The actual impact of shale gas revolution on the U.S. manufacturing sector*

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Preliminary Draft

Abstract

This paper investigates the comparative advantage allowed by the U.S shale gas revolution to the U.S manufacturing sector. It estimates the response of various economic variables related to the U.S manufacturing sector using dynamic panel data models that allow each sector's response to vary with its energy intensity. We show that the decline in natural gas prices in the US relative to natural gas prices in Europe has led to an increase in industrial activity by nearly 2%. W show also that exports increased by 0,86% and imports decreased by 1,11%. Moreover, we find an empirical evidence that the relationship between natural gas prices and imports or exports has experienced structural breaks. Overall, we conclude that the shale gas revolution expended some industries but it does not have a strong effect on the manufacturing sector as a whole.

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1 Introduction

Energy supply remains a major issue of the 21st Century. The geo-energy science confirms the dominance of fossil fuels. They will still meet 87 percent of energy needs in 2025, with natural gas the only source of energy for which global demand grows in all scenarios[1]. Natural gas is now positioned as a major issue and appears as an alternative to other sources of energy due to its abundance and less polluting capacity. In the US, since 2000, the production of natural gas decreased slowly despite the rise in the drilling activity. The lower supply has led to higher prices in the US market. At that time the solution was to import liquefied natural gas (LNG) from the Middle East and Africa. Meanwhile, shale gas operations have been gradually set up and represented only 1% of the total natural gas production of the US in 2000. There was no hope that evolutions of unconventional natural gas production could bring opportunities for enhancing security of supply in the US market. However, unexpected technical advances associated with two existing extraction techniques, horizontal drilling and hydraulic fracturing, have allowed a massive extraction of shale gas resource as from 2006. This development permitted to offset the depletion of conventional natural gas. In 2013, shale gas represented about 40 % of the natural gas[2] market in the US. This positive supply shock lead North America to be ranked as the second region having the lowest costs for energy and raw materials in the world after the Middle East. This achievement of the U.S. arouses heated debate about shale gas worldwide, particularly in Europe. The supporters of shale gas highlight the outlook for economic growth and reduction in energy dependency. Opponents point a clear danger for the environment due to the hydraulic fracturing method . However, two countries stand by their opposing positions. The United States exploit its shale gas stocks while France adopted a law in 2011 that prohibits any activities related to exploration or extraction. In this context, our study aims to identify and evaluate some of the positive effects of the massive shale gas development on the US manufacturing sector and to contribute to this debate by scientific arguments.

Despite of its negative impact on environment, the expansion of the gas industry undeniably provides a bonanza to the US economy in multiple dimensions. Indeed, three effects are observable: a direct one, an indirect one and a competitiveness effect. The direct effect captures changes in the economic activities of oil and gas extractive industries, as employment increases in the mining sites like the number of engineers in the oil industry. The indirect effect relates to upstream sectors of the industry such as suppliers who take advantage of increased demand due to investments in extractive industries. We can mainly mention the metal industries and industrial processes : as US Steel for steel production, Vallourec preparing a new steel pipe plant in Ohio or TMK IPSCO developing its search abilities on extraction of shale gas[3]. Finally, the competitiveness effect corresponds to changes in economic activity in industrial sectors that benefit from lower prices of energy input (natural gas in this case). These prices have been divided by three between 2008 and 2012[4]. Indeed, the fall in energy prices enables companies to reduce their costs of production, which increases the competitiveness of manufacturing sectors, especially the most energy intensive of them.

This industry sector is one of the largest consumers of natural gas: it contains the manufacturing, construction, agriculture and mining industries sectors. It consumed 8.3 quadrillion Btu[5] of natural gas in 2011, about one third of the total consumption of the US. It can be a major beneficiary of the shale gas boom. Also in 2011, natural gas accounts for over 40% of energy used in the industrial sector. For instance, the decline in natural gas prices has directly impacted US industry by lowering the costs of electricity production. During the last two decades, the use of natural gas in electricity generation has significantly increased from 11% in 1990 to 28% in 2012, due to its

[1]Source : U.S EIA, Annual Energy Outlook 2015.
[2]Source : U.S EIA, Annual Energy Outlook 2015.
[3]http ://www.bloomberg.com
[4]Source : U.S EIA, Annual Energy Outlook 2014.
[5]One British Thermal Unit (Btu) is the heat that will raise the temperature of one pound of water by one degree Fahrenheit.

substitution with coal. It is also a key component used in the plastics, polymers, petrochemical, steel, cement and fertilizer production.

The boom in the production of oil and natural gas in the United States has generated a plethora of comments and analysis. A large majority of these studies are purely descriptive (PwC study (2011), Roberts (2013)). Nevertheless, some authors try to quantify the economic impact of this boom.

A first strand of the literature analyses the impact of shale gas exploitation on the U.S economy using a computable general equilibrium model. Houser and Mohan (2014) conducted an in-depth analysis to compute the new production costs for the U.S manufacturing industries considering the decline of the oil and natural gas prices through 2035. Based on these lower costs, they argue that relatively few industries will benefit from a substantial competitive advantage. They point out that this advantage may be short lasting if other nations begin to exploit shale gas, or if the United States start to export LNG. The IMF published a study in 2013, from a computable general equilibrium model, that assesses the impact of the oil and gas energy boom on the economy. Their results show an increase of 0.5 percent of GDP over the coming decade, which is qualified as positive but still modest. Morse et al. (2012) provide initial impact using a computable general equilibrium model as well, to figure out the downstream effect named in their article as "gas-related multiplier effects". This multiplier effect represents a source of increase of 1.1 million of employment in manufacturing, 9 % increase compared to the scenario without the energy boom until 2020. They also find that the real GDP grows by 0.2 percent above baseline by 2020, which implies 1.6 percent increase in manufacturing production knowing that it highlights 12.5 percent of GDP in 2012. The overall effect seems quite modest as the IMF results.

General equilibrium models are based on assumptions of general equilibrium of all markets in order to study the impact of shale gas by using the parameter calibration technique (on past periods). Based on a different approach, this paper uses real data to estimate the effect of the shale development and contributes thus to the second strand of literature on empirical models of trade flows and trade policy.

Celasun et al. (2014) use the cross-country panel data to estimate the response of the manufacturing sector's output considering changes in relative natural gas prices (domestic vs. world average) over the period 2001-2013. According to their results, if the natural gas price differential is multiplied by 2 in favor of the home country, manufacturing industrial production will increase by 1.5 percent. Sendich (2014) explores the direction of causality between gas price and manufacturing industrial production to see whether gas price is a determinant of production. She uses Granger causality tests and focuses on 12 energy-intensive manufacturing industries in the U.S. She concludes that for 8 of the 12 industries, there is a significant link between natural gas prices and production, confirming the potential importance of the downstream effect. The paper in the literature that is closest to our analysis is by Arezki and Fetzer (2015). They investigate the response of U.S manufacturers to change in competitiveness brought about by the decrease in the price of U.S natural gas. The authors estimate the response of various measures of manufacturing activity (exportations, importations, capital expenditures), using a gravity model on a panel data of 167 US industries trading with 233 countries for the period 1996-2012. The model allows each industry's response to vary with its energy intensity. The results suggest that the fall in US gas prices since 2006 is associated with 6 percent increase in exportations for the whole US manufacturing sector. They find no impact on importations and claim that the U.S shale revolution is operating both at the intensive and extensive margins. Their paper is closest to our analysis, however there are four distinct aspects in which our paper differs. First, we study the impact of shale gas on the US economy through five economic variables, which provides a broader and more complete analysis than Arezki and Fetzer (2015), who only consider three economic variables. Indeed, we consider two more variables in our analysis: industrial production and employment. The point we are making is that in standard microeconomic theory, a positive supply shock for an important input such as energy will lead manufacturers to increase output, in turn pushing out the industry supply curve and lowering prices. Insofar as energy and labor are complementary inputs, manufacturing employment should also increase. Second, Arezki and Fetzer use the 2002 Bureau of Economic Analysis Input-Output tables in ordre to build "energy-intensity" variable . They assume that energy consumption of industries is constant and the technology unchanged between 2002 and 2006. In our study, we construct an "energy-intensity" variable using the Manufacturing Energy Consumption survey (MECS) conducted in 2006. This recent data allows for more accurate information which permits better estimation and avoids measurement errors. This variable based on the MECS2006 provides a better indication about which companies should more take advantage from lower gas prices, since they provide information on the levels of gas and the total energy consumption closer to the date of the positive supply shock in the US gas market. Third, the authors find that the U.S shale revolution does not impact imports: according to their results, exports are favored but the imports are not discouraged. This result may be surprising because they claim that U.S manufacturing sectors exports grow up by 6%, and in such case, one could think that the manufacturing imports of the same goods should fall. To further investigate this point, we test for a hypothesis of structural break in the relationship between our five variables and natural gas prices. We find a structural break for imports and exports. These structural breaks may explain why Arezki and Fetzer do not find an impact for imports and overestimate impact for export. We find a decrease of 1,11% for imports and an increase of nearly 0,86% for exports over the period 2006-2013. Finally, we estimate a dynamic panel data which allows us to compute short term and long-term elasticities.

