamma}_k y_{kit} - \ln \hat{v}_i$$
 (2)

where, the measurement error,  $v_i$ , is estimated via the maximum likelihood procedure. This residual undoubtedly also includes fluctuations due to short-run dynamics and measurement errors. We assume that these additional errors are stationary and apply the Hodrick-Prescott filter (Hodrick and Prescott, 1997) to extract the long-run technology component.

#### Data

Details of the data sources used in estimating the econometric model are given in Stern (forthcoming). Carbon emissions data are taken from the IEA database for 1971 to 2006 and updated to 2008 using the growth rates implied by the U.S. Energy Information Administration database. We also updated the shares of fuels in total energy use for India and China using the growth rates from the USEIA database.

In order to generate a business as usual scenario for energy intensity, we need to project the explanatory variables in (1) over the commitment horizon. For technological change we use three different scenarios:

- 1. The forward growth rate is equal to a regression estimate of the mean rate of growth over the 1971-2007 period. For China this yields the highest rate of change (3.2% p.a.) and for India the lowest (0.3%).
- 2. The forward growth rate is equal to a regression estimate of the mean rate of growth over the 1999-2007 period. This yields the lowest rate for China (1.4% p.a.) and the highest for India (2.0%). Note that we find the rate of improvement in underlying energy efficiency to still be quite fast in the 21<sup>st</sup> century in China despite the stalling in energy intensity.
- 3. The forward growth rate is equal to a regression estimate of the mean rate of improvement in the USA over the 1971-2007 period, which is 2.0% p.a.

Projections for the shares of fuels in energy use for 2020 are based on the 2007 World Energy Outlook (IEA, 2007) reference scenario (p119). We interpolated the shares of each fuel linearly between 2008 and 2015 and 2015 and 2030. In China biomass use declines from 10% to 7% over the forecast horizon, oil use increases from 18% to 20% and the other fuels change by one percentage point or less. For India coal increases from 41% to 44%, biomass declines from 27% to 20%, and the other fuels change by one percentage point or less. As a consequence, carbon intensity rises from 2.28 kg CO2 per kgOE to 2.47 over the forecast horizon in India, while in China carbon intensity only increases from 3.05 to 3.08.

To project future industrial structure we used the following methods. For China, we use Downes (2010) estimates for the agricultural sector. We use the growth in the service sector used in the IEA reference scenario (43% in 2015 and 47% in 2030). Manufacturing is assumed to have a constant share over the period and mining and utilities is treated as a residual. Downes projection of the share of manufacturing is roughly constant over time. We do not use his estimates for the non-agricultural sectors directly, because with the exception of agriculture the baseline is slightly different to the World Bank data we used to estimate the model.

For India, we estimate the share of share of agriculture in GDP by assuming the real value of output continued to grow at its historical rate of growth of 2.7% p.a. We then take the projected economic growth rates for India from Garnaut, Howes, Jotzo, and Sheehan (2008) to project total GDP over this period. The ratio of agricultural output to this projected GDP gives the projected share of agriculture in GDP. As a result agriculture falls to 9.94% of GDP

in India by 2020 while it falls to 5.9% of GDP in China. We assumed that India's shares of mining and utilities and manufacturing share will grow at their regression estimated growth rate for the 1971-2007 period. Then the share of services is computed as the residual. We assume that temperature is constant over this period as we do not have a time series for temperature to estimate any trend with.

These projected growth rates allows us to use equation (1) to project business as usual energy intensity. The projection of the energy shares allows us to also project business as usual carbon intensity. We obtain the carbon coefficients for each fuel from the US EIA.

#### **Econometric Results**

Parameter estimates for the model (1) are presented in Table 1. The parameters for the deterministic model measure the effect on distance from the frontier of each of the variables. Countries with warmer winter temperatures are further from the frontier ceteris paribus because they should be able to use less energy per dollar of GDP the warmer their climate. If a warmer country has the same energy intensity as a colder country then it must be less efficient in its use of energy. The four fuels all have lower energy quality (see Stern, in press) than oil, the default fuel. Countries with a lower share of oil in energy use and higher shares of these fuels are, therefore, for a given energy intensity more efficient. Surprisingly the coefficients of natural gas and primary electricity are more negative than coal, whereas it is usually assumed that these fuels are higher quality than coal (Cleveland et al., 2000), however, these differences are not statistically significant. As expected, biomass does have lower fuel quality than the other fuels. The signs of coefficients of the industrial sectors have the opposite interpretation to those of the fuels and temperature. A positive coefficient means that the sector is more energy intensive than the default sector, manufacturing. A country with a larger share of GDP in energy intensive sectors is ceteris paribus closer to the frontier. None of the effects of the industrial sectors are statistically significant but the signs of the mining and services sectors are as would be expected.

