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# Value Added in Motion: Macroeconomic Implications of Energy Price Trajectories

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# VALUE ADDED IN MOTION:

## MACROECONOMIC IMPLICATIONS OF ENERGY PRICE TRAJECTORIES*

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**ABSTRACT**

Taking a 2035 horizon, we examine how world energy consumption and emission patterns will be shaped by the changing demand and technological capabilities of different regions. We combine a convergence model fitting three production factors (capital, labour and energy) and two factor-specific productivities, along with a dynamic CGE model of the world economy. We consider three possible "worlds" with very different energy scarcity, and how Copenhagen pledges change economic agents' calculus in each of these three situations. We find that the most dramatic changes in terms of location of value added are to be expected from the intrinsic differences among the three considered "worlds", not so much in terms of economic impact of environmental pledges.

*JEL Classification:* *E23, E27, F02, F47*
*Key Words:* *Growth, Macroeconomic Projections, long run, global economy*

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## 1. INTRODUCTION

A sounding representation of the future production and consumption patterns is critical to design effective policies and the key is being able to anticipate medium or long run growth scenarios. The main trajectories of world economy, factor allocation and trade in the 2035 horizon considered here are presented in Fouré and Fontagné (2015). These alternative scenarios are derived from the combination of a Growth Model, to derive macroeconomic trends, with a Computable General Equilibrium model (MIRAGE-e) to further decompose sector growth, factor allocation and world trade patterns.

In the present Report, we will focus on a specific projection from MIRAGE-e issued after imposing alternative trajectories for energy prices (high, medium and low prices for oil, coal and gas) and detail the consequence of this assumption for the country specialization patterns and factor across EU sectors and regions. Price trajectories are taken from the International Energy Agency (Outlook 2015), those evolution path are key element in order to have a sound representation of world economic growth. Energy prices, in fact, could vary widely over the next 20 years, not only due to growth volatility but also to geopolitical tensions or technological shocks. The evolution of energy prices in the medium/long term, in fact, can have significant consequences for growth trajectory of world economies.

In the following framework the price level for energy can be seen as a result of a supply side shock (increasing/reducing scarcity). Using the trajectory for key energy fossil fuels we further illustrate the links between resource scarcity and climate change by simulating the effect of country specific environmental policies based on the pledges made by countries in the Copenhagen agreement in 2009 (IEA, 2010)[5].

All these aspects have important implications for the location of value added, trade and country competitiveness. There exist several factors that shape the uncertainty of future energy prices, including changes in worldwide production and supplies of substitutive source of energy as well as technological improvement in energy efficiency. High uncertainty surrounding the evolution of energy prices represents by itself one of the major political concerns across European countries. This is because they create additional cost burdens for households and industries affecting significantly Europe's overall external competitiveness.

Our simulation shows that the targeted reduction in greenhouse gas (GHG) emissions in Copenhagen could be achieved without major cost in term of GDP, i.e. a reduction between 0.5% and 0.69% at the 2030 horizon. Those results are consistent with the multi-model simulation performed by Knopf et al. (2013) showing that the economic cost of targeting the 80% reduction in GHG emission (by 2050) is relatively modest, i.e. –0.7% on GDP at the horizon 2030. Implications in terms of relocation of value added in Europe are limited as well.

The rest of the Report is organized as follow: Section 2 describes the policy framework underlying the oil prices scenarios and the CO2 emission caps; Section 3 describes the simulation model and Section 4 reports and describes the economic scenarios. Section 5 concludes and sketches the major policy implication.

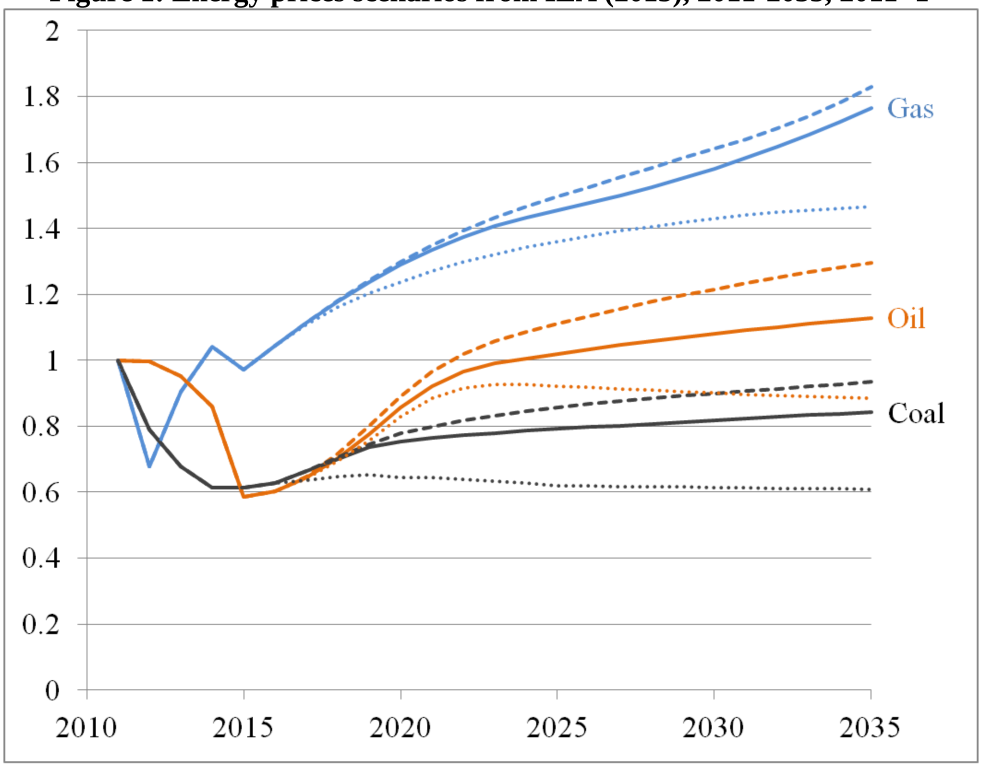
5 We acknowledge that the commitments ratified during the 21st Conference of the Parties (COP21) to the United Nations Framework Convention on Climate Change, negotiated in Paris in December 2015, are different from those of Copenhagen (COP15). At the time this report was prepared national plans with environmental policies were not yet deposed at the United Nations.