To sum up, few quantitative studies have figured out a positive but relatively small impact on the competitiveness of the U.S manufacturing industry as a whole, except for the effects on employment that pointed Morse et al (2012) and on exports by Arezki and Fetzer (2015). To our knowledge, there are until now only two studies using econometrics to quantify exploitation of shale gas on the US economy (Arezki and Fetzer, 2015; Celasun et al., 2014). Other studies are rather descriptive or have used of calculable general equilibrium models. The novelty of the subject associated to the difficulty of obtaining adequate data explains the low number of quantitative studies.

This study considers the manufacturing sector as defined in the North American Industry Classification System (NAICS)[6]. It aims to provide a clear answer to the impact of the production of shale gas on the US manufacturing sector. It uses econometric panel data methods to measure the impact on several macroeconomic variables of the price difference of natural gas between the US and Europe, induced by the production of shale gas. Our estimates indicate that the decline in natural gas prices in the US relative to the price of natural gas in Europe has led to an increase in industrial activity by nearly 2 percent. Even though some industries are expanding, it does not seem to have a great effect on the whole manufacturing sector till now. Industrial activity of the most energy intensive sectors reacts to falling gas prices, amounting to an increase of at least 20%. However, these results should be interpreted with caution given that firms adjust only gradually their production processes. Perhaps the overall effect of this energy boom is coming and not realized yet. The remainder of the paper is organized as follow. Section 2 discusses the existing markets place of naturel gas and their implications on gas prices. Section 3 describes the datasets used and lays out the empirical strategy. Section 4 presents the main results. Section 5 concludes.

2 The natural gas market and the economy

2.1 Specificity of the natural gas market

The international natural gas markets are not integrated like international oil markets. They are segmented into three different geographical areas: North American, European and Asian markets. The prices setting up in natural

[6]The North American Industry Classification System (NAICS) is the standard used by Federal statistical agencies in classifying business establishments for the purpose of collecting, analyzing, and publishing statistical data related to the U.S. business economy, US Census Bureau.

gas markets are governed by different mechanisms. However, they mostly have similarities related to the natural gas intrinsic characteristics inducing entry barriers. These barriers are related with high transport costs (pipeline, methane tanker) and high tranformation costs (liquefaction, regasification) necessary to allow the product to be marketed. Gas transportation represents the most colossal cost of the gas industry. The specific constraint of this type of energy product is due to its gaseous state and its relatively low density. Indeed, a ton of gas represents the energy equivalent to 0.89 ton of oil, which is about the same order of magnitude. However, a ton of oil occupies a volume of 0,85m3 while a ton of gas occupies a volume of 1000m3. Thus, the transport of same amounts of energy to the standard conditions for temperature and pressure is generally 4-6 times more expensive. Pipeline is the most frequently used method for the transportation of natural gas into the world trade (about 80%). In order to be transported by pipeline, the gas is compressed and maintained under pressure compressors installed every 100 km or less over distances up to 6000 km. This compression allows to reduce the volume. Pipelines can be terrestrial (North America, Russia) or submarine or underwater (North sea). The gas may also be transported by ships. To be efficiently transported by boats, natural gas must be transformed into a liquid state at a temperature of -160°C. Once stored as liquid, its volume is 600 times smaller than in its gaseous state, and then carried by a special refrigerated ship to a regasification plant. These exorbitant transportation costs create significant regional gas price differentials, and will provide a competitive advantage to the various economic players in the region which offers the lowest prices. It is the case of North America.

2.2 Trends in US gas market

In the early 2000s, oil and US gas industry was concerned about the depletion of conventional natural gas reserves. Most experts believed that North America would become a net importer of LNG. The US Energy Information Administration (EIA), in its Annual Energy Outlook 1999, anticipated an increase of 12.9% to 15.5% of net imports of natural gas between 1997 and 2020, knowing that consumption increased faster than production. To face up to this situation, five new LNG import terminals were built in the second half of 2000 and other existing installations were returned to service while increasing their capacity. However, against all economic forecasts, these facilities will not be of much use since shale gas is far more promising than expected. Starting from 2006, the gas industry realized that shale gas is an important and economically exploitable resource that could supplement the depletion of conventional gas wells. In 2005, the EIA reported a 6% increase in proved natural gas reserves, the highest since 1970. Driven by high gas prices, over 32,000 exploration and developments wells were drilled annually between 2006 and 2008. In 2010, proven reserves[7] of natural gas and oil have reached the highest levels recorded since 1977 by EIA. The United States became the largest producer of natural gas and oil ahead of Russia. This increase has been possible thanks to technological advances that have allowed exploitation of shale gas, which had not been available neither technically or economically before. In 2000, shale gas represented 1% of the US natural gas supply . The gas obtained from shale currently represents 40% of US gas production, in constant growth. According to EIA, shale gas will account for more than 50% of US gas production by 2035. Annual Energy Outlook 2014 (IEA, 2014) provides that the United States will become overall net exporter of natural gas by 2016, when production will exceed domestic consumption. The large availability of domestic natural gas leads the gas industry to change its objective and strategy. One of them is the reorientation in the construction of LNG import terminals to export terminals in the early 2010. More recently, only in January 2015, there were 48 applications for authorisation to build liquefaction facilities to export in a liquefied form.

The 2008-2009 financial crisis has caused a fall of natural gas prices by almost 75 per cent. Compared with Asian and European prices of gas, the price of US gas (Henry Hub[8]) did not rebound from the crisis. Prices in the United

[7]Proven reserves of crude oil increased by 13 percent (2.9 billion barrels) and proven reserves of natural gas rose by 12 percent (33.8 trillion cubic feet). Oil reserves at the end of 2010 were 25.2 billion barrels and natural gas reserves at the end of 2010 were 317.6 trillion cubic feet– the first time they reached a level over 300 trillion cubic feet.

[8]Spot and future prices set at Henry Hub are denominated in \$/mmBtu (US dollars per millions of British thermal units) and are

States and Canada have remained relatively weak, creating a large gap with those in Asia and Europe. In 2012, the average of natural gas prices in Europe and Japan were respectively $12.00 / MMBtu and $18.10 / MMBtu; and $2.75 / MMBtu in the US. While the increase in proven reserves of natural gas has driven the US prices down, this has not affected the other prices in the world because of the regionalized nature of gas markets. Therefore the price gap between regions gives a clear advantage to the US industry. In 2012, Goldman Sachs estimated that the price gap between the United States and the United Kingdom would lead natural gas producers to potential arbitrage opportunities of 1.2% of GDP per year.

2.3 The Rebirth of the US manufacturing sector

The unexpected expansion of the domestic energy supply gives an important economic advantage to US industry, which is leading some economists to talk about the US Manufacturing Renaissance. Employment in the oil and gas industry increased by 50,000 jobs in 2012, although it was a small part compared to the 2.2 million of new jobs created if direct and indirect effects were entered into the accounts[9]. In early 2011, the Boston Consulting Group (BCG) predicted that within five years, the United States would experience a rebirth of the manufacturing sector as companies relocated their manufacturing operations in North America. The report concludes that the benefits of production cost of goods manufactured abroad have dramatically fallen over the last decade. In 2003, manufacturing costs were 18% lower in China than in the US. In 2011, the difference was only of 7%. Natixis, a French corporate and investment bank, has confirmed that the competitive advantages granted to the US industrial manufacturers through lower gas prices are equivalent to a 17% reduction in wage levels compared to firms belonging to the Euro area[10]. Players of the manufacturing industry congratulated themselves for the supply surplus, as it reduces their production costs, thus improving their competitiveness. Cheaper energy also has the potential to create significant employment growth in both primary industries and secondary industries. Other actors have seen the development of natural gas as an opportunity to use less coal in electricity production and reduce dependence on oil through liquefaction of the gas in the transport sector. Gas producers, meanwhile, saw a great opportunity of benefit by exporting natural gas as LNG.

3 Data and Empirical Specification

3.1 Economic intuition and variable of interest

In order to capture the effect of the exploitation of unconventional gas on various US economic variables, we use natural gas prices, and more specifically, the difference or the ratio of natural gas prices in the US and Europe. The use of gas prices to figure out the effect of shale gas is justified by the positive supply shock happened in 2006 on the US gas market due to the massive exploitation of shale gas. Therefore, prices have been pulled down from 2006. The construction of the variable measuring natural gas prices of the United States compared to the European prices will capture the comparative advantage conferred to the US manufacturing. The German border price of natural gas in Europe is used as a proxy for average world prices. We made this choice for two main reasons. First, knowing that Europe and Asia are the major trade competitor of the US manufacturing industries, and since natural gas price gap between US and Asia is larger than between US and Europe, we only consider the European price in order to compute the lower bound of the comparative advantage provided to the US industries. Second, Russia and Norway are the two main suppliers [11] of natural gas imported by Europe. They have a similar indexation with pegging

generally seen to be the primary price set for the North American natural gas market. North American unregulated wellhead and burnertip natural gas prices are closely correlated to those set at Henry Hub.

