Competitiveness of Energy-Intensive Industries in Europe: The Crisis of the Oil Refining Sector between 2008 and 2013

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ABSTRACT

After the so-called 'golden age' of refining between the years 2005 and 2008, total or partial closures of 13 EU oil refineries from 2009 to 2013 reduced the EU's total refining capacity by about 10%. This paper analyses the drivers behind this crisis, using industry data on performance and cost structure collected at the refinery level and covering the years 2000 to 2012. During this period EU refiners lost ground in terms of net margins, which fell from above to below the average of their non-EU competitors. Our results show that up to 90% of this loss was driven by refineries' energy costs, which grew almost twice as much in Europe than in other global refining regions. Further analysis indicates that this was not the result of increased energy intensity but of increasing unit energy costs. The remaining 10% of the total competitiveness loss can be explained by the relative worsening of EU refineries' utilization rates, reflecting the decline in demand for oil products–in particular gasoline–that occurred in the EU. Environmental and energy policies have likely contributed to this demand side effect, but its competitiveness impact remains of minor importance compared to the energy cost surge.

Keywords: Oil refining, competitiveness, energy-intensive industries, energy prices, EU refinery closures

https://doi.org/10.5547/2160-5890.9.1.rmar

1. INTRODUCTION

Oil refining is the process of converting crude oil into final or intermediate products like gasoline, diesel, heating oil, fuel oil, and petrochemical intermediate products. Currently there are about 650 oil refineries operating worldwide (Kaiser 2017). The close to 100 refineries[1] located in the European Union constitute an important economic factor, accounting for around 100.000 jobs directly and significantly more that are indirectly linked to the industry (EC 2010). Oil refining plays a strategic role for energy security (Jewell 2011; Umbach 2010), given the vital role of oil products in many economic activities (chemical industry, transport sector) and for society at large (residential heating, private transport).[2] As refining takes place

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[1] According to Concawe (2014, p.15), in year 2014 there were 82 mainstream and 16 smaller non-mainstream refineries (production of bitumen and lubricants or processing petroleum condensates) operating in the EU.

[2] Wall Street Journal: http://www.wsj.com/articles/SB10001424127887324328204578569514287514202

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in large industrial installations, refineries also generate significant emissions, amounting to 7.7 % of all EU-wide industrial emissions of SO_2 and 1.8 % of NO_X in the year 2007 (JRC 2013, p.26).[3]

The economics of refining is based on the difference between the costs of crude oil and the aggregate value of the derived petroleum products (gasoline, diesel, kerosene, etc.)—referred to as 'crack spread' in the business jargon. Naturally, refineries incur various types of costs when converting crude oil into marketable products, ranging from the purchase of energy feedstock (often natural gas) and chemicals to personnel costs and the logistical costs associated with the storage and handling of large quantities of flammable and toxic substances. As it generally acts as a price taker both on the crude oil and product market, a given refinery's profitability to a large extent depends on its ability to operate efficiently and minimize these costs.

Moreover, as the refining costs are typically much smaller—by around one order of magnitude—than the price of crude oil and represent an even smaller fraction with respect to the price of refined products 'at the pump', refineries are strongly exposed to the price volatility of the latter two. This means that refineries' operating profits—or *margins*—can show strong fluctuations between one year and another, and in bad years may even be negative. Clearly, to be long-term economically viable, any refinery's margins not only must be positive and exceed operating expenses, but also cover the costs of maintenance and capital investment.

Even though this basic economic set-up is common to all refineries, actual profits typically vary significantly between one refinery and another, depending on their technical configuration, location (access to crude oil, access to product markets), process management, and other characteristics. An important dimension of a refinery's technical configuration is its so-called complexity, a measure of its technological sophistication. A refinery that distils crude oil and does some basic processing has a lower complexity than one that uses additional vacuum distillation or hydro-cracking (Kaiser 2017). More complex refineries achieve a higher output yield of the more valuable oil products, but they also tend to incur higher operating costs.[4]

It can generally be assumed that competition among refineries is intense, given that refined oil products are relatively homogeneous goods that can be transported by bulk shipment to other markets. Historically, the United States and Europe were the two leading refining regions in the world, representing 20% and 19%, respectively, of the total global refining capacity in year 2000. In 2014, the US still accounted for almost the same share, whereas the European Union's markedly declined to 14.6%, lower than China's much increased share of 15.0% (up from 7% in 2000). During this period the US' total refinery capacity grew in absolute terms, while the EU's actually contracted by 9% between 2000 and 2014, or by 12% with respect to its peak value in year 2006 (BP 2017).

These facts epitomize what was widely perceived as "the crisis in European refining"[5], which fully unfolded after 2008, and thus directly followed the so-called "golden age" of re-

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[3] According to the European Environmental Agency, the 79 most polluting refineries were responsible for 10 % of the total EU-wide damage costs associated with air pollution (NO_X, SO_X, PM_{10}, NMVOC, NH_3) from industrial facilities in the year 2009 (EEA 2011).

[4] The following four types of refineries—in increasing order of complexity—are commonly differentiated: (i) hydro-skimming refineries (only distillation and reforming, no cracking), (ii) catalytic cracking refineries, (iii) refineries with hydrocracking, and (iv) refineries with coking. In our sample of European refineries, year 2012 operating costs were on average 3.4 USD per barrel of throughput in the group of the simplest refineries, and 4.5 USD per barrel in the group of highest complexity (Solomon Associates 2014b). The actual operating costs of an individual refinery are quite sensitive to the crude oil and natural gas price, but typically range between 1.50 USD and 5.59 USD per barrel (IEA-ETSAP 2014).

[5] http://www.theguardian.com/commentisfree/2012/jan/25/crisis-european-refining-petroplus-bankruptcy

fining from 2005 to 2008. This article's objective is to understand how Europe quite suddenly became the region "where the crudes have no margin"[6], and experienced the shut-down of 13 refineries.[7]

Various arguments have been made on what the reasons for these EU capacity reductions were. Clingendael (2012) and Legrand et al. (2012) point to structural overcapacity, arisen as the consequence of falling EU domestic demand and strong competition from new refineries in the Middle East and Asia. In fact, after a peak in 2005, EU consumption of oil products steadily fell, and in 2014 was 15% below its year 2000 level. This contrasts starkly with the non-OECD countries, where consumption grew by 65% between 2000 and 2014. These regions also invested strongly into new and modern refining capacity: by 2009, China, India, and the Middle East had increased their refining capacity by, respectively, 75%, 61%, and 22% compared to 2000, with the total added capacity corresponding to 44% of the EU's total existing capacity in 2009 (BP 2017). Especially the Middle East's capacity expansion–and to lesser extent also India's–exceed the expectation for domestic demand, suggesting that a significant share of this new capacity is oriented towards export markets (Clingendael 2012, pp.39–43). Hence, at the time in question EU refineries were indeed subjected to intense competitive pressure, both on domestic and export markets.