Looking at the factors that explain the level of technology, TFP has the expected effect. Countries with higher TFP are more energy efficient, *ceteris paribus*. The elasticity is quite large. A 1% increase in TFP results in a 0.54% improvement in energy efficiency as lower levels of the technology term, u, imply greater energy efficiency. On the other hand, a higher

exchange rate relative to the PPP level results in less energy efficiency. The elasticity here is 0.80. It appears that the cost of imported fuel is the key factor here. Relatively poor countries with low exchange rates can potentially be quite energy efficient. Over the course of economic development rising exchange rates may offset the gains from increased levels of general productivity and result in less improvements in energy efficiency than one might naively expect. This makes sense, as globally, outside of the poorest countries there is no strong relationship between energy intensity and the level of GDP per capita (both measured in PPP terms). This has potentially important implications for China (and India) as its currency is revalued. This will lower the effective price of energy and act against the energy efficiency goals unless taxes are simultaneously raised on petroleum etc.

The more open an economy is the less energy efficient it is. This counters the usual idea that opening to trade will allow the adoption of more energy efficient technologies. Possibly, more open economies have more of their economic activity in energy intensive industries. The transparency indicator is scored so that zero is the most corrupt and ten the least corrupt country. More corrupt countries are somewhat less energy efficient in line with theory on this issue (e.g. Lopez and Mitra, 2000). Countries with greater fossil fuel reserves relative to the size of their economies are less energy efficient. Protestant Europe (Scandinavia, Germany, Switzerland, and the Netherlands) is more energy efficient, *ceteris paribus*, and former communist countries less so.  $\sigma_d$  is insignificantly different from zero indicating that there is little unexplained variation in the technology variable, u.

Using (2) we can derive the underlying energy efficiency trends for each country. Figure 3 presents these for India, China and several developed economies: U.S.A., Australia, Germany, and Japan, while Figure 4 compares China and India to the other four developing economies that have proposed reductions in emissions relative to BAU: Brazil, Indonesia, Mexico, and South Africa. Again, the very different histories of China and India are illustrated. Rapid improvements in energy efficiency are seen in both countries following economic reform, which came in China in the 1980s and in India only recently. In the 1970s China was one of the more inefficient countries in the world while India was one of the more efficient. Many developing economies were more efficient than the developed economies. However, on the whole, like India they have not improved as much since then as the developed economies and some are less efficient today than in the 1970s.

It is important to understand that this measure of energy efficiency includes the effects of both particular technologies and how they are used and managed. The technologies in place in developing countries are likely to be less efficient than in the developing economies but given the high price of energy are likely to be used more efficiently. There has, thus, been convergence over time. China, like other post-communist states has converged particularly rapidly. In the beginning of the 2000's China came close to the level of efficiency of the developing and developed economies sampled here (with the exception of Australia and South Africa, which it overtook). The average rate of efficiency improvement in China over the entire period is 3.2% p.a. while in the U.S. it is 2.0%, Germany 2.1%, Australia 1.2%, Japan 1.0%, and India 0.3%. South Africa saw a reduction in efficiency of 0.2% p.a., Indonesia 0.3%, Brazil 0.5%, and Mexico 0.6%. From this perspective, China became more like a normal developing country since 2000 (Naughten, 2007). If China was to catch up to Germany's current level of energy efficiency it would need a 36% improvement from its current position, which is still less than its commitment for emissions intensity (which can be achieved through reductions in both energy intensity and carbon intensity of energy supply). But as we see, most developing economies have not been characterised by rapid increases in energy efficiency. India's recent rapid rate of improvement in energy efficiency is also anomalous in the developing country context to date.