## 2. POLICY FRAMEWORK

*Energy Prices (Fossil Fuels)*

In the simulation exercise, described in Section 3, we consider three alternative paths for fossil fuels energy prices (Coal, Gas and Oil) provided by the International Energy Agency (IEA) in the 2015 World Energy Outlook, resulting in a High price a Medium price and a Low price scenario at the 2035 horizon. Notwithstanding an increasing demand for energy over the whole period, future development shows an interesting deceleration over time: from 1.4% in the 2010-2020 to below 1% in the 2030s. Figure 1 reports the trajectories from the IEA (2015) for the high price (dashed line), the medium price (continuous line) and the low price (dotted line) scenario, used in the following simulation.

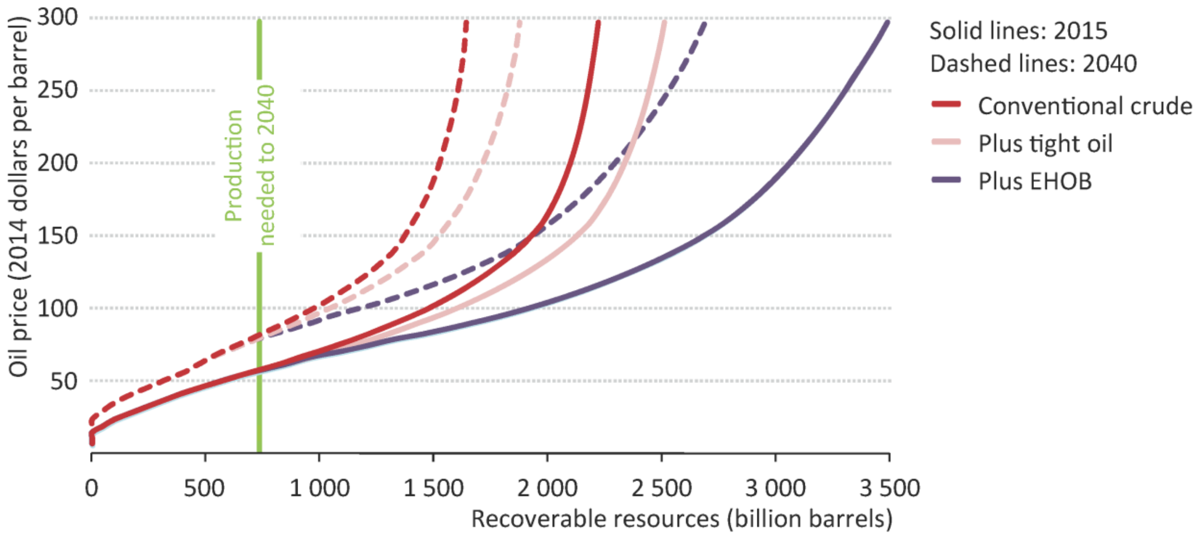
**Figure 1: Energy prices scenarios from IEA (2015), 2011-2035, 2011=1**




Note: Plain line corresponds to the "Medium Price" (medium resources) scenario, dashed lines to the "High Price" (scarce resources) scenario and dotted lines to the "Low Price" (abundant resources) scenario from the 2015 World Energy Outlook of the International Energy Agency (IEA).

During the past few years oil prices have been almost stable at a very high level, over 110$ per barrel. From the mid-2014, however, prices drop significantly, with the price per barrel falling more than 50% by the end of 2015 (and ranging from 40-60$ per barrel). This has been the result of two main forces: the global demand slowdown coupled with the increase in supply (especially from North America) and lack of adjustment from the OPEC. The sharp fall in prices between 2014 and 2015 is reflected in a weaker dynamic for oil prices at the beginning of the projection period for all the different scenarios, as the time horizon expand however markets tend to rebalance at higher price levels. There is nothing like a very low price of energy in the long run according to these projections, and one should not infer future prices from the very recent evolution. In the high price scenario Oil rebound more quickly, sustained by higher consumption with the average crude import price (proxy for world price) reaching $150 per barrel in 2040 whereas the equilibrium price in the low price scenario is expected to be around $95 per barrel. In general, oil prices will reflect the "level needed to stimulate sufficient investment in supply in order to meet projected demand in each scenario" (IEA 2015). As a consequence higher demand implies increasing production from costly fields whereas with a weaker demand market equilibrium can be found at a lower price: these two situations are characterized in the simulations in Section 3 as the scarce resource setup (high prices) and the abundant resources setup (low prices). In order to better characterize the relation between price and availability of resources in the long-run we report in Figure 2 the supply cost curves for 2015 and 2040 for non-OPEC producers under the medium price scenario[6]. Not surprisingly, prices and volumes of resources are positively correlated; the picture however changes over time: the 2040 cost curves (dashed) are higher and steeper than those for 2015 (continuous). Operating costs and capital investments, in fact, became increasingly higher with the gradual depletion of fossil resources and the need to exploit more remote (and costly) fields. According to the long-run projection, under the medium price scenario oil should reach 128$ per barrel in 2040.

**Figure 2: Non-OPEC supply cost curves for 2015 and 2040 in the Medium Price Scenario**




Notes: EHOB = extra-heavy oil and bitumen. The vertical green line indicates the amount of production required between 2015 and 2040 in the Medium Price Scenario. Source: IEA (2015).