Another argument, emphasized by industry, highlights the burden of EU environmental and energy regulation (e.g. Europia 2010), and points to a "swath of current and impending legislation, including directives on industrial emissions and fuel quality, as a crucial challenge".[8] Possible hypotheses on how recent EU legislation might have adversely affected industry's competitiveness include:

- Legislation promoting biofuels and energy efficiency has reduced demand for oil products in general, and energy taxation favouring diesel contributed to decreasing the demand for gasoline in particular.[9]
- The EU Emissions Trading Scheme (EU ETS) for CO_2 emissions has increased the costs of refineries' energy generation and purchase of electricity.
- The desulphurization of road fuels mandated by the Fuel Quality Directive has increased refineries' energy consumption and costs.
- Due to regulation of industrial emissions the relatively cheap energy generation with heavy fuel oil had to be largely phased out.[10]

Although the concluding section briefly discusses these arguments, a detailed analysis of individual pieces of regulation is beyond the scope of this article. However, a comprehensive study of the impact of these (and other) European directives can be found in Lukach et al. (2015).

Overall, despite the prominence of the subject, the European 'refining malaise' has so far not been analysed quantitatively, most probably due to the lack of reliable performance data, such as gross and net refining margins, operating costs, energy costs, etc. Such data is generally

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6. Oil & Gas Financial Journal, July 2013. Archived: https://rbnenergy.com/where-the-crudes-have-no-margins-european-refinery-woes

7. Between 2007 and 2013, according to IEA (2014a, p.10f.), 13 EU refineries with a total capacity of 1.7 mbbl/d were shut down. In particular, the closed refining capacity in France amounted to 585 kbbl/d, in Germany 400 kbbl/d, in UK 405 kbbl/d, and in Italy 260 kbbl/d. See also the list of recent closures in Concawe (2014, p.16).

8. Financial Times, October 2013. https://www.ft.com/content/12c2514c-2f47-11e3-ae87-00144feab7de

9. Refers to the Renewable Energy Directive, Energy Efficiency Directive, and Energy Taxation Directive

10. EU Directives 'Industrial Emissions', 'Large Combustion Plant', 'Integrated Pollution Prevention and Control'

confidential and therefore not publically available. Various sources provide *estimated* refining margins (e.g. IEA, BP Statistical Review, Wood Mackenzie), but these would by themselves still be insufficient to analyse the drivers of the observed economic performance. In the present study we can make use of otherwise unavailable proprietary data which was obtained from specialized consulting firms, allowing us to analyse the economic performance (net cash margins) of EU refineries vis-à-vis other important competitor regions, and to identify the drivers of the European refining crisis.

The remainder of this article is organized as follows: Section 2 presents the data sources. The main quantitative results are derived and discussed in Section 3, and Section 4 concludes.

2. REFINING SECTOR DATA

In addition to publically available data (e.g. BP Statistical Review, International Energy Agency), our analysis is based on proprietary data obtained from two industry consultants, Solomon Associates and IHS.[11]

First, Solomon Associates (2014a,b) provide aggregated data originally collected by this company from individual refineries—which pay to participate in the survey—for the purpose of industry performance benchmarking. It covers the years 2000 to 2012 on a biennial basis. Solomon Associates (2014a) reports data for EU refineries as one aggregate and, correspondingly, the aggregate refining data for five competitor regions: United States Gulf Coast, United States East Coast, Russia, Middle East, South Korea/Singapore. The aggregation is computed by weighing each refinery by its actual total throughput. The total number and composition of refineries in each year can vary, as not all refineries participated in the survey in all years. The overall coverage of Solomon Associates data exceeds 85% of the total global distillation capacity, and in the EU around 80 refineries supplied data in any of its biennial surveys. As seen on the left panel of Figure 1, confidentiality restrictions required refining margins to be indexed: the value observed for the EU in year 2000 is set to 100, and all the values of other years and regions are expressed relative to this value.[12] However, this still allows analysing trends and their underlying drivers.

Second, for complementary analysis and to check the robustness of our results, we also use data for European and global refining margins purchased from industry consultant IHS (2014). The data consists of annual time series spanning over the period 2000 to 2013, with detailed information on gross and net margins, costs, throughput, etc. In addition to data for EU refineries, key variables are also provided for the non-EU regions, so as to enable comparative analysis. The data points were in part simulated with IHS's proprietary refinery simulation model. Unfortunately, the IHS geographical regions do not fully match those of the Solomon Associates (2014a) data.[13]

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[11] The refining data from Solomon Associates was purchased jointly by the European Commission and the industry association Fuels Europe in order to facilitate the 'Oil Refining Fitness Check', a sectoral study carried out by the European Commission between 2013 and 2015. The IHS refining data was purchased by the European Commission through a public procurement procedure.

[12] E.g. a value of 300 for the US Gulf Cost in year 2006 means that the actual net margins were three times higher than the year 2000 net margins of the EU.

[13] In the IHS (2014) data, Europe includes some countries like Switzerland and Norway which are not EU28 members. Instead of Russia, this data's geographical reference area is 'Former Soviet Union'.