#### **Business as Usual Projections vs. Country Targets**

Table 2 presents the reductions in emissions intensity that we find under the three scenarios for China and India (described in detail under section "Data" above). The implications for energy and emissions intensity are also shown in Figures 5 and 6. None of the scenarios look inherently unreasonable in the Figures. Scenario 1 – continuation of the historic 1971-2007 rate of improvement in energy efficiency combined with IEA projections of changes in carbon intensity of energy supply – results in a 39% reduction in emissions intensity in China, which almost meets China's proposed target of 40-45%. However, since 1999 the rate of progress in China has slowed down as China reached convergence with both other developed and developing economies as shown in Figures 3 and 4. A 36% percent improvement in energy efficiency would bring China to the current level of Germany, the most efficient country in this group. Furthermore, as we have shown, most developing economies have seen a moderate decline in energy efficiency over time. Therefore, it is hard

to see this scenario as a realistic BAU scenario for China. Scenario 2 (23% reduction in emissions intensity) and scenario 3 (29% reduction) would seem to be much more likely a priori – China moves forward either at its recent rate of progress or at the rate of a developed economy with some similarities to China in terms of size and climate, the United States.

These results for China are comparable with an analysis by Garnaut, Jotzo, and Howes (2008), whose projections for GDP growth, energy use and carbon intensity imply a 21% reduction in BAU emissions intensity for China from 2005 to 2020.

For India, the long-run historic rate of improvement in energy efficiency was low as is typical for developing economies and, therefore, scenario 1 results in only a 4% reduction in emissions intensity by 2020. The other two scenarios both yield a 23% reduction in emissions intensity, as the India's rate of progress in energy efficiency in recent years is the same as that of the US over 1971-2007.

A 23% reduction in emissions intensity would meet India's goal of a 20-25% in emissions intensity by 2020. Yet that is a rapid rate of progress for a developing economy most of which progressed much slower or saw declining energy efficiency over time. And as shown in Figures 3 and 4 India is already one of the most energy efficient economies.<sup>2</sup>

In interpreting these BAU projections, it is important to note that in all scenarios we use IEA projections for fuel shares, and thus change in carbon intensity of energy supply. To the extent that these IEA projections already include policies that shift the energy mix towards lower-carbon fuels (e.g. substitution from coal to gas, or increased renewable electricity generation), the "true" BAU projection would yield lower reductions in emissions intensity.

<sup>&</sup>lt;sup>2</sup> The idea that countries such as India are relatively energy efficient may be counterintuitive but our econometric results showed that both countries with high levels of general total factor productivity and countries with undervalued exchange rates were both more energy efficient. The latter presumably use more energy efficient technologies because of their high price of oil and presumably other types of energy. Poor energy efficient countries such as India presumably use labor-intensive technologies while wealthy energy efficient countries such as Germany use capital-intensive technologies that employ very energy efficient capital. Additionally energy efficiency measures not just physical technologies but behaviors. High energy prices are an incentive for conservation. Energy is more likely to be used in productive activities that generate GDP than in activities, which may just marginally improve utility for consumers. These hypotheses should be the subject of future research.

In conclusion, it is likely that China is likely to need to implement ambitious policies aimed at reducing carbon emissions, in order to meet its announced emissions intensity goal. For India the conclusion is less clearcut, as India's target might be met with only limited or even no dedicated mitigation policies.

#### **Alternative Policy Scenarios for China**

China also has a policy of increasing the share of energy derived from non-fossil sources to 15% by 2020. How much impact will this existing policy have? Under BAU primary electricity and biomass provide 11.3% of China's energy in 2020. We assume the gain comes entirely from increasing the contribution of primary electricity while not changing the share of biomass (and decreasing the shares of the three fossil fuels equally to make up for the increase non-fossil energy). This means increasing the former's share from 4.1% to 7.8% of primary energy supply. The non-fossil target itself reduces emissions intensity in 2020 by 3%, far less than the aggregate reduction required compared to the BAU scenarios laid out in the previous section.

In order to reach the 40% emissions intensity reduction target with only a 1.4% p.a. rate of improvement in energy efficiency entirely by switching to non-fossil energy, China would need to increase the share of primary electricity and biomass in primary energy supply to 35%. Assuming that direct use of biomass is the same as under the base scenario, primary electricity would need to rise to 28% of total primary energy supply in 2020. Based on the reference scenario of the World Energy Outlook this does not seem possible. According to the reference scenario, by 2020 about 41% of primary energy supply will be used to produce electricity. Of this 41%, 27 percentage points represent growth in energy use between 2005 and 2020 and 14 percentage points represent the energy that was already being used to produce electricity in 2005. Therefore, if all new electricity capacity added between 2005 and 2020 was non-fossil fuel electricity the goal could just be reached. Obviously, given the investments that have already taken place since 2005 in additional fossil fuel fired electricity generation plants, the 40% reduction in emissions intensity will not be achieved by this strategy unless the share of electricity use in final energy use increases substantially relative to the reference scenario. It is also obvious that switching to natural gas from coal would contribute less than switching from coal to non-fossil energy.