Noteworthy, geopolitical and logistical constraints may significantly affect the equilibrium prices above/below the market clearing level implied by economic fundamentals. The economic condition in both OPEC and non-OPEC countries, in fact, could lead to higher prices than the level suggested by the supply cost. Considering the economic factors alone, in the medium price scenario, in fact, oil market should clear at a significantly lower level: between 80$ and 120$.

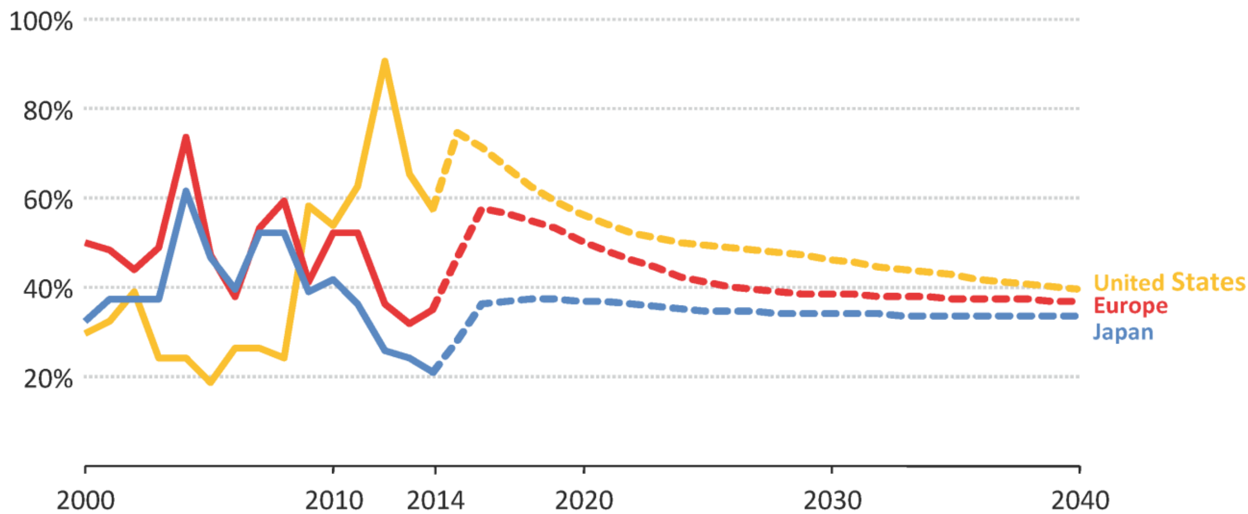
Contrary to oil, exchanges of natural gas and coal, despite a degree of global tradability, are organized in regional markets. For natural gas there are three main regional markets: North America, Asia-Pacific, and Europe; each of them with different rules and pricing strategies. Given these feature of the gas market, prices depend on the domestic cost of production as well as on the possibility of intermediaries to charge mark-ups. The future evolution of gas prices will thus be driven by technology as well as by the dynamics behind regional competitiveness. In the last years Europe's gas and electricity sectors are moving from public monopolies to liberalized markets made up of competitive private companies, where users, rather than tax-payers, bear the cost of new energy investments. On a global scale regional price differentials still

6 The cost-supply curves are derived from the IEA, World Energy Model.

persist (IEA 2015), however they seems to converge to a level reflecting transport costs across markets, such convergence process has been propelled by the increased availability of liquefied natural gas, whose traders tend to seek for the best prices in multiple markets helping for price convergence.

Coal markets tend to be more regionalized, with respect to natural gas, being also segmented by quality and transport infrastructures, resulting in relatively higher volatility across regions; despite that international prices are useful proxy for the overall developments in the sector.

**Figure 3: Coal price relative to gas price by region in the Medium Price Scenario**




Notes: in energy equivalent terms. Source: IEA (2015).

Price dynamics in the major markets for coal are reported in Figure 3. The sharp decline in prices from 2011 is imputable to an increased in supply capacity (World Energy Outlook 2015), associated with a declining demand growth, notably in China. The IEA projection for coal suggest that up to 2020 the market should regain the equilibrium, afterward the main determinant of price should be the "marginal supply cost". Both demand and policy interventions may, however, affect significantly the price in the next decades. In the High price scenario, for instance, demand factors and international trade will sustain the increase in price for coal up to 123$ per tons with respect to 108$ in the medium price scenario.

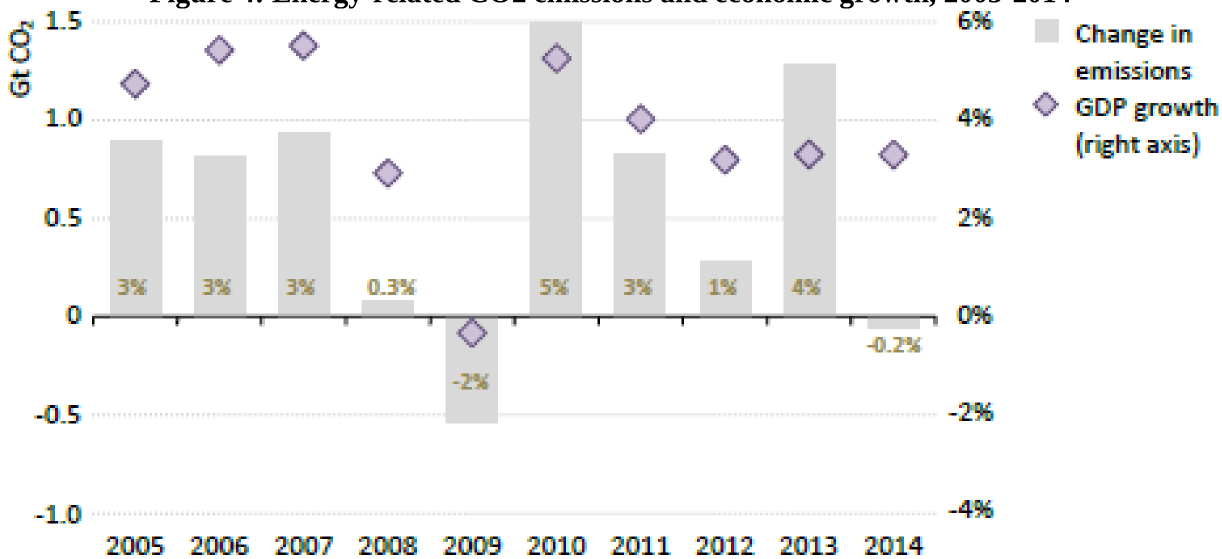
Simulations results in Section 4 will focus on the effect of the environmental policies on the long-term demand for coal as well as other energy sources.