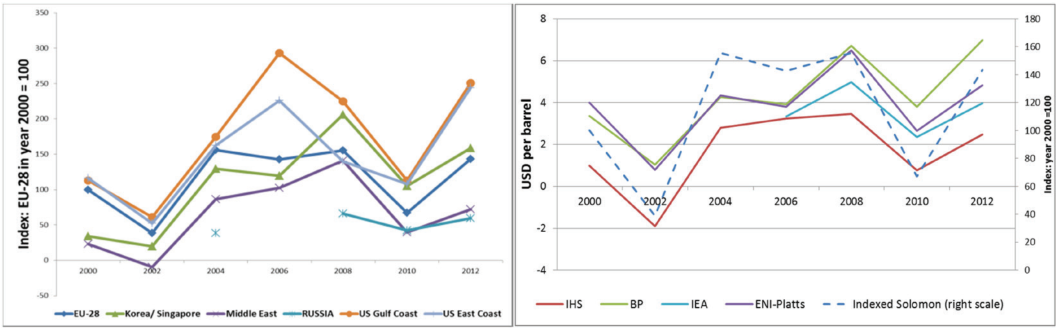

FIGURE 1

[left panel] Average net cash margins of oil refining in the EU and five competitor regions, indexed to EU year 2000 value (=100). [right panel] European refining absolute margin estimates from different sources (left-hand Y-axis) and indexed margins (right-hand Y-axis).

Source: Solomon Associates (2014a).

To check the robustness of our two main proprietary data sources, we also collected several other estimates of EU refining margins that can be obtained from public sources: IEA[14], ENI (2013), and BP (2017). Although the precise definition of refining margins may differ among them, all of these sources aim to produce a similar measure of profitability that is based on the spread between the value of refining inputs and produced outputs, and (an estimate of) refining operating costs.

As can be seen on the right panel of Figure 1, the margin estimates from the various data sources differ in terms of levels, but are very similar in their trend behaviour. Excluding the IEA series due to its limited time coverage, all the other sources show a weak positive trend (average increase of 0.2 USD/barrel per year), and the average coefficient of linear correlation between any two series is 0.87. For our two main data sources, Solomon Associates (2014a) and IHS (2014), the coefficient of correlation becomes an even higher 0.96 (but note the distinct Y-axis on the right-hand of the indexed Solomon data). All sources show a plateau of high margins during 2004 to 2008, which corresponds to what was referred to before as the 'golden age' of refining.

The variation between these data sources can to some extent be explained by the use of different accounting approaches. Accounting differences relate to the use of crude oil and product price quotes, the choice of included feedstock inputs or the use of different systemizations of operating costs. For example, Solomon Associates computes margins as USD per 'net raw material input', which is mostly crude oil (≈90%) but for the rest also includes other feedstocks. Moreover, while some estimates represent benchmark values (e.g. the "North-West Europe Brent cracking" benchmark used by IEA), others represent estimates of real averages.

Overall, although the estimates vary considerably in the absolute level of margins, there seems to be less ambiguity regarding the upswings and downswings. Hence, the actual European margin trend seems to be captured with good reliability, which allows drawing conclusions about the extent of margins' movements and spreads between different refining regions. The remaining analysis will therefore focus exclusively on margins' (and costs') trend behaviour and not discuss their absolute level.

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[14] IEA Oil Market Reports, data available at https://www.iea.org/oilmarketreport/omrpublic/

3. RESULTS

This section first compares the evolution of net margins in Europe and in other refining regions during the years 2000 to 2012. Subsequent analysis then attributes the observed overall divergence to divergences in one or more of the underlying components of net margins.

There are different ways of defining refining margins, but all of them start by comparing the value of the outputs (oil products like gasoline, diesel, etc.) with the value of the inputs (crude oil and, in some cases, other feedstocks). This difference is called the *gross margin* and represents an upper bound on what can be earned by refineries. By including the running costs of production—or operating expenses—net refining margins are obtained. They are also called *net cash margins* to emphasize that they exclude investment costs and capital depreciation. Operating expenses can be subdivided in different ways, e.g. in fixed and variable operating costs, or in energy, personnel, and other operating costs. Since the main data source of this article is Solomon Associates (2014a,b), Solomon's definition of net cash margin is used:

$$\begin{aligned}\text{Net Cash Margin} &= \text{Gross Margin} - \text{Operating Costs}\\ \text{Net Cash Margin} &= \text{Gross Margin} - \text{Personnel Costs} - \text{Energy Costs} - \text{Other}\\ &\quad\ \text{Operating Costs} \qquad (1)\end{aligned}$$

To be able to compare the performance of refineries of different sizes, it is customary to normalize the obtained value by either the total processed crude oil or by 'net raw material input' (i.e. crude oil and other feedstocks). This is the case with all margin data presented here. Thus, the net margins are expressed in USD per barrel, or USD per ton.

Finally, it needs to be emphasized that net margins do not capture any capital costs for new investments or plant depreciation. They thus represent a necessary rather than a sufficient measure of competitiveness, if the latter is conceptualized as 'ability to survive in the market'.

3.1 Evolution of net margins: EU falling behind other refining regions

Both panels of Figure 1 confirm that EU refining net margins—although with strong fluctuations—show a weak positive trend: following Solomon Associates (2014a), they were 43% higher in year 2012 than in 2000. However, as can be seen on the left panel of Figure 1, the competitor regions exhibit a similar trend, and on average improved even more. As a consequence, while the EU net margin was higher than the average margin of its competitors in year 2000, in 2012 it was lower.

Formal analysis allows corroborating this observation. To this end, let us consider the time series consisting of the difference between the EU net margin and the average net margin of the competitor regions, as shown in Figure 2 for the indexed data from Solomon Associates (2014a) and IHS (2014) on the left and right panels, respectively.[15] In these graphs the negative *relative* trend of the EU margins shows up quite clearly, confirmed by a high R^2 of 0.68 for the Solomon data and a somewhat lower of 0.37 for the IHS data.

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[15] We take a simple non-weighted average of the competitor regions, because we are interested in how the competitiveness of the EU refining region fared vis-à-vis the competitiveness of other relevant refining regions. Hence, each region represents one 'data point' of equal importance with regard to the posed question.

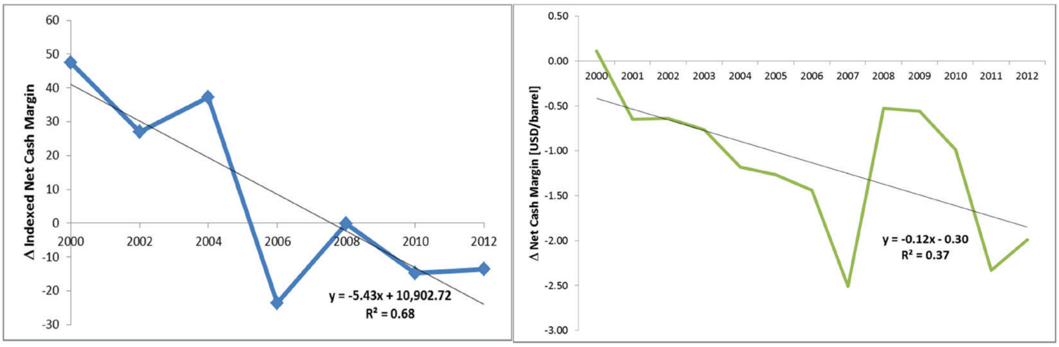

FIGURE 2

Difference between EU net cash margins and average of competitor regions, along with trend-line based on a linear regression.