[9]Kent Wosepka, Stephen Levine and Huan Zhen, "The U.S. Energy Revolution : How Shale Energy Could Ignite the U.S. Growth Engine," Asset Management Perspectives, Goldman Sachs, September 2012.

[10]Nicholas Bray, Karel Cool, and Quentin Philippe, "Shale Gas : Hype or Hope ?" INSEAD Knowledge, May 7, 2013.

[11] They represent respectively 40% and 35% of imports in 2015. Source BP Statistical Review 2015

of over 80% to fuel oil products[12]. Consequently, gas purchased from these countries display similar price levels. Indeed, given the fact that much of the Europe's current supply of gas come from these two countries, it is natural to use the eastern German border price [13]. In addition, by using co-integration analysis of import prices, Asche, Osmunden & Tverteras (2001, 2002, cited by Robinson, 2006) found that Belgium, German and French market are integrated. Multiplying this ratio of prices by the energy intensity of each sector will allow the construction of a new proxy which is more interesting because it distinguishes the advantage of the various sectors depending on their energy intensities. Indeed, it provides a double benefit. The first one is to obtain a measure of sectoral comparative advantages. The second aspect concerns the econometric; it creates more variability in the data, which improves the efficiency of the used estimators.

3.2 Data description

Our study aims to identify the response of the US manufacturing sector to the massive shale gas development. The responses will vary with energy intensity of each sector. To conduct our empirical study that takes advantage from variations in energy intensities by industry, we need to implement a variable that measures this intensity. There are at least four measures[14] of energy consumption allowing computation of the energy intensity for each manufacturing sector; amoung them the Manufacturing Energy Consumption Survey (MECS) conducted every four years by the US Administration for Energy Information (EIA). The MECS last survey was done in 2010 with preliminary results published in March 2012. MECS is a national sample survey that collects information on the stock of U.S. manufacturing establishments, their energy-related building characteristics, and their energy consumption and expenditures. The 2006 MECS sample size of approximately 15,500 plants was drawn from a nationally representative sample frame representing 97-98% of the manufacturing payroll. The MECS measures energy consumed as fuel (such as for heating and lighting), and the energy consumed as a feedstock (such as naphtha used in the production of ethylene). Based only on energy consumption as fuel, MECS provides several measures of energy intensity for the different sectors. Amoung them, total fuel consumption in thousands of British thermal units (Btu) per dollar of value added and shipments. These two measures exclude the energy used as feedstock. However, a firm will take advantage from lowered energy prices whether it is used as fuel or feedstock. So, we need measures of energy intensities that reflect energy use as fuel or feedstock. Thus, we calculate similar measures of energy intensity related to the total energy consumption and total consumption of natural gas in two stages[15]. We obtain four measures of energy intensity by sector: a measure of energy intensity of natural gas and of total energy per dollar of value added and per dollar of shipments. Having two measures of calculation (natural gas and total energy) allows to take into account that the intensive energy industries (oil, gas, coal) can substitute other energy sources to natural gas. The four measures are presented in Tables 5 and in the appendix.

In the rest of the study, we focus on the measures in thousands Btu of total energy consumption and natural gas per dollar of added value and per dollar of shipment, from the survey MECS 2006. First, this choice is justified by the coincidence of the realization of the survey with the boom in the production of shale gas in the US. Accordingly, these measures provide a better indication about which companies should more take advantage from lower gas prices, since they provide information on the levels of gas and the total energy consumption closer to the date of the positive supply shock in the US gas market.

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[12] According to the Energy Sector Inquiry

[13] The interest here using the spot price of Henry Hub would be limited due to the low representation and use of this gas in continental Europe especially as the UK became a net gas importer since 2005.

[14] Annual Survey of Manufactures (ASM), Bureau of Economic Analysis (BEA) using its KLEM (Capital, Labor, Energy, Materials) dataset and BEA's Input/Output data.

[15] The first stage aims to reconstruct measures of added value and shipments for each industry covered by the MECS, from the intensity and level data based on consumption as fuel. The second stage consists on dividing the total energy consumption and the total consumption of natural gas (Btu), including fuel and feedstock, by the added value and the shipments constructed in the first step.

Matching between measures of energy intensity and different economic variables for each industry was achieved on the basis of the North American Industry Classification System (NAICS). However, the industrial sector in 2006 MECS database does not necessarily have an exact match for each economic variable. Each organization involved in the production of these economic variables can cover a different set of manufacturing industries in addition of implementing the NAICS slightly differently. These variables are derived from different sources, the Table 6 in the appendix gives sources and units and shows the number of sectors that are matched with the MECS2006 database. Finally we managed to establish 79 concordances for the total energy intensity and 78 for natural gas intensity between MECS 2006 database and other agencies that provide economic variables for each sector.

We consider five economic variables for each industrial sector: industrial production, employment, capital expenditure, exports and imports. Variables are indicated for the period 1997-2013 except for capital expenditures that are only available until 2011, and employment until 2012. All these variables are in volume (exports, imports, industrial production) and transformed into logarithm in order to interprets the results in terms of elasticity. Our database also includes natural gas spot prices. We have henry hub prices in the United States, and eastern German border price in Europe, both taken from International Monetary Found (IMF). We obtain a balanced panel of 79 industrial sectors identified by NAICS codes ranging from 3 to 6 digit for the period 1997-2013. The number of observations varies with economic variables since they are not all available during the whole period. However, it is superior to 1000 for all economic variables, allowing us to obtain results from the asymptotic properties of estimators that are used.

3.3 Methodology

3.3.1 Econometric modeling and estimation method

The econometric model to estimate is the following;

$$ln(Z_{i,t}) = \beta_0 + \gamma\, ln(Z_{i,t-1}) + \beta_1[ln(\frac{GN_t^{USA}}{GN_t^{EUR}}) * Intensit\acute{e}_{2006}] + \beta_2[ln(\frac{GN_{t-1}^{USA}}{GN_{t-1}^{EUR}}) * Intensit\acute{e}_{2006}] + \alpha_i + \nu_t + \epsilon_{i,t}$$

where the variable Z denotes alternatively industrial production, exports, imports, employment and capital expenditure, and GN_t is the price of natural gas at time t.

It is a linear dynamic panel-data model including one lag of the dependent variable as covariates. This modeling allows to take into account the gradual adjustments of the dependent variable. It will further distinguish between the short-term effect and long term effect. For example, the level of industrial production during t will depend on industrial production during *t-1*, on the ratio of gas prices in t and *t-1*, on some observable or not observable variables that are fixed in time and captured by individual fixed effets (α_i), and finally on macroeconomic shocks (impact on GDP, exchange rates, ...) caught by time fixed effects (ν_t). The individual fixed effects allow to capture the impact of specific unobservable and *observable* variables of each sector and constant over time. The combination of individual fixed effects with time fixed effects avoids any endogeneity problem related to omitted variables. Estimation of this model by usual estimators of panel data (OLS, Within, Between) is biased due to the presence of the lagged dependent variable among the regressors. OLS and Between estimators are also biased because of the correlation between the individual effects and some explanatory variables in the model. An alternative solution is to use the Within estimator that can eliminate the fixed effects. This estimator is effective in the linear range of models, that do not incorporate dynamic dimension. However, in the case of dynamic panel as is the case here, the Within estimator is ineffective and biased. The simple illustration of the bias of the Within estimator in dynamic panel is given from the following example. Consider the following simple dynamic model;

$$y_{i,t-1} = \alpha\, y_{i,t-1} + \beta\, x_{i,t} + \eta_i + \varepsilon_{i,t}$$

Applying the Within estimator model eliminates the fixed effects and avoids the problem of endogeneity due to the correlation between individual fixed effects and the explanatory variable x_i. Then we get:

$$y_{i,t} - y_{i,..} = \alpha\,(y_{i,t-1} - y_{i,..-1}) + \beta\,(x_{i,t} - x_{i,..}) + (\eta_i - \eta_i) + (\epsilon_{i,t} - \epsilon_{i,..})$$

with

$$y_{i,..} = \frac{1}{T}\sum_{t=1}^{T} y_{i,t} \qquad x_{i,..} = \frac{1}{T}\sum_{t=1}^{T} x_{i,t} \qquad \epsilon_{i,..} = \frac{1}{T}\sum_{t=1}^{T} \epsilon_{i,t} \quad (i =, \ldots\ldots., n \qquad t = 1, \ldots\ldots.., T)$$

Here in this dynamic panel, another endogeneity problem appears when applying the Within estimator. The error term $\epsilon_{i,..}$ contains the error term $\epsilon_{i,t-1}$, then $E\,(y_{i,t-1}, \epsilon_{i,..}) \gtreqless 0$. We are again faced with the violation of the assumption of exogeneity of the explanatory variables. This violation implies that the Within estimator is biased in the framework of a dynamic panel model with a finite time dimension. The bias introduced by the Within estimator is known as Nickell bias[16]. The Within estimations are provided in the Appendix (see table 13), where we highlight the existence of the Nickell bias. This endogeneity problem is solved by using the Arellano-Bond estimator. The fist step in our study is to avoid any problems related to non-stationary time series, for that we take the first difference of variables, despite the fact that theoretically the time dimension of 15 points is not long enough to face the problems of non-stationary variables (Hurlin and Mignon, 2006). The second stage of the Arellano-Bond estimator is to use lags of dependent variables in levels as instruments to solve the problem of endogeneity due to the presence of the differenciated dependent variable as covariates. In order to determine the appropriate lags of dependent variable for use as instruments, we have to control for the order of autocorrelation in the first-differenced errors, AR(1). If the first-differenced errors is not serially correlated at order 2, then we can take instruments in level from the lag $y_{i,t-2}$, otherwise, instrumentation begins at higher lags ($y_{i,t-3}$ or $y_{i,t-4}$ depending on the order of autocorrelation of error term in level).