Thus, a policy aimed at reaching the 40% target must depend on a faster rate of improvement in underlying energy efficiency than the 1.4% p.a. been realized recently. Shifts in the energy supply mix can help by reducing the carbon intensity of the energy used. But even much stronger policies to foster low-emissions energy sources than those currently planned by China, would likely fall short of achieving the emissions intensity target.

An interesting question to ask is how much improvement in emissions intensity China could achieve if all new investment going forward was at the same efficiency level as Germany. We project future German energy efficiency using the historic 1971-2007 rate of improvement. Then we find the level of energy efficiency of new German investment, z, from this equation:

$$Z_{t} = \frac{z_{t}I_{t} + Z_{t-1}(1 - \delta)K_{t-1}}{I_{t} + (1 - \delta)K_{t-1}}$$
(3)

where Z is the energy efficiency of installed capacity, K is the capital stock, I is investment, and  $\delta$  is the rate of depreciation assumed to be 6%. We assume that German investment grows at the historic rate of 1.4% p.a. For the growth of Chinese investment we assume the share of investment in GDP remains constant in the future so that investment grows at the rate of economic growth. This scenario results in a 53% improvement in energy efficiency over the projection horizon of 2005-2020. However, if new investment in China is only of the same efficiency as German overall existing capacity in that year, energy efficiency improves by 41% over the projection horizon.

In conclusion, achieving the goal through improving the energy efficiency of new investment alone would require reaching the average level of existing equipment in the most efficient developed economies in new investment in China.

#### **Comparing Developed and Developing Country Targets**

Following the Kyoto blueprint developed country targets have been framed in terms of absolute reductions of carbon emissions as a percentage of emissions in a base year such as 1990, 2000, or 2005. By contrast, China's and India's unilaterally declared targets have been framed in terms of percentage reductions in carbon intensity at 2020 relative to 2005 emissions intensity, while some other developing countries have defined their commitments as absolute reductions relative to a BAU trajectory. Among others, the US has proposed a

reduction of 17% relative to 2005, the EU either 20% to 30% relative to 1990, and Australia 5-25% relative to 2000. Australia's target, like those of Brazil and Indonesia includes a large amount of emissions from forestry and land-use change, which does not fit into our framework of analysis.

These two different types of targets can be compared. The comparison depends on making assumptions about the rate of economic growth in the developed economies over the commitment period. This allows us to convert the developed country emissions reduction target into a carbon intensity target. The relationship between emissions reduction and carbon intensity targets is:

$$(1 - I) = \frac{1 - E}{1 + G} \tag{4}$$

where I is the intensity reduction target, E is the emissions reduction target (positive numbers) and G is the total percentage growth of the economy over the commitment period.

The United States currently proposes to reduce emissions by 17% in 2020 relative to 2005. China proposes to reduce its emissions intensity by 40-45%% in 2020 relative to 2005. For the US commitment to yield the same reduction in emissions intensity over the period, the growth of the US economy over the period must be 44% or 2.5% per year. According to the Penn World Table, the U.S. economy grew at 2.7% between the end of 1999 and 2007. GDP declined over 2008 and 2009. A growth rate of 2.5%, therefore, may be a realistic growth rate for 2005-2020. With that economic growth rate, the US and Chinese targets are then identical in terms of reductions in emissions intensity.

Next, we compare the mid-point of the EU's 20-30% target range with the mid-point of the Chinese target range. A 25% reduction in emissions relative to 1990 implies a reduction in carbon emissions of 23% relative to 2005, as aggregate emissions in EU-27 countries fell by around 2% from 1990 to 2005 (with a significant contribution from collapse of low-efficiency, high-carbon socialist economies). For this to translate into the same reduction in emissions intensity as under China's target, economic growth would need to be 1.9% p.a. from 2005-20. The EU(27) economy has grown at a rate of just over 2% p.a. since 1990. Hence, a continuation of this growth rate, combined with the stringent end of the EU target range, would imply only a slightly larger reduction in emissions intensity than the Chinese target.