Sources: [left panel] Index-based data from Solomon Associates (2014a), [right panel] IHS (2014).

According to the data from Solomon Associates, the EU was performing better than the five regions' average in 2000[16], but over time its relative performance deteriorated and became worse from 2006 onwards.[17] According to the estimated data from IHS (2014), the EU refining margins were initially on par with the average of US Gulf Coast, US East Coast, Middle East, Former Soviet Union, and OECD Asia (which includes South Korea), but then deteriorated notably, falling behind the competitors' margins with an average trend of 0.12 USD/barrel per year (in constant 2013 USD).

Given the slightly different data specifications (geographical scope, currency, etc.), and the uncertainty regarding some market data (e.g. actual crude costs and product prices), the main result stemming from the two data sources—that in terms of net cash margins the EU fell behind the average of its competitors—is deemed to be robust.

3.2 Drivers of the net margin trend: predominance of energy costs

By Equation 1 net refining margins are defined as the difference between gross margins and three types of operational costs (personnel, energy, other). Hence it is possible to identify the relative share by which each of these components contributed to the relative deterioration of EU net margins.

Gross margins are given by revenues minus the costs of crude oil and other feedstock inputs, thus reflecting the general supply-demand market conditions for oil products. Data from Solomon Associates (2014a) indicates that European gross margins increased during 2000 to 2012, a positive evolution that was shared by the average gross margins of Europe's competitors. Computing again the difference between EU gross margins and the average gross margins of the competitor regions, as shown on the left panel of Figure 3, reveals that the EU has

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[16] Note that the seemingly 'high' advantage of almost 50 index points between the EU and the average competitor, being relative to the normalized year 2000 EU margin value of 100, could actually be rather small, e.g. just below 1 USD/barrel if the actual year 2000 EU margins were 2 USD/barrel.

[17] Note that for Russia only years 2004, 2008, 2010, and 2012 were reported in Solomon Associates (2014a). A consistent integration of these data-points into the trend analysis can be achieved by rescaling such that Russia's average for the four available years coincides with the corresponding average of the four other regions, since otherwise spurious spikes (and thus spurious trends) would be introduced at the points where Russian data starts to be included in the time series. Excluding the incomplete time series of Russia produces nearly the same result, with a trend of –5.42 instead of –5.43. Further analysis (not shown) done individually for each competitor region shows that EU margins have deteriorated with respect to all five considered regions.

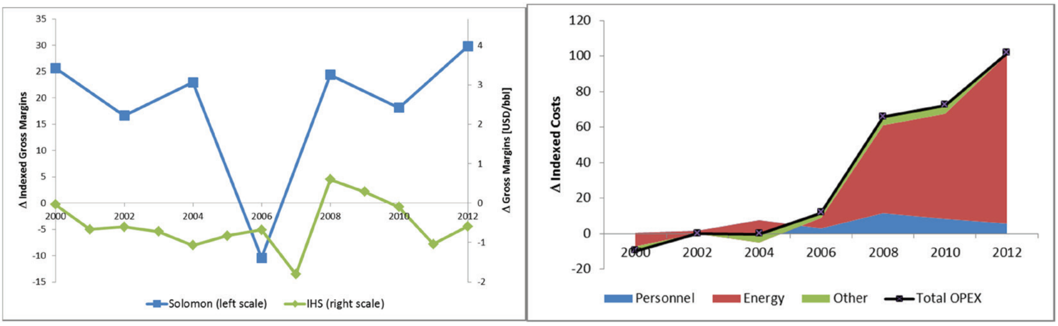

FIGURE 3

[left panel] Difference (Δ) between EU gross margins and average of competitor regions. [right panel] Difference between EU operating costs and the average of competitor regions ('Total OPEX', black line), along with the contributions to the difference coming from each of the three subcategories of operating costs.

Sources: [left panel] Solomon Associates (2014a) and IHS (2014), [right panel] Solomon Associates (2014a).

enjoyed a robust advantage vis-a-vis its competitors, except in the year 2006 (the US regions experienced a positive spike in that year). However, as there is no significant trend (linear regression yields an R^2 of 0.01) it can be concluded that the evolution of EU and non-EU gross margins has had no impact—positive or negative—on the competitiveness of EU refining. This conclusion is still supported when switching to the estimated gross margins data of IHS (2014), with the result depicted in the same chart, where again no significant trend is discernible, although in this data EU gross margins are overall below the average of the competitors.

If the effect of gross margins can be ruled out, it must be the evolution of operational costs that explains the relative deterioration of European refining margins. Indeed, computations based on data from Solomon Associates (2014a) and from IHS (2014) both indicate that EU operational costs have steadily grown above those of the competitor regions. For the Solomon data this is shown on the right panel of Figure 3, where the curve 'Total OPEX' represents the difference in operational costs between the EU and the average of the competitors. There is a significant positive trend (R^2=0.90), with an average slope of 9.72 index units per two years.

Although the actual data from Solomon Associates (2014a) is indexed to protect confidential information, the fact that it uses a consistent indexation for total operating costs and its three subcomponents allows quantifying the relative contributions attributable to each subcomponent. In other words, the observed relative rise of EU operating costs by 9.72 index units per two years can be decomposed into contributions from personnel[18], energy[19], and other operating costs.

As apparent from the right panel of Figure 3, even though all three cost categories have contributed to the relative rise of EU operating costs, energy costs were the dominating driver. Linear regressions quantitatively confirm the only limited contributions from personnel and other operating costs—relative increases, respectively, of 0.59 and 0.34 index units per two years—and the dominating role of energy costs, with a slope of 8.79 index units per two years. In other words, the observed rise of EU total operating costs above the competitors' average

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[18] Includes the salaries, wages and benefits of the refinery staff. It includes all contractor costs (mainly for maintenance, but contractors are also used in other areas). It also includes an allocation of personnel costs from G&A (General and Admin), and all labour costs associated with turnarounds.