This estimator is criticized for weak instruments induced by the use of instrument in level for variables in first difference. The validity of the instruments can usually be tested through the Sargan test assuming homoscedasticity disturbances. It is the most appropriate test. But, in our estimates, we corrected the residuals variance-covariance matrix to account for heteroscedasticity, and once applying the correction, Sargan test statistic cannot be calculated. Finally, we cannot use it to test the validity of our instruments. We use thus an alternative method consisting in the computation of correlations between the instruments and instrumented variables (see table 7). The number of instruments in level ranges from 3 to 6 according to the estimated model. We restricted this number, because with 15 time points, this is necessary to avoid the problem of weak instruments. The total number of instruments is given in the results tables in the Appendix (tables 8, 9, 10, 11 and 12).

Following the positive supply shock on the US gas market, we suspect that the relationship between some variables and gas prices undergoes a structural change, meaning that the nature of the link between the channel of natural gas prices and the rest of the variables has changed since 2006. In order to control for structural breaks, we perform Chow type tests to assess the evidence of breaks in the estimated functions. The results are given in the results tables in the Appendix (tables 11 and 12)

[16] Nickell S. (1981), "Biases in Dynamic Models with Fixed Effects", Econometrica, 49, 1399-1416

3.3.2 Short-run elasticities

The database accounts for 79 industrial sectors. The estimation of the different parameters of the various models gives us two parameters β_1 and β_2 that are the same for all sectors for each dependant variable PI . Using β_1 (or$\beta_2$whenβ_1 is not significantly different from zero), we compute the short-term elasticity of each of the dependent variables for each sector with respect to the ratio of gas prices.

$$ln(PI_{i,t}) = \beta_0 + \gamma\, ln(PI_{i,t-1}) + \beta_1[ln(\frac{GN_t^{USA}}{GN_t^{EUR}}) * Intensity_{2006}] + \beta_2[ln(\frac{GN_{t-1}^{USA}}{GN_{t-1}^{EUR}}) * Intensity_{2006}] + \alpha_i + \nu_t + \epsilon_{i,t}$$

For example, the short-run elasticity of industrial production with respect to gas price ratio when we use gas intensive measure is $\hat{\beta}_2 * Intensité_{2006}$. Finally, we get as many different short run elasticies as many sectors.

3.3.3 Long-run elasticities

The computation of long-run elasticities of the different dependent variables with respect to gas price ratio assumes that the variables of the different models are stationary. The Arellano-Bond estimator has the advantage to estimate the model in first differences. Those variables in first differences are stationary.

For example, the long-run elasticity of industrial production with respect to gas price ratio is $\frac{\hat{\beta}_1+\hat{\beta}_2}{1-\hat{\gamma}} * Intensity_{2006}$.

Here becomes clear the advantage of taking into account the energy intensities for different sectors, because the elasticities differ with intensity.

3.3.4 Long-term elasticity for the manufacturing sector as a whole

The computation of the total elasticity of the manufacturing sector is done by weighting the different sectoral elasticities by the weight of each manufacturing sector in the economy (measured by the ratio of its value added to the total value added of all sectors):

$Overall\_Elasticity = \sum_{i=1}^{79} Long\_term\_Elasticity_i * Sector\_share_i$

These elasticities are available in the results tables (8, 9, 10, 11 and 12).

4 Regression results

Gas intensive measure

This section focuses on presentation and interpretations of the results: table 14 in the Appendix present the long-run elasticities of all the variables of U.S manufacturing sectors with respect to the natural gas price ratio of US and Europe. They are statistically significant at the 5% level and consistent with the expected signs. Indeed, industrial production, employment, capital spending, and exports have increased with the decline in the relative prices of natural gas, while imports have declined. As a result of our estimation strategy, the response to shale gas operations varies greatly between sectors according to their energy intensity. The most energy-intensive industries[17] hold the highest short-term and long-term elasticities in absolute terms for all the variables. The decline in the relative price of natural gas over the period of 2006-2013 by about 65%, is associated with approximatively three-fold and 0,04% increase in capital spending, two-fold and half and 0,03% in industrial production, 60% and 0,01% in exports and rise of 15% and 0,003% of employment for the most gas-intensive[18] and the less gas-intensive[19] industry, respectively. The decline of the natural gas price induced a decrease of the imports by 61% and 0.01%.

Table 1 gives the long term elasticities of the top 20 gas-intensive industries for all the variables[20]. The first

[17] See figure 1 in Appendix
[18] Nitrogenous Fertilizers
[19] Tabacco
[20] See table 14 in Appendix for more details.

Table 1: Long-term elasticity for the 20 most gas-intensive sectors (gas consumption)

Industries	IP	CE	Emp	Exp	Imp
Nitrogenous Fertilizers	-2,1890	-2,5664	-0,221	-0,9140	0,9440
Alkalies and Chlorine	-0,3157	-0,3702	Nd	-0,1318	0,1361
Carbon Black	-0,2309	-0,2708	Nd	-0,0964	0,0996
Flat Glass	-0,2145	-0,2515	-0,0217	-0,0895	0,0925
Glass Containers	-0,1384	-0,1623	-0,0140	-0,0578	0,0597
Ethyl Alcohol	-0,1304	-0,1529	-0,0132	-0,0544	0,0562
Gypsum	-0,1205	-0,1413	-0,0122	-0,0503	0,0519
Other Basic Organic Chemicals	-0,1146	-0,1344	-0,0116	-0,0478	0,0494
Industrial Gases	-0,1122	-0,1316	-0,0113	-0,0468	0,0484
Plastics Materials and Resins	-0,1117	-0,1310	-0,0113	-0,0466	0,0482
Phosphatic Fertilizers	-0,1116	-0,1308	-0,0113	-0,0466	0,0481
Secondary Smelting and Alloying of Aluminum	-0,1006	-0,1180	-0,0101	-0,0420	0,0434
Wet Corn Milling	-0,0923	-0,1083	-0,0093	-0,0385	0,03984
Iron and Steel Mills	-0,0860	-0,1009	Nd	-0,0359	0,0371
Paperboard Mills	-0,0806	-0,0945	-0,0081	-0,0336	0,0347
Synthetic Rubber	-0,0767	-0,0899	-0,0077	-0,0320	0,0330
Alumina and Aluminum	-0,0758	-0,0888	-0,0076	-0,0316	0,0326
Noncellulosic Organic Fibers	-0,0733	-0,0859	Nd	-0,0306	0,0316
Aluminum Sheet, Plate and Foils	-0,0705	-0,0827	-0,0071	-0,0294	0,0304
Mineral Wool	-0,0635	-0,0745	-0,0064	-0,0265	0,0274
Glass Products from Purchased Glass	-	-	-0,0057	-	-
Pulp Mills	-	-	-0,0054	-	-
Nonmetallic Mineral Products	-	-	-0,0053	-	-
Primary Metals	-	-	-0,0053	-	-
Average elasticity of the twenty most gas-intensive sectors	**-0,2254**	**-0,2643**	**-0,0203**	**-0,0941**	**0,0972**
Average elasticity of the twenty less gas-intensive sectors	-0,0037	-0,0041	-0,0006	-0,001	0,0016

Nd: Notdocumented

observation that can be made is about the high elasticity of the nitrogenous fertilizers due to its outsized energy intensity, which itself is linked to outsize use of methane from natural gas to produce amonia. In order to check that our results are not mainly driven by this industry, we compute the response of the variables on a sample that does not include it. The results still hold without this industry, so we can say that they are not driven by one potential outlier[21]. The second observation concerns the asymetric response of the variables to the price decline. In fact, these variables split in two groups: in one group we have capital expenditure and industrial production which react relatively more to the price decline than the second one consisting on export, import and employment. Finally, shale gas boom has a larger effect on the domestic market than on the international market. If we take a closer look to the results, we see that average long term elasticities for the top 20 gas-intensive for industrial production (-0,2254) and capital expenditure (-0,2643) are higher than for export (-0,0941) and imports (0,0972). In addition, elasticities of investment (-0,2643) are significantly higher than those of employment (-0,0203). This difference may be related to the domination of industries which are capital intensive. The manufacturing sector is composed of heavy industries like chemicals and plastics industries, steel production, oil refining and many others, requiring large investment in order to enter the market. This could explain the weak impact of a lower gas prices on employment.