*$CO^2$ Reduction: prospects and implications*

Another reason why energy prices are at the centre stage of political debate is that CO2 emissions are extremely sensitive to price trends and energy consumption. Economic activity has been by far and large the main driver of energy demand and carbon emissions over the past.

Interestingly the sharp decline in energy prices during the 2014 was associated with a decrease in carbon emission notwithstanding a 3.3% expansion of global economy, see the Figure 4. The availability of increasingly efficient technologies, the development of renewable energy sources (representing half of the new power capacity in 2014) as well as the widening of policy initiatives to control global warming has weakened significantly the link between economic growth and carbon emission.

**Figure 4: Energy-related CO2 emissions and economic growth, 2005-2014**




Notes: Gt CO2 = gigatons of carbon dioxide. Percentage shows year-on-year change in emissions. GDP growth is calculated using 2014 dollars in PPP terms. Source: IEA (2015).

Energy consumption patterns are changing in several countries, from the increasing share of electricity from renewable sources in China to the policy effort in many OECD countries to attain sustainable growth while reducing emissions. European policies and regulations on CO2 emission are ultimately shaping energy demand, and by that energy prices, across European countries. The European Energy Roadmap indicates that by 2030, energy-related CO2 emissions should be between 38 and 41% lower to 1990 levels, while greenhouse gas (GHG) emissions should decrease by 40–42%.

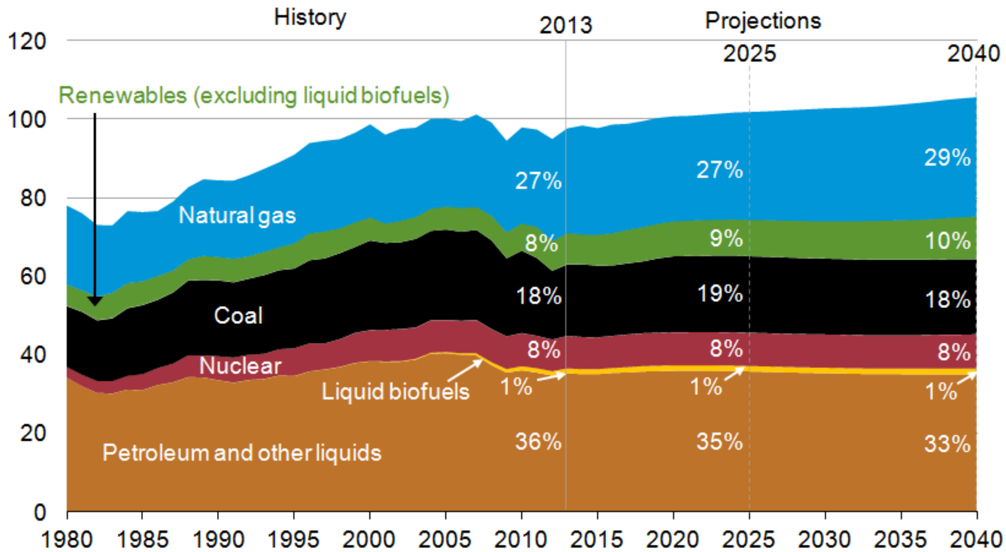
The multi-model simulation of the medium/long term European energy system performed by Knopf et al. (2013) show that there are several possible trajectories to achieve a substantial reduction of emission by 2030/2050. Most of the reviewed models allow for a substantial reduction of GHG emissions, targeting the 80% reduction, without a significant decline in economic activity, with just a –0.7% on GDP.

However, it would be crucial to set the right price in order to prevent over-investment into carbon technologies. To ease long term then it should be defined a clear set of binding targets in the medium terms to allows investment in strategic (low emission) energies.

Higher shares of renewable energy, in fact, can deliver CO2 reductions so long as these do not substitute other low-carbon energy sources while improved energy efficiency can help reduce GHG emissions and facilitate attainment of the reduction targets. Renewable provide an increased share of electricity generation, reflecting rising long-term natural gas prices and the high capital costs of new coal and nuclear generation capacity. Alternative gas supplies, such as shale gas or Caspian gas, are also being developed, requiring further investment.

Improved efficiency of energy consumption in end-use sectors and a shift away from more carbon-intensive fuels help to stabilize energy-related carbon dioxide emissions. Forecasts from the EIA show that consumption in US will favor renewable sources mainly at the expense of oil and petroleum products (see Figure 5). It is difficult to assess the impact of different paths for energy prices and of constraints on carbon emissions as well. In the following, we will rely on detailed modeling exercise adapting a macroeconomic perspective on energy efficiency. Prices of energy and technological catch up will drive energy efficiency at the level of countries.

**Figure 5: U.S. primary energy consumption quadrillion Btu**




*Source: EIA, Annual Energy Outlook 2015 Reference case*

We will also consider how these constraints shave the geography of value added in Europe. We have to acknowledge that one dimension will be missing: firms heterogeneous in terms of energy efficiency will be differently affected by changes in energy price or carbon price. As shown by Rubashkina et al (2015), environmental policies are an incentive to innovation for firms.