#### **Discussion and Conclusions**

In this paper, we have shown that China and India's emissions intensity targets for 2020 are feasible but would not be easy to achieve. Chinese energy efficiency has converged with developed and other developing economies in recent years and its rate of improvement slowed down. Furthermore, the rate of improvement in energy efficiency in many developing economies is very low or even negative (a reduction in efficiency). Given this, BAU for China assuming that the rate of improvement of energy efficiency is similar to the past decade is a 23% reduction in emissions intensity. The reduction could be as high as 29% if China imitates developed economies going forward and lower if it behaves more like other developing economies. In no way is a 40-45% reduction in emissions intensity, "business as usual".

China's existing non-fossil energy goal will only contribute about an additional 3% reduction in emissions intensity by itself. Even drastic shifts towards low-carbon electricity sources, and fast displacement of direct use of fossil fuels with electricity, by themselves would not be enough to meet the emissions intensity target. Achieving China's goal through maximizing the energy efficiency of new investments alone would require China to match the average energy efficiency of Germany in all new investments. Hence, it is likely that policy action in all aspects of the energy sector will be needed to achieve the target.

India could achieve its goal of a 20-25% cut in emissions intensity if the recent rate of progress in energy efficiency is maintained. But this rate is much faster than India's historical average or that of other developing economies. However, it is about the same as that of developed economies. As India – according to the measure of underlying energy efficiency defined in this paper – is already as energy efficient as the developed economies we did not analyse the effect of increasing the energy efficiency of new investments. Increasing the share of electricity generated by non-fossil technologies would obviously help India achieve its goal, but as only around 20% of final energy consumption in India is expected to be in the form of electricity in 2020, this would have only limited effect.

Finally, comparing the targets for absolute emissions put forward by the US and the EU, we show that the rate of reduction in emissions intensity implicit in their targets is similar to the Chinese target. A comparison of rates of change of emissions intensity is informative and relevant, as it strips away the "emissions dampening" effect of relatively slow economic

growth in the advanced economies, which is certainly not the effect of any deliberate policy intervention.

Seen in this light, the EU and US targets are no more ambitious than China's in terms of the change towards low-carbon and high-efficiency energy technologies. Conversely, it stands to reason that making the same rate of progress is more difficult in countries that are already more efficient (in particular many EU countries). It can also be argued that it is harder in a slow-growing economy to achieve the same rate of emissions intensity reductions because the new capital stock added routinely each year is a smaller share of the total than in fast-growing countries, so it requires especially efficient or low-carbon investment, and/or premature scrapping of existing facilities.

But such arguments ignore that developed countries, going back to the Rio Convention of 1992, explicitly agreed to put in greater effort than developing countries in mitigating climate change.

The debate now is no longer over whether developed countries should do 'something' while developing countries continued to do 'nothing' for climate change mitigation. Rather, it appears that countries' targets on the table since Copenhagen, despite all the disagreements over their legal status, can be the starting point for a serious debate about who does how much, and how.

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	Table 1. Econo	metric Results	
Deterministic	: Model	Stochastic M	Iodel
Constant	2.218	Constant	3.847
	(1.68)		(1.90)
Winter	0.013	ln TFP	-0.536
	(1.77)		(-3.16)
Coal	-0.407	ln PPP	0.797
	(-1.14)		(5.64)
Natural Gas	-0.544	ln Open	0.137
	(-1.26)		(2.30)
Primary Elec.	-0.598	Corruption	-0.029
	(-1.70)	_	(-1.11)
Biomass	-0.878	Fossil Res.	0.010
	(-4.31)		(2.36)
Agriculture	0.079	Prot. Europe	-0.216
	(0.11)	_	(-1.31)
Mining	0.372	Former Comm.	0.422
	(0.36)		(2.29)
Services	-0.433	$\sigma_{\!$	0.229
	(-0.60)		(9.09)
		$\sigma_{\!_d}$	0.004
			(0.01)
t-statistics in parenthes	es	1	

Table 2. DAC	ble 2. BAU and Alternative Policy Scenarios: 2005-2020		
	China	India	
BAU Scenario 1 (1971-2007 rate of tech change)	-39%	-4%	
BAU Scenario 2 (1999-2007 rate of tech change)	-23%	-23%	
BAU Scenario 3 (US rate of tech change)	-29%	-23%	
Contribution of Non-Fossil Fuel Energy Target	-3%		
New Investment = German Average Efficiency	-41%		
New Investment = German Marginal Efficiency	-53%		