Table 2 shows overall long-term elasticities and percentage of variation over the period 2006-2013 using gas intensive measures. The results appear to be robust to the two different measures of gas consumption as there is not much variation in the response between the two measures. Despite the fact that the response of energy intensive

[21] Results are available upon request.

Table 2: Elasticities and variation throught 2006-2013 periode

Variables	IP		CE		Emp		Exp		Imp	
Measures	NGVA	NGSH	NGVA	NGSH	NGVA	NGSH	NGVA	NGSH	NGVA	NGSH
overall elasticity	-0.025	-0.033	-0.029	-0.045	-0.0024	-0.0038	-0.01	-0.013	0.01	0.017
%_variation_06_2013	1.65	2.15	2	3	0.15	0.25	0.68	0.86	-0.71	-1.11

industries are very large (see Table 1), the overall effect is quite modest (see Table 2). We obtain an elasticity of -0.025 for industrial production, -0.03 for capital expenditure, -0,01 for exports, -0,0024 for employment and 0,01 for imports[22]. This weak global effect of shale exploitation on the manufacturing sector as a whole is explained by the small share[23] of the top 20 gas intensive industries in the total value added of the manufacturing sector.

We compute the total impact of a decline in the relative price of natural gas over the period of 2006-2013 taking into account the share of the value added and shipment of each sector in the economy. Results show an increase of 2% for IP, 2.5% for CE, 0,20% for Emp, 0,75% for exports and a decrease of 0,90% for imports over the period (see table 2). It should be noted, however, that these responses using gas intensive measure do not take into account a possible substitution from coal and oil to gas that may occur due to the lower price of gas. Finally, these results give us the minimal impact of shale gas operation on US manufacturing sector.

Total energy intensity measure

Table 3 gives the long term elasticities of the top 20 energy-intensive industries for all the variables which allow to take into account the differentiated impact of substitution possibilities among sectors, according to their energy use as energy sources or as feedstock. Despite the fact that elasticities are also robust, consistent, and of the expected signs, the new top 20 energy intensive industries show some differences relative to the top 20 gas intensive industries. First, the use of total energy consumption as measure changes the rank order in the top 20. Some industries which are oil or coal intensive enter into the top 20 because they use a large amount of energy source other than gas. Second, the value-added share of the top 20 rose from 5% to 13% due to the fact that these new sectors carry a larger weight in the manufacturing sector. A significant increase of 8 points compared to top 20 intensive-gas sectors. Third, total energy consumption as measure allows to compute the maximum impact that may result from exploitation of shale gas assuming that gas prices remain at a low level. Low gas prices are a signal for industries that are consuming oil and coal to substitute them by natural gas in the long-term.

Table 4 presents the results for overall long-term elasticities and percentage of variation over the period 2006-2013. The overall impact is greater for all the variables when we assume that oil and coal consuming industries became exclusively gas consuming industries. This overall effect may be characterized as maximal effect that may occur if the substitution process is achieved totally by all industries.

Overall effect

In the presence of 79 industrial sectors, a measure of the overall impact on all manufacturing sectors is useful. We compute the aggregate effect as a weighted average of the effects of each sector, based on the share of each sector in total value added of all manufacturing sectors in 2011. The results show that the total effect on the manufacturing sectors as whole when we use the gas intensive measure is relatively low (see Table 2). Indeed, over the period 2006-2013, capital expenditure increased by 2,5%, industrial production increased by 2%, employment and exports show increase below 1%. Imports fell by about 1%. The impact of shale gas is weak on the manufacturing sector as

[22]See tables 9,10,11, 12, 13 in the appendix for more details
[23]Figure 2 in Appendix

Table 3: Long-term elasticity for the 20 most gas-intensive sectors (total energy consumption)

Industries	IP	CE	Emp	Exp	Imp
Type of energy	TEVA	TEVA	TEVA	TEVA	TEVA
Nitrogenous Fertilizers	-1,5358	-1,7285	-0,2146	-0,847374201	0,621404648
Other Petroleum and Coal Products	-0,7870	-0,8858	-0,1100	Nd	Nd
Carbon Black	-0,7034	-0,7916	Nd	-0,3880	0,2846
Lime	-0,5963	-0,6711	-0,0833	-0,3290	0,2412
Pulp Mills	-0,5620	-0,6326	-0,0785	-0,3101	0,2274
Plastics Materials and Resins	-0,3421	-0,3850	-0,04782	-0,1887	0,1384
Paperboard Mills	-0,3197	-0,3598	-0,0446	-0,1764	0,1293
Alkalies and Chlorine	-0,30735	-0,3459	Nd	-0,1695	0,1243
Petroleum Refineries	-0,2975	-0,3349	-0,0415	-0,1641	0,1203
Petroleum and Coal Products	-0,2709	-0,3049	-0,0378	-0,1495	0,1096
Cements	-0,2606	-0,2933	-0,0364	-0,1438	0,1054
Electrometallurgical Ferroalloy Products	-0,2319	-0,2610	Nd	-0,1279	0,0938
Wet Corn Milling	-0,2164	-0,2436	-0,0302	-0,1194	0,0875
Other Basic Organic Chemicals	-0,2083	-0,2345	-0,0291	-0,1149	0,0843
Other Pressed and Blown Glass and Glassware	-0,2025	-0,2280	-0,0283	-0,1117	0,0819
Newsprint Mills	-0,2025	-0,2280	-0,0283	-0,1117	0,0819
Petrochemicals	-0,1966	-0,2213	-0,0274	-0,1084	0,0795
Flat Glass	-0,1937	-0,2180	-0,0270	-0,1069	0,0783
Paper Mills, except Newsprint	-0,1752	-0,1972	-0,0244	-0,0967	0,0709
Iron and Steel Mills	-0,1697	-0,1910	Nd	-0,0936	0,0686
Industrial Gases	-	-	-0,0234	-0,0925	0,0678
Sugar Manufacturing	-	-	-0,0217	-	-
Paper	-	-	-0,0200	-	-
Alumina and AluminumNotdocumented	-	-	-0,0177	-	-
Average elasticity of the twenty most gas-intensive sectors	**-0,39**	**-0,43**	**-0,05**	**-0,2**	**0,14**
Average elasticity of the twenty less gas-intensive sectors	-0,009	-0,0068	-0,00084	-0,0036	0,062

Nd: Notdocumented

TABLE 4 : Elasticities and variation throught 2006-2013 periode

Variables	IP		CE		Emp		Exp		Imp	
Measures	TEVA	TESH	TEVA	TESH	TEVA	TESH	TEVA	TESH	TEVA	TESH
overall elasticity	NS	-0,09	-0,068	-0,084	-0,008	-0,009	-0,033	-0,062	0,024	NS
%_variation_06_2013	NS	8,8	4.41	5.46	0.52	0.60	2.14	4.05	-1.57	NS

NS: Non-significatif. Meaning that when we estimate with this measure, the coefficient was no significant.

whole. This weakness is due to the small share represented by the most energy-intensive industries in the total value added of manufacturing sectors. Let us now focus on the comparison between the most and the least 20 energy-intensive industries. The first group of industries accounts for 5% of the total value added of manufacturing sectors, while the second group represents 45% of it. As the manufacturing sector is dominated by low-intensive industries in energy, it reacts weakly to the shale gas boom. From these results, it appears that claiming a renaissance of American manufacturing sector following to massive shale gas exploitation would be prematured even with the results obtained with the total energy measures. However, the revival of some of the most intensive industries in natural gas is an undeniable fact.

Moreover, these estimates seem broadly consistent with earlier studies. Celasun et al (2014) find that a halving of relative natural gas prices leads to a 1.5 percent increase in industrial production, while the results of Morse et al (2012) are consistent with a 1.6 percent increase in manufacturing output. The two only anomalies appear to be the outsized export gains and the no impact on import reported by Arezki et Fetzer. Their 6 percent increase in manufacturing export is quite a bit larger than the roughly 0,80 percent increases found in this study. Also they find no impact on import, while we find an impact of roughly 1 percent. These differences could be a result of no taking into account the potential occurence of a structural break in their estimation. In our study, we have checked for structural break for the five measures of activity. We find that a structural break occurs for export and import variables (see tables 11 and 12 in the Appendix), meaning that the nature of the relationship between export, imports, and natural gas prices over the period 1997-2005 can be different from the period 2006-2013 following the positive supply shock in the U.S gas market. We can clearly point out that the nature of the relationship has changed between the two periods, because the estimated parameter is significantly different between the two periods for export and import. The break point happens in 2006, which coincide with the boom of shale gas on the U.S market. Since there is a structural break, econometric-model of Arezki and Fetzer (2015) did not capture the impact of shale gas on imports, and overestimates the impact on exports.