[19] Purchased (natural gas, heat, electricity, solid fuels) and own production of energy.

with a speed of 9.72 index units per two years can be written as the sum 0.59+0.34+8.79, which implies that the relative contributions from personnel, other, and energy operating costs were 6.1%, 3.5%, and 90.4%, respectively.

A region-by-region analysis reveals that this main finding about the EU margins falling behind due to a relative deterioration of EU energy costs holds with regard to all of the competitor regions except Singapore/South Korea, where energy costs evolved roughly as in the EU until 2010, and actually became higher in year 2012. In fact, for this particular region it is the relative deterioration of gross margins that constitutes the main driver of the EU's relatively worse net margin performance (i.e. a more favourable evolution of crude oil and/or product prices in that region than in the EU).

3.3 Deterioration of EU energy costs: due to increasing consumption of energy or unit energy costs?

Although in the year 2000 EU energy operating costs were actually lower or not higher than in most of the competitor regions, they have since then increased nearly four-fold, while the average energy costs of the competitor regions increased only less than two-fold (Solomon Associates 2014), as can be seen on the left panel of Figure 4.[20] As energy costs (USD per throughput) are the product of quantity (energy units per throughput) and price (USD per energy unit), it can be analysed which of the two (if not both) was the main driver of the observed trend. In the latter case of an increase of the unit energy costs, two different effects could be at play: it could be the simple price effect of one unit of natural gas or electricity becoming more expensive, or be a composition effect, i.e. a switch of EU refineries towards inherently more costly sources of energy, e.g. from fuel oil to natural gas.

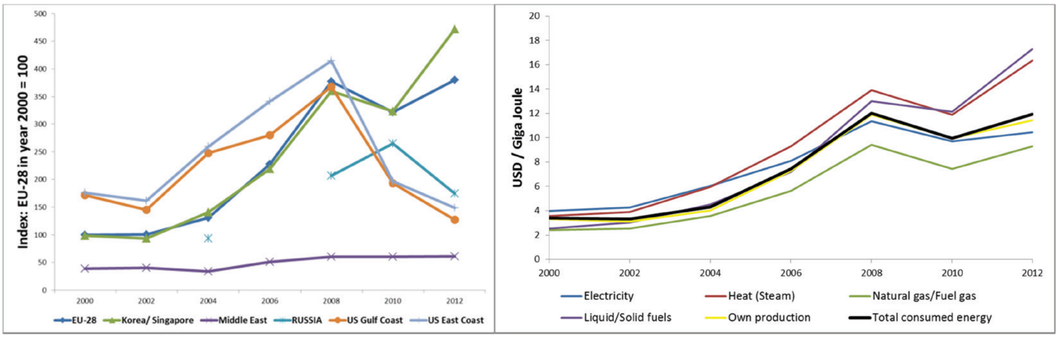

FIGURE 4

[left panel] Energy operating costs in EU and competitor regions. [right panel] Unit energy costs of EU refineries for various energy sources.

Sources: Solomon Associates (2014a,b).

Unfortunately, the data acquired from Solomon Associates (2014a) does not encompass refineries' energy consumption for the competitor regions. We can therefore use this data only for the analysis of the nearly four-fold absolute increase of European refining energy costs.

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[20] More specifically, in the US Gulf and East Coast they were actually lower in 2012 than in 2000, in the Middle East there was a 60% increase, and in Russia they doubled from 2004 to 2012, while at the same time tripling in the EU. South Korea/ Singapore costs were comparable to the EU's until 2010, but became higher in 2012.

In terms of energy intensity, the data shows that in Europe the energy use per throughput (Joule/ton) has increased by 7% between 2000 and 2012. However, a closer look reveals that this was merely a consequence of the overall increase in complexity of EU refineries, as more complex refineries tend to use more energy; within each class of complexity, energy intensity has actually remained constant.[21]

Conversely, in terms of unit energy costs (USD/Joule) the data shows a sharp increase across all classes of refinery complexity. As the right panel of Figure 4 shows, the costs of all types of refining energy were subject to a strong—on average about 350% —increase, the average cost for one unit of consumed refinery energy being 3.4 USD/GJ in year 2000 and 11.9 USD/GJ in year 2012.[22] This increase is evidently related to the four-fold increase in crude oil prices during the same time period (shown in the left panel of Figure 5), which largely determines the market price of fuel oil and thereby the costs of a large part of self-produced refining energy. Because of the widespread use of forward contracts linked to the oil price, the latter also strongly influences the natural gas price in Europe, which in fact also increased nearly four-fold, as shown in Figure 5. On the contrary, with the emergence of massive non-conventional oil and gas resources in the US, the price of West Texas Intermediate crude oil was between 15 to 20 USD/barrel lower than European Brent during 2011 to 2013,[23] and by 2011 the US' domestic natural gas price returned to the low level of year 2001 (IHS 2014).

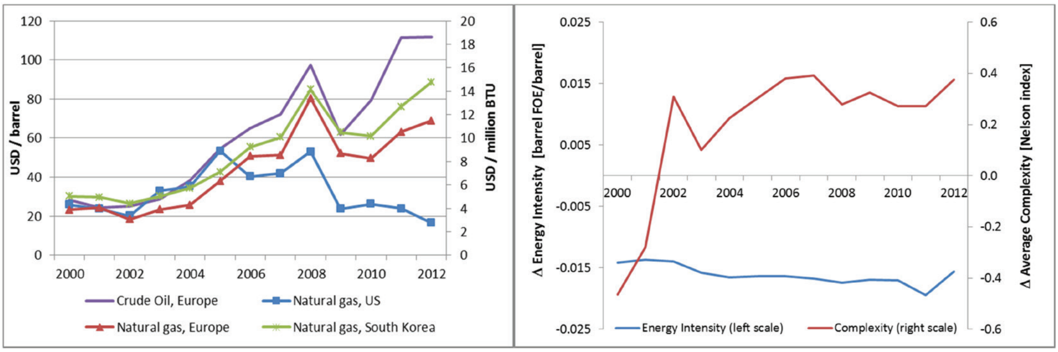

FIGURE 5

[left panel] Price of crude oil (Brent dated, left scale) and of natural gas (right scale). [right panel] Difference between Europe and five competitor regions in terms of (left scale) average refining energy intensity (barrels of fuel oil equivalent per barrels of throughput) and (right scale) average refinery complexity (Nelson index).