Beyond effects on Value Added allocation across sectors an effect on allocation within sectors must be considered: firms that adapt more quickly to the evolution of the energy prices will have more chance to gain market shares and stay in the market. Ultimately, the average energy efficiency within the sector will be shaped by the reallocation of resources among firms. We will model the aggregate effect, but the disaggregated effect must be stressed when the design of economic policies is addressed.

## 3. The Model: Scenarios and Simulations

This paper adopts the GDP-driven CGE approach described in detail in Fontagné & Fouré (2015)[7]. In what follows we briefly summarize the building blocks of the simulation procedure. The first step, called the "Macro" step starts with a theoretically derived model, which is estimated in order to recover the growth projections for more than 160 countries. The key elements of this model are conditional convergence (based inter alia on human capital accumulation), demographic transition, saving behaviour and energy use and efficiency. This first step is performed with the MaGE model (Fouré et al., 2013) where the only differences across the specifications are the trajectories of fossil fuel prices.

The second step, labelled the "Secto" step, consists in calibrating the CGE model to recover the dynamic trajectory (for both the sectoral TFP and the level of natural resources) that matches the Macro projections (respectively GDP and energy prices). To proceed we use an updated version of MIRAGE (Fontagné et al., 2013b). The CGE provides sector decomposition of growth, factor allocation, and country specialization. In this second stage, to encompass the consequences of a climate change policy, we will depict three different worlds for the upcoming 20 years.

These three worlds are taking stock of the calibration made in the "Macro" step, by including the pre-experiment on transaction costs and transport TFP. The three worlds are *different only in terms of natural resource scarcity*: natural resource availability for fossil fuel production (coal, oil gas) is calibrated such that energy prices match the three scenarios provided by IEA (2015). Namely, we consider the alternative scenarios called "Current Policies" (Scarce resources), "New Policies" (Medium resources) and "450" (Abundant resources), and use the associated crude oil price projections, natural gas price in the United-States and OECD steam coal import prices, all in real terms[8].

Finally, the CGE is mobilized in a third step, the "Environmental Policy" step, to build *alternative scenarios of the world economy*. For sake of clarity, the corresponding scenarios are named "CO2", while the corresponding baselines are named "BAU" (business-as-usual). To illustrate the links between resource scarcity and climate change policy, we define a climate policy scenario based on the pledges made by countries in the Copenhagen agreement in 2009 (IEA, 2010)[9]. The model setup for both the "Macro" and the "Secto" step are summarized in **Erreur ! Référence non valide pour un signet.**.

The climate change policy assumptions we retain in the third step are described in Table 3[10]. The first three columns present the very pledge, including the target year, the amount of reduction and the metric of this reduction. The metric can be of three types: (i) reduction from a past level of emission, (ii) reduction in the $CO_2$-intensity of GDP and (iii) reduction from the business-as-usual.

Consequently, the two latter metrics will depend on the world in which emission reduction take place, whereas the first is BAU-independent. The last column describes how these emissions reduction commitments are implemented in the model, which takes 2011 as the base year. Pledges are converted to targets relative to emissions in year 2011 using UNFCCC data (and when not available WDI data). Finally, the commitments of the Copenhagen agreement encompassed all GHG emissions, whereas we only consider $CO_2$ emissions. We make the assumption that all the effort in reducing GHG emissions will

7 Fontagné and Fouré (2015), Value Added in Motion: Modelling world trade patterns at the 2035 Horizon.
8 Price trajectories are reported and discussed in Section 2, Figure 1.
9 As already underlined in the introduction we acknowledge that the Paris agreement (December 2015) induced commitments that can be different from those of Copenhagen, but at the time this report was prepared there were no available information on the country specific environmental policies following the COP21 agreement.
10 The different scenarios for the "Environmental Policy" simulation are summarized in
Table 2.

be distributed between $CO_2$ and other GHGs proportionally to their $CO_2$-equivalent conversion coefficient.

These emission reduction policies will all take place simultaneously between 2012 and 2020. During this period of time, we assume that the ton of carbon will be priced such that the target is attained in 2020, following a linear shape. Since we do not know what will be the climate change policy after 2020, we assume that the carbon price attained in 2020 will be maintained constant up to 2035. The revenue from the pricing of carbon will be redistributed to the representative agent in each country on a lump-sum basis.

**Table 1: Macroeconomic Setup under different energy price trajectories**

| | | **Scarce resources BAU** | **Medium resources BAU** | **Abundant resources BAU** |
|---|---|---|---|---|
| **MaGE** | **Oil price** | High price scenario (IEA) | Medium price scenario (IEA) | Low price scenario (IEA) |
| **MIRAGE** | **Energy prices** | High price scenario (IEA) | Medium price scenario (IEA) | Low price scenario (IEA) |
| | **Transaction costs** | 25% cut | 25% cut | 25% cut |
| | **Transport TFP** | 2% annual growth | 2% annual growth | 2% annual growth |
| | **Tariffs** | No change (w.r.t. 2011) | No change (w.r.t. 2011) | No change (w.r.t. 2011) |

Note: Setup for the macroeconomic model (MaGE) and the CGE model (MIRAGE). Energy prices, reflecting the abundance/scarcity of resources, are from the IEA (2015) projections.

**Table 2: Environmental Policy, Simulation Setup**

| **Scenario name** | **Pre-experiment** | **Natural resources** | **Climate change policy** |
|---|---|---|---|
| **Abundant resources BAU** | Included | Abundant | No |
| **Abundant resources CO2** | Included | Abundant | Copenhagen pledges |
| **Medium resources BAU** | Included | Average | No |
| **Medium resources CO2** | Included | Average | Copenhagen pledges |
| **Scarce resources BAU** | Included | Scarce | No |
| **Scarce resources CO2** | Included | Scarce | Copenhagen pledges |

Note: Simulation setup for the Environmental policy shock, the detailed list of emission reduction pledges are reported in Table 3.