5 Conclusion

This study measures the impact of shale gas on the US manufacturing sector through different economic variables related to this sector. The economic benefit from the exploitation of shale gas is assumed to be captured by the impact of the relative fall in the price of natural gas in the United States compared to the price of gas in Europe. The effect of this decline on industrial production, exports, capital investment, employment and imports is measured through calculations of elasticities according to their energy intensities for different industrial sectors. This paper distinguishes between short-run elasticities and those of long-term. The results show that the impact of the positive supply shock of natural gas following to the massive exploitation of shale gas on the manufacturing sector as a whole is relatively low considering or not the substitution effect. However, even if this impact is very significant for the most energy-intensive manufacturing industries, they have a small share in the total value added of the manufacturing sector. The revival of some of the most intensive industries in natural gas is an undeniable fact, however claiming a renaissance of American manufacturing sector would be prematured.

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Table 5 : Energy intensity of 2006 (Thousand BTUs per $ of Value Added and Shipments)

NAICS Code	Industries	Natural gas	Total energy	Natural gas	Total energy
		per $ of Value Added		per $ of Shipments	
325311	Nitrogenous Fertilizers	300.096	309.31	87.44	90.12
325181	Alkalies and Chlorine	43.28	61.9	22.37	32
325182	Carbon Black	31.66	141.66	12.79	57.23
327211	Flat Glass	29.40	39.02	15.94	21.15
327213	Glass Containers	18.98	24.3	11.01	14.10
325193	Ethyl Alcohol	17.88	24.56	10.26	14.09
32742	Gypsum	16.52	18.7	9.72	11
325199	Other Basic Organic Chemicals	15.72	41.96	5.29	14.14
32512	Industrial Gases	15.39	33.76	8.48	18.60
325211	Plastics Materials and Resins	15.32	68.90	4.67	21.03
325312	Phosphatic Fertilizers	15.3	21.74	3.7	5.25
331314	Secondary Smelting and Alloying of Aluminum	13.8	16.1	2.31	2.7
311221	Wet Corn Milling	12.66	43.6	5.28	18.2
331111	Iron and Steel Mills	11.79	34.18	4.44	12.87
32213	Paperboard Mills	11.05	64.4	5.541	32.3
325212	Synthetic Rubber	10.51	17.8	3.545	6
3313	Alumina and Aluminum	10.39	25.52	2.83	6.97
325222	Noncellulosic Organic Fibers	10.05	21.57	3.9	8.37
331315	Aluminum Sheet, Plate and Foils	9.67	13.6	2.34	3.3
327993	Mineral Wool	8.71	12.7	5.49	8
327215	Glass Products from Purchased Glass	7.84	9.8	4.08	5.1
32211	Pulp Mills	7.358	113.2	3.24	49.9
327	Nonmetallic Mineral Products	7.28	17.64	4.03	9.77
331	Primary Metals	7.19	19.90	2.69	7.46
32411	Petroleum Refineries	7.13	59.92	1.53	12.92
31131	Sugar Manufacturing	6.87	31.3	2.67	12.2
324	Petroleum and Coal Products	6.75	54.57	1.525	12.32
331521	Aluminum Die-Casting Foundries	6.68	9.8	3.34	4.9
3112	Grain and Oilseed Milling	6.62	17.55	2.15	5.71
322121	Paper Mills, except Newsprint	6.54	35.3	3.63	19.6
331524	Aluminum Foundries, except Die-Casting	6.50	8.36	3.37	4.34
331316	Aluminum Extruded Products	5.84	8.6	1.7	2.5
322	Paper	5.81	28.9	2.75	13.7
325188	Other Basic Inorganic Chemicals	5.68	19.02	3.21	10.75
32741	Lime	5.17	120.1	3.26	75.8
325	Chemicals	5.16	15.22	2.77	8.17
3212	Veneer, Plywood, and Engineered Woods	4.68	17.6	1.81	6.8
322122	Newsprint Mills	4.53	40.8	2.32	20.9
32511	Petrochemicals	4.33	39.60	1.80	16.47

Following Table 5:

NAICS Code	Industries	Natural gas	Total energy	Natural gas	Total energy
		per $ of Value Added		per $ of Shipments	
3114	Fruit and Vegetable Preserving and Specialty Foods	4.10	5.5	2.08	2.8
325192	Cyclic Crudes and Intermediates	3.80	8.8	2.20	5.1
3315	Foundries	3.69	8.30	2.07	4.67
331511	Iron Foundries	3.6	12.6	1.86	6.51
324199	Other Petroleum and Coal Products	3.44	158.50	1.14	52.70
313	Textile Mills	3.14	8.6	1.49	4.1
3312	Steel Products from Purchased Steel	3.023	6.51	1.14	2.47
3115	Dairy Products	2.94	4.3	0.89	1.3
314	Textile Product Mills	2.93	4.6	1.15	1.8
3116	Animal Slaughtering and Processing	2.81	4.38	1.02	1.59
32731	Cements	2.74	52.5	1.78	34
3314	Nonferrous Metals, except Aluminum	2.69	9.20	0.84	2.88
311	Food	2.68	5	1.18	2.2
331112	Electrometallurgical Ferroalloy Products	2.12	46.71	1.02	22.64
321	Wood Products	2.03	10.54	0.782	4.05
332	Fabricated Metal Products	1.57	2.59	0.78	1.29
326	Plastics and Rubber Products	1.40	3.71	0.64	1.70
321113	Sawmills	1.31	15.20	0.43	5.03
3219	Other Wood Products	1.21	5.68	0.54	2.53
325992	Photographic Film, Paper, Plate, and Chemicals	.95	3.8	.6	2.4
3121	Beverages	0.94	2.35	0.43	1.07
336	Transportation Equipment	0.88	1.69	0.311	0.59
335	Electrical Equip., Appliances, and Components	0.86	2.13	0.38	0.94
336111	Automobiles	0.80	1.5	0.21	0.4
336112	Light Trucks and Utility Vehicles	0.75	1.3	0.17	0.3
323	Printing and Related Support	0.68	1.5	0.45	1
312	Beverage and Tobacco Products	0.52	1.37	0.33	0.88
315	Apparel	0.5	1	0.25	0.5
333	Machinery	0.49	1.2	0.24	0.6
316	Leather and Allied Products	0.36	1.1	0.2	0.6
334413	Semiconductors and Related Devices	0.36	1.21	0.27	0.91
3364	Aerospace Product and Parts	0.35	0.91	0.15	0.40
3254	Pharmaceuticals and Medicines	0.34	0.68	0.26	0.51
337	Furniture and Related Products	0.31	1.11	0.17	0.61
325412	Pharmaceutical Preparation	0.29	0.6	0.24	0.5
336411	Aircraft	0.24	0.6	0.08	0.2
339	Miscellaneous	.22727273	0.6	0.15	0.4
334	Computer and Electronic Products	.22340426	.70496454	0.12	0.40
3122	Tobacco	0.075	0.3	0.075	0.3
327212	Other Pressed and Blown Glass and Glassware		40.80		24.89

Table 6 : Economic variables

Variables	Source	Units	Time Period	Matches for MECS and NGI	Matches for MECS and TEI
Capital expenditure	Census annual survey manufacturers	Millions of $	1997-2011	78	79
Industrial production	Board of Governors of the Federal Reserve System	Index, 2007=100	1997-2013	78	79
Employment	Quarterly Census of Employment and Wages	Thousands	1997-2012	78	79
Imports	U.S. International Trade Commission	Billions of $	1997-2013	75	76
Exports	U.S. International Trade Commission	Billions of $	1997-2013	75	76

NGI : Natural Gas intensity
TEI : Total Energy intensity

Table 7: Correlation between IV and endogenous variable for Arellano-Bond model (Capital expenditure)

Variable	Diff($log\, DCapital_{t-1}$)	Diff($log\, DCapital_{t-2}$)	Diff($log\, DCapital_{t-3}$)	Diff($log\, DCapital_{t-4}$)
$log\, DCapital_{t-2}$	-0.121			
$log\, DCapital_{t-3}$	-0.0681	-0.114		
$log\, DCapital_{t-4}$	-0.0486	-0.0681	-0.092	
$log\, DCapital_{t-5}$	-0.0524	-0.0486	-0.0604	-0.093

Here the correlations are around 0.1. We do not face the problem of weak instruments. The results are similar for the other variables.