Sources: [left panel] World Bank 'Pink Sheet', IEA, BP (2017). [right panel] Own computations based on IHS (2014).

Finally, checking the data with respect to the composition effect, i.e. whether EU refineries switched towards more costly forms of energy, leads to a negative result: there only was a slight shift towards natural gas and electricity, which both represent below-average cost options according to Solomon Associates (2014b), and hence we conclude that EU energy costs did not increase due to a composition effect.

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[21] The complexity of a refinery is a measure of its technological sophistication. In the Solomon Associates (2014b) data EU refineries are classified into five different groups of increasing complexity.

[22] In EUR terms the increase would be somewhat less, as over this period the EUR appreciated against the USD.

[23] https://www.eia.gov/todayinenergy/detail.php?id=11891. Also recall that the US had an export ban for crude oil until year 2015.

Comparative data on the evolution of energy use in the EU and other refining regions is included—albeit based on estimates and simulations—in IHS (2014). From this data the difference between the average energy intensity of refining in Europe and the average energy intensity of refining in the competitor regions is computed, measured in terms of barrels of fuel oil equivalent (FOE) per barrel of crude oil throughput. As can be seen on the right panel of Figure 5, EU refineries are estimated to have had a lower average energy intensity than their competitors in year 2000, and over the years managed to slightly reinforce their advantage. Comparing the evolution of the average refinery complexity in the EU and in the competitor regions shows that this is not merely a consequence of EU refineries falling behind in terms of complexity–recall that higher complexity typically goes along with higher energy intensity–since actually average complexity (Nelson index) increased faster in Europe than in the competitor regions (Figure 5, right panel).

Overall, this leads to the conclusion that the particularly high increase in unit costs was the principal driver of the relative deterioration of EU refiners' energy cost. As said before, refining energy costs in the EU are highly correlated with international crude oil prices, meaning that the dramatic nearly four-fold increase of oil prices during 2000 to 2012 had a strong impact on unit energy costs for refineries, transmitted in particular by rising natural gas prices (see left panel of Figure 5). It can be safely assumed that this increase was less strong in those competitor regions which dispose of abundant domestic fossil resources (Middle East, Russia) or newly exploited unconventional resources (US, see natural gas price evolution in Figure 5). Only the South Korea/ Singapore region was in a similar situation as Europe and, accordingly, suffered a similar and even worse increase in energy costs.

To double-check the plausibility of our analysis, we can carry out a simple back-of-the-envelope calculation: we take as the average specific energy consumption (SEC) of a refinery 0.45 million BTU per barrel of throughput.[24] Next, let us assume for the natural gas price a 5 USD/million BTU cost disadvantage of the EU vis-à-vis its competitors: according to IGU (2017, p.36), between 2010 and 2014 it was actually worse with respect to the US and Russia, and even more so vis-à-vis the Middle East, but on the other side prices in the Asia-Pacific region were similar as in the EU. If, as an extreme assumption, 100% of a refinery's energy were produced with natural gas, the 5 USD/million BTU cost disadvantage would translate into a 5 x 0.45 = 2.23 USD/barrel margin disadvantage. According to Solomon Associates (2014b), EU refineries in 2012 produced 64% of their energy with gaseous fuels (including also fuel gas, methane, etc.). Taking this as a globally representative figure, the 5 USD/million BTU price gap would imply a 1.4 USD/barrel short-fall of EU margins vis-vis its competitors. However, note that another 11% of EU refineries' energy was produced with liquid fuels, the price of which is linked to crude oil, which in the EU was also more expensive than in most of the competitor regions (e.g. with respect to the US, Brent-WTI spreads of 15 to 20 USD/barrel were common between 2011 and 2013). Assuming that 5% of the total processed crude oil is retained for supplying this energy (Rao 2016), and that the EU price disadvantage is on average 10 USD/barrel, EU refining margins would be set back by another 0.05 x 10 = 0.5 USD/barrel. The total, a relative loss of 1.9 USD/barrel seems plausible and in agreement with the estimate of IHS (2014) shown on the right panel of Figure 2.

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[24] The average of average figures for the US (0.52, from Elgowainy et al. (2014)), the EU (0.34, from Solomon Associates (2014b)), and India (0.47, from Rao (2016)). The specific energy consumption can vary considerably between individual refineries, depending on their configuration and complexity.

3.4 European utilization rates

A sufficiently high utilization rate is vital for the economic viability of any refinery. This indicator measures how much of the theoretical crude oil distillation capacity of a refinery is actually used. A rate of 85% is seen as the minimum for a healthy state.[25] According to BP (2017), EU utilization rates exhibited a decreasing trend after 2005, and already in 2006 dropped below the 85% mark. Our data from Solomon Associates (2014b) confirms the negative trend and even indicates a slightly lower overall utilization rate.

Although the utilization rate does not appear explicitly in the formula for computing net margins, it affects their value indirectly, as a decreasing utilization rate implies that the fixed operating costs per throughput will increase. More specifically, if with a utilization rate of 80% each barrel of throughput is burdened by fixed costs of X, then at 90% utilization these fixed costs would decline to a fraction of 80/90, or 88.8% of X, representing a decrease of about 11%.

Energy costs (USD/throughput), the largest single component of operating costs for EU refineries, are variable costs and hence unaffected by utilization rates. However, fixed operating costs still account for 30% to 40% of total operating costs in the EU (Solomon Associates 2014b). In terms of the three components of operating costs analysed here, one can approximately view energy costs as the variable part, and personnel together with 'other' as the fixed part of operating costs.[26] Recalling our earlier finding that the latter two components contributed about 10% to the falling behind of EU refining margins, we now analyse whether these 10% might be explained by a falling behind of EU utilization rates. To this end we assess how European utilization rates fared compared to those of the competitor regions.

Over the period 2000 to 2012, data from Solomon Associates (2014b) indicates a weak negative trend for average utilization rates in the EU, of about –0.3 percentage points per year.[27] According to estimated data from IHS (2014), the negative trend was more pronounced with –1.2 percentage points per year, while data from BP (2017) suggests a value of –0.4 percentage points per year. These values, as well as the corresponding ones for the competitor regions (or geographical proxies thereof) are reported in Table 1.