**Table 3: GHG emissions reduction pledges as in the Copenhagen agreement**

| Zone | Target year | Pledge | Reference year | Equivalent from 2011 emissions |
|---|---|---|---|---|
| **EU** | 2020 | -20% | From 1990 level | -2.22% |
| **USA** | 2020 | -17% | From 2005 level | -10.68% |
| **Canada** | 2020 | -17% | From 2005 level | -12.90% |
| **Japan** | 2020 | -25% | From 1990 level | -29.14% |
| **Australia and New Zealand** | | | | -15.59% |
| Australia | 2020 | -5% | From 2000 level | -14.07% |
| New Zealand | 2020 | -10% | From 1990 level | -26.64% |
| **Russian Federation** | 2020 | -15% | From 1990 level | +25.15% |
| **Brazil** | 2020 | -36% | From BAU | N.A. |
| **China and Hong Kong** | 2020 | -40% | From 2005 intensity | -28.11%+ |
| **South Africa** | 2020 | -34% | From BAU | N.A. |
| **India** | 2020 | -20% | From 2005 intensity | -13.48%+ |
| **Mexico** | 2020 | -30% | From BAU | N.A. |
| **Korea** | 2020 | -30% | From BAU | N.A. |
| **ASEAN** | 2020 | -7.55%* | From BAU | N.A. |
| Singapore | 2020 | -16% | From BAU | N.A. |
| Indonesia | 2020 | -26% | From BAU | N.A. |

Note: * The level of pledge for ASEAN countries is computed using the share of Singapore and Indonesia in latest GHG emissions data available from UNFCCC (i.e. year 2000).+ Measured in $CO_2$ intensity of GDP (data : WDI

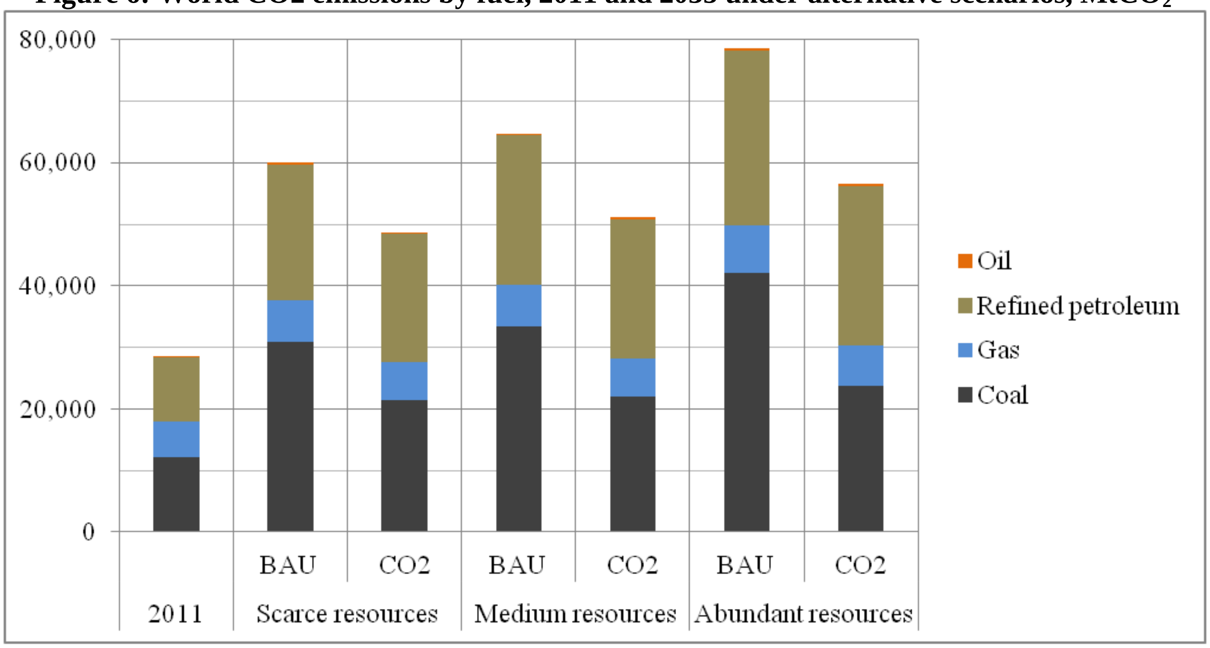
### 4. Simulation Results

We now present the results of the two scenarios ('business-as-usual' and 'CO2') simulated in MIRAGE, provided that MIRAGE gives the sectoral decomposition of the value added from derived from the Macro step under different paths for the energy prices. We now add the shocks on Environmental policy, as described in Table 4, to obtain the 'CO2' scenario.

The projection on CO2 emission, reported in Figure 6, confirms that whatever be the availability of natural resources, world CO2 emissions are likely to more than double within the next 20 years, up to over 60 thousand $MtCO_2$ from less than 30 thousand in 2011.

However, the extent to which emissions reductions will take place is sensitive to the level of natural resource scarcity. For instance, climate policy outcomes under abundant resources are not much below the level of emissions that could be achieved with no climate policy (BAU) at all but a high energy price (scarce resources) scenario.

**Figure 6: World CO2 emissions by fuel, 2011 and 2035 under alternative scenarios, $MtCO_2$**




Note: In metric tons of carbon dioxide equivalent (MtCO2). Source: MIRAGE, authors' calculation.

The economic cost of Copenhagen pledges under different scenarios for energy prices are reported in Table 4. Two effects are occurring in parallel. First, the cost of adjustment to emissions reduction commitments is increasing in the constraint level (high constrain leads to higher costs of adjustment). Second there is evidence of an energy market effect on Russia, Middle-East countries and Sub-Saharan Africa: a high constraint in the world lead to a drop in demand for fuel, implying greater losses for energy producing countries. In general, within pledging countries, the lower the constraint, the even lower the cost, interestingly some countries even experience an increase in GDP, due to the "free-rider" effect (USA, ASEAN).