Table 8 : Estimation results for capital expenditure

Estimation method	GMM-IV (Arellano-Bond)			
Energy Intensity measure	Natural gas per $ of Value added	Natural gas per $ of Shipments	Total energy per $ of Value added	Total energy per $ of Shipments
$Dépense\_C_{i,t-1}$	0.480***	0.474***	0.463***	0.461***
	(4.31)	(4.22)	(3.72)	(3.62)
$(GN^{USA}/GN^{EUR})_t$	-0.0044***	-0.0159***	-0.0029***	-0.0077**
	(-3.66)	(-6.14)	(-2.92)	(-2.42)
$(GN^{USA}/GN^{EUR})_{t-1}$	0.0017*	0.0074*	0.0009	0.0033
	(1.92)	(1.74)	(1.20)	(1.63)
Cons	7.292***	7.426***	7.646***	7.661***
	(4.57)	(4.66)	(4.27)	(4.17)
Time fixed effects	Yes	Yes	Yes	Yes
Sectors	78		79	
Observations	1014		1027	
Time Périod	1999-2011		1999-2011	
Total elasticity	-0,029	-0,045	-0,068	-0,084
%_variation_Capital_expenditures_06-2013	1,93	2,94	4.41	5.46
Number of instruments	73			

t-stat are in () ; *, ** And *** denote the significance levels of 10%, 5%, 1%

Table 9 : Estimation results for employment

Estimation method	GMM-IV (Arellano-Bond)			
Energy Intensity measure	Natural gas per \$ of Value added	Natural gas per \$ of Shipments	Total energy per \$ of Value added	Total energy per \$ of Shipments
$Emplois_{i,t-1}$	0.709***	0.707***	0.687***	0.685***
	(11.01)	(11.21)	(10.58)	(10.90)
$(GN^{USA}/GN^{EUR})_t$	-0.00005	-0.00023	-0.00017	-0.00050
	(-1.00)	(-0.85)	(-1.44)	(-1.62)
$(GN^{USA}/GN^{EUR})_{t-1}$	-0.00021**	-0.00080**	-0.00021**	-0.00051*
	(-2.44)	(-2.31)	(-2.49)	(-1.73)
Cons	3.203***	7.426***	3.470***	3.501***
	(4.48)	(4.66)	(4.79)	(5.00)
Time fixed effects	Yes	Yes	Yes	Yes
Sectors	78		79	
Observations	1074		1088	
Time Période	1999-2012		1999-2012	
Total elasticity	-0,0024	-0,0038	-0,0080	-0,0090
%_variation_employment_06-2013	0.15	0.25	0.52	0.60
Number of instruments	79			

t-stat are in () ; *, ** And *** denote the significance levels of 10%, 5%, 1%

Table 10 : Estimation results for industrial production

Estimation method	GMM-IV (Arellano-Bond)			
Energy Intensity measure	Natural gas per $ of Value added	Natural gas per $ of Shipments	Total energy per $ of Value added	Total energy per $ of Shipments
$Prod\_indus_{i,t-1}$	0.905***	0.903***	0.913***	0.914***
	(69.19)	(37.29)	(68.48)	(68.48)
$(GN^{USA}/GN^{EUR})_t$	-0.0005*	-0.00091	-0.0004*	-0.0014**
	(-1.81)	(-0.91)	(-1.70)	(-1.97)
$(GN^{USA}/GN^{EUR})_{t-1}$	-0.0006**	-0.0017**	-0.00034	-0.00063
	(-1.97)	(-2.11)	(-1.40)	(-0.97)
Cons	0.454***	0.5025***	0.477***	0.498***
	(7.09)	(4.32)	(7.12)	(6.65)
Time fixed effects	Yes	Yes	Yes	Yes
Sectors	78		79	
Observations	1170		1185	
Time Période	1999-2013		1999-2013	
Total elasticity	-0,025	-0,033		-0,136
%_variation_industrial-prod_06-2013	1.65	2.15		8.8
Number of instruments	60			

t-stat are in () ; *, ** And *** denote the significance levels of 10%, 5%, 1%

Table 11 : Estimation results for exports

Estimation method	GMM-IV (Arellano-Bond)			
Energy Intensity measure	Natural gas per $ of Value added	Natural gas per $ of Shipments	Total energy per $ of Value added	Total energy per $ of Shipments
$Exp_{i,t-1}$	0.673***	0.682***	0.686***	0.751***
	(7.74)	(7.95)	(7.47)	(9.98)
$(GN^{USA}/GN^{EUR})_{t,97-05}$	0.00037	0.00106	0.00064**	0.00205*
	(1.14)	(0.91)	(1.97)	(1.96)
$(GN^{USA}/GN^{EUR})_{t,06-2013}$	0.00033	0.00084	0.00074	0.00232*
	(0.92)	(0.66)	(1.83)	(1.91)
$(GN^{USA}/GN^{EUR})_{t-1,97-05}$	-0.00050***	-0.00145	-0.00064**	-0.00216**
	(-2.60)	(-1.30)	(-2.36)	(-2.19)
$(GN^{USA}/GN^{EUR})_{t-1,06-2013}$	-0.00099***	-0.00285*	-0.00092**	-0.00268**
	(-3.25)	(-1.71)	(-2.44)	(-2.12)
Cons	7.372***	7.1734***	6.976***	5.597***
	(3.80)	(3.75)	(3.50)	(3.37)
Structural break	Yes	Yes	No	No
Time fixed effects	Yes	Yes	Yes	Yes
Sectors	75		76	
Observations	1125		1140	
Time période	1999-2013		1999-2013	
Total elasticity	-0,010	-0,013	-0,033	-0,062
%_variation_Exp_06-2013	0.68	0.86	2.14	4.05
Number of instruments	85			
Equality test of the coefficients	*Reject* H_0	*Reject* H_0	*No Reject* H_0	*No Reject* H_0

t-stat are in () ; *, ** And *** denote the significance levels of 10%, 5%, 1%

Here we test the hypothesis of equality of the parameters for the period 1997-2005 and 2006-2013. The rejection of H0 means that the parameters are different on the two periods. It proves the existence of a structural break.

Table 12 : Estimation results for imports

Estimation method	GMM-IV (Arellano-Bond)			
Energy Intensity measure	Natural gas per $ of Value added	Natural gas per $ of Shipments	Total energy per $ of Value added	Total energy per $ of Shipments
$Emplois_{i,t-1}$	0.517***	0.483***	0.459**	0.416**
	(2.71)	(2.55)	(2.57)	(2.46)
$(GN^{USA}/GN^{EUR})_{t,2005}$	0.00046	-0.00022	0.0004536	0-.00003
	(0.56)	(-0.06)	(0.75)	(-0.02)
$(GN^{USA}/GN^{EUR})_{t,2013}$	0.00055	.0001827	.0005918	0.00035
	(0.71)	(0.05)	(0.98)	(0.21)
$(GN^{USA}/GN^{EUR})_{t-1,2005}$	0.00114***	0.00479**	.0007523**	0.00182
	(2.79)	(2.11)	(1.99)	(1.49)
$(GN^{USA}/GN^{EUR})_{t-1,2013}$	0.00151***	0.00592***	0.00108***	.0025651
	(3.49)	(2.65)	(2.62)	(1.87)
Cons	10.863***	11.604***	12.095***	13.090***
	(2.50)	(2.68)	(2.98)	(3.41)
Structural break	Oui	Oui	Oui	Oui
Time fixed effects	Yes	Yes	Yes	
Sectors	78		79	
Observations	1074		1088	
Time période	1999-2012		1999-2012	
Total elasticity	0,010	0,017	0,024	
%_variation_Imp_06-2013	-0.70	-1.11	-1.57	
Number of instruments	62			
Equality test of the coefficients	*Reject* H_0	*Reject* H_0	*Reject* H_0	

t-stat are in () ; *, ** And *** denote the significance levels of 10%, 5%, 1%

Here we test the hypothesis of equality of the parameters for the period 1997-2005 and 2006-2013. The rejection of H0 means that the parameters are different on the two periods. It proves the existence of a structural break.

Table 13 : Comparison of estimators for exports (Nickell biais)

Estimation method	MCO	Within	Arellano-Bond	Anderson–Hsiao
Energy	Natural gas			
Intensity	per $ of			
measure	Value added			
$Exportation_{i,t-1}$	0.996***	0.889***	0.740 ***	0.714
	(237.75)	(40.00)	(7.96)	(0.82)
$(GN^{USA}/GN^{EUR})_t$	0.0007**	0.0010***	-0.0005	-0.00005
	(5.11)	(5.45)	(-1.46)	(-0.04)
$(GN^{USA}/GN^{EUR})_{t-1}$	-0.00079***	-0.0006426***	-0.0010***	-0.0010
	(-5.55)	(-4.00)	(-3.43)	(-0.80)
Cons	0.121	2.327***	5.894***	0.018
	(1.34)	(4.90)	(2.85)	(0.32)
Time fixed effects	No	Yes		
Sectors	75			
Observations	1200		1125	
Time période	1998-2013		1999-2013	
Number of instruments	0		80	17

t-stat are in () ; *, ** And *** denote the significance levels of 10%, 5%, 1%

Theoretically the estimator of Anderson-Hsiao underestimates the coefficient of the lagged variable and the OLS overestimates it. The Arellano-Bond estimation must be between them. We are in this case, confirming the robustness of our results. The estimator Within meanwhile suffers from a bias known as Nickell biais.