TABLE 1

Average annual change of regional utilization rates during 2000 to 2012, in percentage points per year.

	BP (2017)	IHS (2014)	Solomon Associates (2014b)	EIA (2016)	*average*
European Union	–0.4	–1.2	–0.3		–0.65
United States	–0.7	–0.7		–0.7	–0.7
Middle East	–0.1	±0.0			–0.05
Russia / Former SU	+2.7	+2.1			+2.4
Singapore & Korea / Asia	–0.5	–0.1			–0.3

Data sources as indicated; EIA stands for US Energy Information Administration. Note that in the last two rows, BP (2017) refers to Russia and Singapore/Korea, respectively, and IHS (2014) to Former Soviet Union and Asia, respectively.

As can be seen, for the period 2000 to 2012 the negative trends in Europe and the US appear to be robust across all data sources, with the US having experienced a similar decrease

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[25] http://www.reuters.com/article/europe-refineries-closures-idUSL6N0RQ2WL20140925

[26] Energy costs account on average for 90% of total variable costs. The two components personnel and other operating costs are on average 85% fixed and 15% variable costs. Source: Solomon Associates (2014b).

[27] Average EU capacity utilization was 83% in year 2000, had a high of 85% in 2004, and came down to 81% in 2012.

in utilization rates as the EU. Given that in the Middle East region the trend was essentially flat, slightly negative in Singapore & Korea / Asia, and significantly positive in Russia, the overall conclusion would be that Europe experienced a relative decline of its average utilization rate vis-à-vis the average of the competitor regions. Indeed, using only IHS (2014) data would indicate a relative worsening of –1.4 percentage points per year, and –0.8 according to BP (2017).

To quantify the impact of the relative decline of EU utilization rates, we use the detailed European refinery data from Solomon Associates (2014b) and compute the change in fixed operational costs implied by a—hypothetically—higher throughput. For example, if the average EU utilization rate had remained at its year 2000 level of 83% until 2012, most of its relative decline vis-à-vis the average of the competitors would have been avoided. Computations using Solomon Associates (2014a,b) show that in this case also the relative deterioration of EU operating costs would have been noticeably lower, with a trend of only 0.25 instead of 0.93 index units per two years for the deterioration of EU personnel and other operating costs (see Section 3.2), hence avoiding more than 70% of the actually observed effect.[28] Further calculations shows that a—hypothetical—weak positive trend of 0.2 percentage points per year (i.e. from a utilization rate of 83% in 2000 to 85.4% in 2012) would have been sufficient to fully avoid the 10% loss of EU competitiveness related to non-energy operating costs.

What caused the decline of utilization rates in Europe? Clearly, the annual demand for oil products in Europe fell sharply, by about 100 Million tons between 2000 and 2012 (Lukach et al. 2015, p.102), or 12% of the total (BP 2017).[29] What made things worse for European refiners is that the basket of oil products was not affected uniformly: consumption of mid-distillates like diesel and jet-fuel actually increased by 7% over this period, while all other products fell by 26% (BP 2017).

This structural change in product demand is the well-known phenomenon of 'dieselisation' that occurred in Europe during these years. As shown in Figure 6, in about one decade European road traffic switched from a situation where diesel and gasoline were on par, to one where diesel dominated by more than 2-to-1 (diesel +34%, gasoline –37%). As a consequence, EU refineries faced a substantial gasoline surplus, reinforced in the most recent years by an increasing presence of bio-fuels (representing 3.4% of all consumed gasoline in 2012).[30]

Because of the coupled production process characterising oil refining, in which the output shares of different products are relatively fixed, such a fast (compared to the industry's typical investment cycle) and large demand switch poses a substantial challenge. A somewhat higher yield share of diesel can be achieved by shifting to different crude oil types and increasing conversion capacity, but a direct transformation of gasoline into diesel is not possible, meaning that a reduction of gasoline output can, eventually, only be achieved by also reducing the output of all other product types.

Although the export of gasoline, especially to the US, helped to ameliorate the situation to some extent, this buffer was also not unlimited and hence EU refineries' gasoline output and, as a consequence, their utilization rate had to decrease. At the same time, the EU became a net

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[28] Total processed crude is rescaled to give 83% utilization of crude distillation capacity, as observed in 2000. Net raw material input is then rescaled with the same factor, and used to compute the implied fixed costs per barrel of throughput. Variable costs per throughput remain unchanged.

[29] Actually the decline of total EU oil product consumption only started after 2006, dropping by 15% until 2012 (BP 2017).

[30] Source: Eurostat data [nrg_102a] and [nrg_107a].

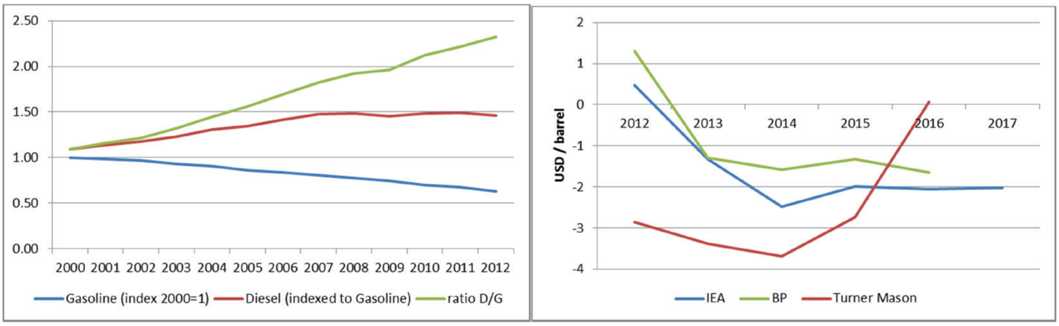

FIGURE 6

[left panel] Consumption of gasoline and diesel in EU road transport, indexed to year 2000 level of gasoline. 'ratio D/G' is the ratio of the two. Includes biofuels. [right panel] Evolution of average EU refining margins relative to those of the US Gulf Coast and Singapore region after 2012.

Sources: [left panel] Eurostat data [nrg_102a] and [nrg_107a]. [right panel] Own computation based on public data from IEA, BP (2017), Turner, Mason & Company.

importer of diesel and jet-fuel, showing that the real bottleneck for refineries' utilization was not a low demand for refined products as a whole, but the low demand for gasoline in Europe.