**Table 4: Variation in 2035 GDP due to Copenhagen pledges under alternative scenarios**

| | Scarce resources | Medium resources | Abundant resources |
|---|---|---|---|
| Russia | -1.92 | -2.06 | -2.48 |
| Other Middle East | -1.45 | -1.76 | -2.49 |
| Japan | -1.67 | -1.74 | -1.81 |
| Australia & New Zealand | -0.88 | -0.96 | -1.22 |
| India | -0.74 | -0.95 | -1.87 |
| Mexico | -0.72 | -0.79 | -1.04 |
| China | -0.63 | -0.71 | -0.97 |
| South Africa | -0.47 | -0.51 | -0.66 |
| Korea | -0.57 | -0.49 | -0.18 |
| Sub-Saharan Africa | -0.35 | -0.46 | -0.80 |
| Brazil | -0.46 | -0.42 | -0.34 |
| Spain | -0.17 | -0.22 | -0.27 |
| Other EU28 | -0.14 | -0.19 | -0.26 |
| Canada | -0.14 | -0.17 | -0.27 |
| Italy | -0.13 | -0.16 | -0.18 |
| United Kingdom | -0.08 | -0.12 | -0.22 |
| Germany | -0.08 | -0.12 | -0.18 |
| North Africa | -0.03 | -0.11 | -0.37 |
| France | -0.04 | -0.06 | -0.07 |
| USA | 0.01 | 0.01 | 0.02 |
| ASEAN | 0.06 | 0.03 | -0.21 |
| Rest of the World | 0.11 | 0.07 | -0.07 |
| Turkey | 0.40 | 0.41 | 0.39 |
| World | -0.45 | -0.51 | -0.69 |

Source: MIRAGE, authors' calculation.

Table 5 reports the expected energy price variation due to the CO2 emission mitigation policy with a breakdown by sources. Results point to an evidence of carbon leakage: constraining CO2 emissions lead to a decrease in world demand for fossil fuels, implying a decrease in their prices. Not surprisingly, the most CO2-emissive fossil fuel, i.e. coal, absorbs the majority of climate policy price effect. Ultimately, countries with no emissions reduction target have incentives to use more fossil energy and emit more CO2. For electricity: the cost of fossil fuel raises the price of inputs, leading to an increase in electricity price. This is not the case for refined petroleum, because crude oil is transformed by this sector and not burned.

Table 6, reporting the variation in CO2 emission due to the Copenhagen agreement across acting and non-acting countries confirm the case for carbon leakage. The leakage rate, however, is relatively small; giving that only few countries do not take commitments the potential for an increase in overall emission is fairly limited. Nevertheless, the scarcer the resources the higher will be the leakage rate; this is mainly due to the "energy-price" channel mentioned above, i.e. world price of fossil energy decreases with the size of the carbon constraint.

**Table 5: Variation in energy prices due to CO2 emissions mitigation policy under alternative scarcity of natural resources**

| | Scarce resources | Medium resources | Abundant resources |
|---|---|---|---|
| Coal | -13.2 | -12.9 | -10.1 |
| Oil | -3.9 | -4.3 | -5.0 |
| Gas | -3.8 | -3.8 | -3.8 |
| Refined petroleum | -2.6 | -2.8 | -2.8 |
| Electricity | 12.4 | 14.0 | 19.1 |

Source: MIRAGE, authors' calculation.

**Table 6: Variation in CO2 emissions due to Copenhagen agreement (MtCO2) in acting countries and non-acting countries, and leakage rate, 2035**

| | Scarce resources | Medium resources | Abundant resources |
|---|---|---|---|
| Coalition (MtCO2) | -11636 | -14012 | -22441 |
| Non-Coalition (MtCO2) | 316 | 348 | 403 |
| Leakage rate (%) | 2.7 | 2.5 | 1.8 |

Note: In metric tons of carbon dioxide equivalent (MtCO2). Source: MIRAGE, authors' calculation.

The reallocation of Value Added across sectors in the European Union, following the implementation of the Copenhagen pledges, is represented in Table 7. Within the European Union, the cost of complying with the environmental agreement is too low to induce any significant change in the sectoral allocation of value added. This is true for both the aggregate sectors – reported in Table 7 – as well as the detailed sector level[11]. Noteworthy, since services are relatively less energy-intensive its share in European Value Added tent to increase with the emission reduction pledge. This important result means that changes expected to occur in terms of location of the value added in Europe will be mostly driven by the macroeconomic forces, demography and technological trajectories already contained in our baseline.

There is even a counter-intuitive outcome: the manufacturing sector slightly increases its share in EU value added after the implementation of emissions reduction policy in every scenario. This is due to a "free rider" effect: the constraint on EU emissions is so low in this scenario, only 2% less emissions in 2020 compared to 2011, and its relative competitiveness, compared to its main competitors subject to their own emissions reduction pledges, increase. However, this result must be interpreted with caution, as the "natural" trend in the manufactured value added in Europe is decreasing otherwise. This positive effect would only slightly dampen the expected negative evolution. All in all, the bottom line of this exercise is that pledges will not be the driver from deindustrialization of Europe.

The result for Europe can be better understood by considering a counter-example, which is provided by Japan. Table 8 shows the allocation of Value Added in Japan after the implementation of the environmental policy. Since Japan is among the most constrained countries the reallocation of economic activity is slightly higher, with a shift from manufacturing to services. This shift is however modest, less than 1 percentage point, whereas is marginally more important between sectors inside the three broad categories (see Table 9). The main sectoral reallocation occurs between CO2-intensive sectors (Metals, Other Manufacturing) and less intensive sectors (Machinery, Cars and Trucks, Food).