Figure 1: China Historical Energy, Emissions, and Carbon Intensity

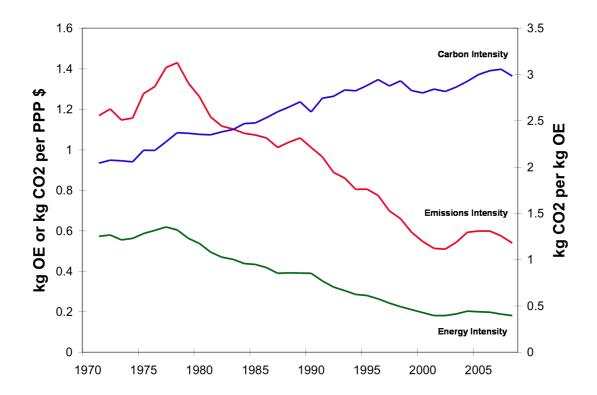


Figure 2: India Historical Energy, Emissions, and Carbon Intensity

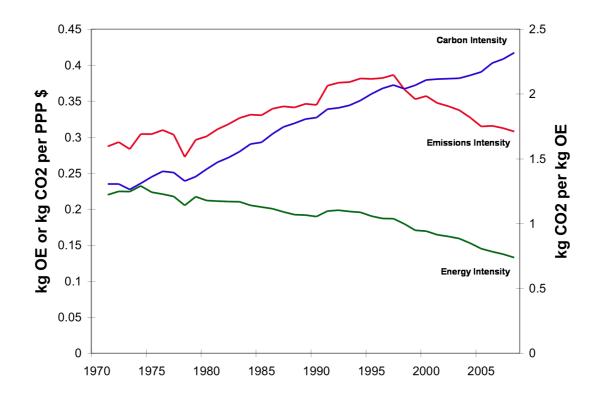


Figure 3: China, India, and Four Developed Economies: Underlying Energy Efficiency

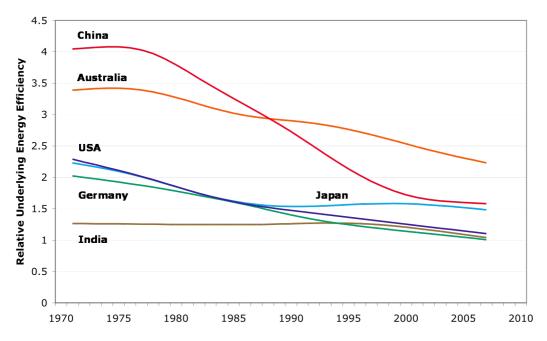


Figure 4: China, India, and Four Developing Economies: Underlying Energy Efficiency

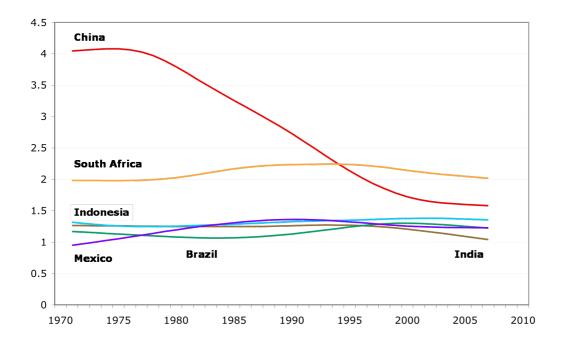


Figure 5: BAU Scenarios for China

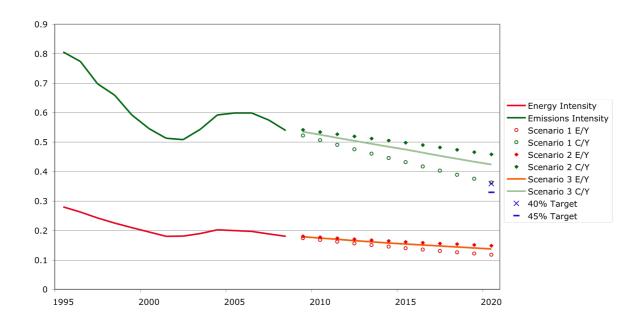


Figure 6: BAU Scenarios for India