Table 14 : Long-term elasticies (Thousand Btus per $ of Value Added)

Industry	IP	Ca	Emp	Exp	Imp
Nitrogenous Fertilizers	-2,1890	-2,5664	-0,221	-0,9140	0,9440
Alkalies and Chlorine	-0,3157	-0,3702	-	-0,1318	0,1361
Carbon Black	-0,2309	-0,2708	-	-0,0964	0,099
Flat Glass	-0,2145	-0,2515	-0,0217	-0,0895	0,0925
Glass Containers	-0,1384	-0,1623	-0,0140	-0,0578	0,0597
Ethyl Alcohol	-0,1304	-0,1529	-0,0132	-0,0544	0,0562
Gypsum	-0,1205	-0,1413	-0,0122	-0,0503	0,0519
Other Basic Organic Chemicals	-0,1146	-0,1344	-0,0116	-0,0478	0,0494
Industrial Gases	-0,1122	-0,1316	-0,0113	-0,0468	0,0484
Plastics Materials and Resins	-0,1117	-0,1310	-0,0113	-0,0466	0,0482
Phosphatic Fertilizers	-0,1116	-0,1308	-0,0113	-0,0466	0,0481
Secondary Smelting and Alloying of Aluminum	-0,1006	-0,1180	-0,0101	-0,0420	0,0434
Wet Corn Milling	-0,0923	-0,1083	-0,0093	-0,0385	0,0398
Iron and Steel Mills	-0,0860	-0,1009	-	-0,0359	0,0371
Paperboard Mills	-0,0806	-0,0945	-0,0081	-0,0336	0,0347
Synthetic Rubber	-0,0767	-0,0899	-0,0077	-0,0320	0,0330
Alumina and Aluminum	-0,0758	-0,0888	-0,0076	-0,0316	0,0326
Noncellulosic Organic Fibers	-0,0733	-0,0859	-	-0,0306	0,0316
Aluminum Sheet, Plate and Foils	-0,0705	-0,0827	-0,0071	-0,02947	0,0304
Mineral Wool	-0,0635	-0,0745	-0,0064	-0,0265	0,0274
Glass Products from Purchased Glass	-0,0571	-0,0670	-0,0057	-0,0238	0,0246
Pulp Mills	-0,0536	-0,0629	-0,0054	-0,0224	0,0231
Nonmetallic Mineral Products	-0,0531	-0,0623	-0,0053	-0,0221	0,0229
Primary Metals	-0,0524	-0,0614	-0,0053	-0,0219	0,0226
Petroleum Refineries	-0,0520	-0,0610	-0,0052	-0,0217	0,0224
Sugar Manufacturing	-0,0501	-0,0587	-0,0050	-0,0209	0,0216
Petroleum and Coal Products	-0,0492	-0,0577	-0,0049	-0,0205	0,0212
Aluminum Die-Casting Foundries	-0,0487	-0,0571	-	-	-
Grain and Oilseed Milling	-0,0483	-0,0566	-0,0048	-0,0201	0,0208
Paper Mills, except Newsprint	-0,0477	-0,0559	-0,0048	-0,0199	0,0205
Aluminum Foundries, except Die-Casting	-0,0474	-0,0556	-0,0048	-0,0198	0,0204
Aluminum Extruded Products	-0,0426	-0,0500	-	-0,0178	0,0183
Paper	-0,0424	-0,0497	-0,0043	-0,0177	0,0183
Other Basic Inorganic Chemicals	-0,0414	-0,0486	-	-0,0173	0,0178
Lime	-0,0377	-0,0442	-0,0038	-0,0157	0,01628
Chemicals	-0,0376	-0,0441	-0,0038	-0,0157	0,0162
Veneer, Plywood, and Engineered Woods	-0,0341	-0,0400	-0,0034	-0,0142	0,0147
Newsprint Mills	-0,0330	-0,0387	-0,0033	-0,0138	0,0142
Petrochemicals	-0,0315	-0,0370	-0,0032	-0,0131	0,0136
Fruit and Vegetable Preserving and Specialty Foods	-0,0299	-0,0350	-0,0030	-0,0124	0,0129
Foundries	-0,0269	-0,0316	-0,0027	-0,0112	0,0116

Following table 14 :

Industry	IP	Ca	Emp	Exp	Imp
Iron Foundries	-0,0262	-0,0307	-0,0026	-0,010964791	0,011325377
Other Petroleum and Coal Products	-0,0251	-0,0294	-0,0025	-	-
Textile Mills	-0,0229	-0,0268	-0,0023	-0,0095	0,0098
Steel Products from Purchased Steel	-0,0220	-0,0258	-0,0022	-0,0092	0,0095
Dairy Products	-0,0215	-0,0252	-0,0021	-0,0089	0,0092
Textile Product Mills	-0,0214	-0,0251	-0,0021	-0,0089	0,0092
Animal Slaughtering and Processing	-0,0205	-0,0240	-0,0020	-0,0085	0,0088
Cements	-0,0200	-0,0235	-0,0020	-0,0083	0,0086
Nonferrous Metals, except Aluminum	-0,0196	-0,0230	-0,0019	-0,0082	0,0084
Food	-0,0196	-0,0230	-0,0019	-0,0081	0,0084
Electrometallurgical Ferroalloy Products	-0,0154	-0,0181	-	-0,0064	0,0066
Wood Products	-0,0148	-0,0173	-0,0015	-0,0061	0,0063
Fabricated Metal Products	-0,0114	-0,0134	-0,0011	-0,0047	0,0049
Plastics and Rubber Products	-0,0102	-0,0120	-0,0010	-0,0042	0,0044
Sawmills	-0,0095	-0,0112	-0,0009	-0,0039	0,00413
Other Wood Products	-0,0088	-0,0103	-0,0008	-0,0037	0,0038
Photographic Film, Paper, Plate, and Chemicals	-0,0069	-0,0081	-0,0007	-0,0028	0,0029
Beverages	-0,0068	-0,0080	-0,0006	-0,00286	0,0029
Transportation Equipment	-0,0064	-0,0075	-0,0006	-0,0026	0,0027
Electrical Equipement, Appliances, and Components	-0,0063	-0,0074	-0,0006	-0,0026	0,0027
Automobiles	-0,0058	-0,0069	-0,0005	-0,0024	0,0025
Light Trucks and Utility Vehicles	-0,0055	-0,0064	-0,0005	-	-
Printing and Related Support	-0,0050	-0,0058	-0,0005	-0,0020	0,0021
Beverage and Tobacco Products	-0,0038	-0,0045	-0,0003	-0,0016	0,0016
Apparel	-0,0036	-0,0042	-0,0003	-0,00152	0,00157
Machinery	-0,0036	-0,0042	-0,0003	-0,0015	0,00155
Leather and Allied Products	-0,0026	-0,0031	-0,00025	-0,0011	0,00115
Semiconductors and Related Devices	-0,0026	-0,0030	-0,00024	-0,0011	0,0011
Aerospace Product and Parts	-0,0025	-0,0029	-0,00024	-0,00106	0,0011
Pharmaceuticals and Medicines	-0,0025	-0,0029	-0,00023	-0,0010	0,0010
Furniture and Related Products	-0,0022	-0,0026	-0,00022	-0,0009	0,0009
Pharmaceutical Preparation	-0,0021	-0,0024	-0,00021	-0,0008	0,0009
Aircraft	-0,0017	-0,0020	-0,00014	-0,0007	0,0007
Miscellaneous	-0,0016	-0,0019	-0,00013	-0,00069	0,0007
Computer and Electronic Products	-0,0016	-0,0019	-0,00012	-0,0006	0,0007
Tobacco	-0,0005	-0,0006	-0.00005	-0,0002	0,0002

Figure 1: Share of energy intensity

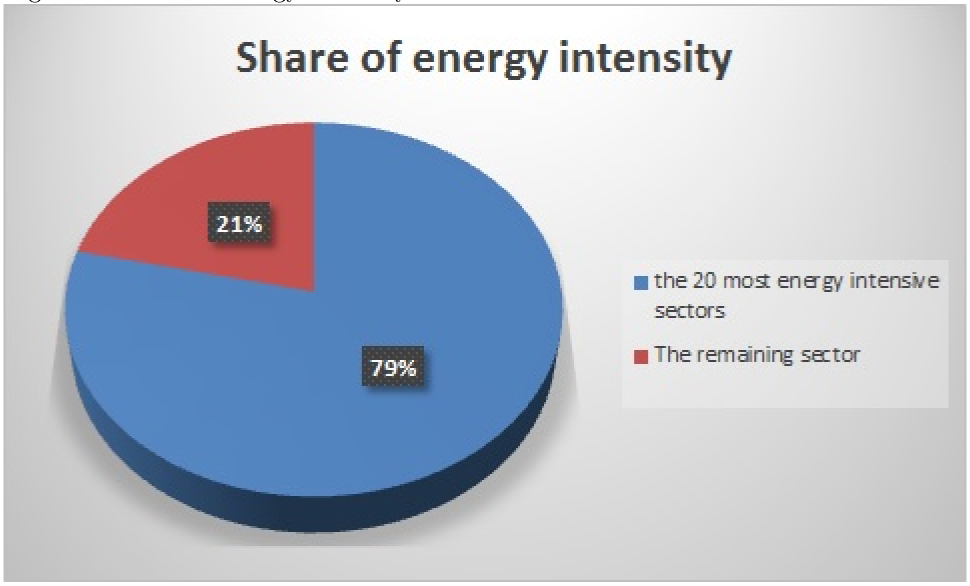

Figure 2: Share of the added value