In general, it is confirmed across different results that the adjustment will be more important the higher is the level of initial resources. However, the CO2 constraint is too low to observe significant reallocation between EU Member states (see Table 10).

**Table 7: Sector allocation of value-added in the European Union, 2011 and 2035 under alternative scenarios**

| | 2011 | Scarce resources | | Medium resources | | Abundant resources | |
|---|---|---|---|---|---|---|---|
| | | BAU | CO2 | BAU | CO2 | BAU | CO2 |
| Primary | 2.95 | 2.79 | 2.70 | 2.78 | 2.69 | 2.75 | 2.64 |
| Manufacturing | 22.13 | 16.99 | 17.02 | 16.93 | 16.95 | 16.82 | 16.86 |
| Services | 74.91 | 80.22 | 80.28 | 80.29 | 80.36 | 80.43 | 80.50 |

Source: MIRAGE, authors' calculation.

**Table 8: Sector allocation of value-added in Japan, 2011 and 2035 under alternative scenarios**

| | 2011 | Scarce resources | Medium resources | Abundant resources |
|---|---|---|---|---|

11 The detailed table is not reported here but available upon request.

| | | BAU | CO2 | BAU | CO2 | BAU | CO2 |
|---|---|---|---|---|---|---|---|
| Primary | 1.28 | 1.08 | 1.08 | 1.08 | 1.08 | 1.08 | 1.08 |
| Manufacturing | 16.30 | 12.75 | 12.33 | 12.71 | 12.27 | 12.62 | 12.16 |
| Services | 82.42 | 86.17 | 86.59 | 86.21 | 86.65 | 86.30 | 86.76 |

Source: MIRAGE, authors' calculation.

**Table 9: Share of manufacturing sectors in manufacturing value added in Japan, 2011 and 2035 under alternative scenarios**

| | 2011 | Scarce resources | | Medium resources | | Abundant resources | |
|---|---|---|---|---|---|---|---|
| | | BAU | CO2 | BAU | CO2 | BAU | CO2 |
| Food | 13.6 | 11.1 | 11.6 | 11.2 | 11.7 | 11.3 | 11.9 |
| Textile | 2.2 | 2.5 | 2.6 | 2.5 | 2.6 | 2.5 | 2.6 |
| Other Manuf. | 27.5 | 28.2 | 27.6 | 28.4 | 27.7 | 28.6 | 27.8 |
| Petroleum and coal products | 0.6 | 0.5 | 0.5 | 0.6 | 0.5 | 0.6 | 0.5 |
| Metals | 15.0 | 15.2 | 14.5 | 15.2 | 14.4 | 15.2 | 14.3 |
| Cars and Trucks | 9.7 | 12.3 | 12.7 | 12.3 | 12.7 | 12.3 | 12.7 |
| Transport Equipment | 2.0 | 2.0 | 2.1 | 2.0 | 2.1 | 2.0 | 2.1 |
| Electronic | 10.4 | 8.7 | 8.7 | 8.7 | 8.6 | 8.7 | 8.7 |
| Machinery | 19.1 | 19.4 | 19.8 | 19.2 | 19.7 | 18.9 | 19.5 |

Source: MIRAGE, authors' calculation.

**Table 10: Regional allocation of value-added in European Union, 2011 and 2035 under alternative assumptions**

| | 2011 | Medium resources | | Scarce resources | | Abundant resources | |
|---|---|---|---|---|---|---|---|
| | | BAU | CO2 | BAU | CO2 | BAU | CO2 |
| France | 15.38 | 16.13 | 16.13 | 16.13 | 16.13 | 16.14 | 16.13 |
| Germany | 21.02 | 16.68 | 16.69 | 16.68 | 16.69 | 16.68 | 16.68 |
| Italy | 12.27 | 9.72 | 9.71 | 9.71 | 9.71 | 9.72 | 9.72 |
| Spain | 8.61 | 7.87 | 7.87 | 7.87 | 7.87 | 7.88 | 7.88 |
| UK | 14.07 | 17.94 | 17.92 | 17.95 | 17.93 | 17.92 | 17.90 |
| OtherEU28 | 28.65 | 31.65 | 31.68 | 31.65 | 31.67 | 31.66 | 31.69 |

Source: MIRAGE, authors' calculation.

## 5. CONCLUSIONS

How will the location of value added in Europe be shaped by underlying demographic, technological and macroeconomic factors on the one hand, and pledges in terms of CO2 emissions on the other hand. Taking a 2035 horizon, we answered these questions and have shown how world energy consumption and emission patterns will be shaped by the changing demand and technological capabilities of different regions.

To proceed, we combined a convergence macroeconomic model fitting three production factors (capital, labour and energy) and two factor-specific productivities at country level, for more than 150 countries in the world, along with a dynamic CGE model of the world economy. We considered three different "worlds" corresponding respectively to high, medium and low prices of energy as envisaged by the IEA. These three trajectories corresponding to "scarce resources", "medium resources" and "abundant resources" lead to very different outcomes in terms of CO2 emissions. Against such background, it is no surprise that pledges in terms of CO2 emissions impact differently the world economy. We observe in particular that markets (here the price of energy – we do not model directly the carbon price) play a big role in limiting emissions, through reduced consumption of energy. In contrast, pledges, although complementing the price channel, are confronted to carbon leakages. Ultimately, the impact on emissions of scarce resources (high price of energy) without pledges is not dramatically different from a world with low energy prices and pledges. Indeed, combining high prices of energy and prices is the most efficient policy, especially because it is cushioning the increasing use of coal.

Our next result is that pledges are not taking a big toll on growth. Neither do they deeply modify the allocation of value added in Europe. Ultimately, European industries should not consider such pledges as a threat in the medium run.

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