Why Europe switched to diesel is under debate; one study (Miravete et al. 2018) suggests that it was a mix of technological innovation, emissions (NOx) policy, and the generally lower fuel taxes applied to diesel. It seems plausible that persistently high fuel prices, caused by the high oil price observed after 2006, also induced a switch towards generally more fuel efficient diesel engines.

4. CONCLUSIONS AND OUTLOOK

Motivated by the reporting on the European refining crisis which reduced total EU refining capacity by about 10%, this article provides a quantitative analysis of the EU28 oil refining sector's international competitiveness vis-à-vis five important competitor regions: US Gulf Coast, US East Coast, Middle East, Russia, and the aggregate of South Korea & Singapore. This analysis shows that between the years 2000 and 2012 average EU net refining margins fell from above to below the average margin of their competitors, even though they slightly increased in absolute terms. As the most important result, 90% of this loss of competitiveness was found to be attributable to the increase in energy operating costs, which in the EU rose relatively stronger than in the average competitor region. In absolute terms, during 2000 to 2012 energy costs per barrel have increased almost four-fold in the EU, while on average less than two-fold in the competitor regions.

The fact that in the considered time period the EU refining region had a more favourable evolution of energy efficiency than the average competitor region indicates that energy operating costs deteriorated because of the evolution of unit energy costs in the EU. In fact, along with the spectacular four-fold increase of the crude oil price between 2000 and 2012, all forms of energy used in EU refineries (electricity, natural gas, fuel oil, etc.) experienced a similarly strong cost increase. This is not surprising given the relative scarcity of domestic energy resources in the EU, whereas Russia and the Middle East were able to resort to their own abundant oil and gas resources as a buffer, and the US to its newly developed non-conventional resources ('shale gas revolution'). From a broader perspective, our findings provide further support to recent arguments on the limits of energy efficiency improvements: they can alleviate regional energy price disparities only up to certain point, beyond which they cannot prevent a decline of competitiveness (IEA 2014b, p.279ff.).

Further data analysis suggests that the remaining 10% of the competitiveness deterioration which are not explained by the relative increase of EU energy costs are likely related to the relative decline of EU utilisation rates, which caused a relative increase of EU fixed costs (i.e. personnel and other operating costs). Our computations indicate that if EU utilisation rates had remained stable at their year 2000 level (instead of falling slightly), the negative competitiveness effect related to non-energy costs would have been to large extent avoided.

The declining utilization of refining capacity in Europe is a consequence mainly of the drastic 12% drop in domestic demand for oil products, or even 26% if one excludes the mid-distillate products like diesel and jet fuel (BP 2017). This led to structural overcapacity in the EU refining region, in which the gasoline market became the bottleneck that held down the utilization rate of many EU refineries, since outside-EU outlets for the gasoline surplus were hardly available, and a switch of refineries from gasoline to diesel production technically not feasible. In this sense, the EU gasoline market experienced a double ‘hit’ as it was affected both by the overall falling demand for oil products, and the shift from gasoline towards diesel.

Although exports to the United States traditionally absorbed the largest part of the EU excess gasoline, this became more difficult when the US’ non-conventional oil production set in, which eventually turned this decade-long net importer of gasoline into a net exporter by the year 2010.[31] Accordingly, the volume of EU gasoline exports to the US contracted by 90% between its peak level during the ‘golden age’ of 2005–2007 and the years 2011–12.[32]

Because the mid-distillates (diesel, jet fuel, heating oil) resisted the overall negative demand trend, EU refineries that were able to produce higher shares of such products—e.g. the ones with hydrocrackers—found themselves in a better competitive position. This was generally not the case for simple refineries of low complexity. Reflecting this, out of nine EU refineries shut-down until 2012, seven were in the lowest or second-lowest complexity class (Lukach et al. 2015, p.262).

Evidently, the question of the competitiveness of the EU refining sector did not become irrelevant after the year 2012, which is when our industry data series stops. A contraction of EU refining capacity is still observed, but at a slower pace, with a total decline of 2.6% between 2013 and 2016 (BP 2017). Two major refineries ceased to process oil in 2015, one in France and one in the UK (S&P Global Platts 2018). Meanwhile, the oil price surge observable in Figure 5 has been followed by a rapid decline starting in 2014, touching prices as low as 30 USD/barrel in early 2016. How has this affected the competitiveness of EU refining? Given that an update of our industry data is not possible, we have to rely on the few data series of *estimated* refining margins that are publically available. Since Russia and the Middle East region are not covered by such data, and the US East Coast only to limited extent, we focus on EU refining margins relative to those of the US Gulf Coast and Singapore region. Hence, these figures cannot be directly compared to our previously analysed EU margins computed with respect to all five competitor regions. Still, as can be seen on the right-hand panel of Figure 6, all avail-

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[31] US Energy Information Administration: “U.S. Net Imports of Finished Motor Gasoline”. Available online at: https://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=PET&s=MGFNTUS2&f=A

[32] US Energy Information Administration: “US Net Imports by Country”. Available online at: https://www.eia.gov/dnav/pet/pet_move_neti_a_epm0f_IMN_mbblpd_a.htm

able data sources indicate a declining competitiveness of EU refining until 2014.[33] This was the period when high oil prices of around 100 USD/barrel and, consequently, high refining energy costs in the EU were observed. A halt and partial reversal of this trend set in between 2014 and 2015, which was when the oil price dropped by about 50%. However, two out of the three margin series indicate that on average EU refineries still remain less profitable than those of the US Gulf Coast and Singapore region. Overall, this is consistent with our previous analysis, reflecting the importance of the oil and natural gas prices for short–term European margin performance on the one hand, but on the other also pointing towards more structural aspects, like overcapacity and dieselization, which continued to have a negative impact on EU refining even after 2012.

Finally, an important caveat of our study is that its analysis is based only on *net refining margins*. Although this represents the most widely employed economic performance indicator, it remains a proxy for the overall competitiveness of the refining industry. Most importantly, it does not capture the costs of investments refineries are incurring in order to maintain and upgrade their capacities, to achieve mandatory product specifications, and to comply with pollution regulation. Other economic indicators, such as return on investment, would allow complementing our analysis in this respect, but because of its commercial sensitivity such data was not obtainable from industry.

However, one example of such analysis is provided in the regulatory impact study of Lukach et al. (2015), which used industry data for the EU and the competitor regions capturing two types of investment costs, namely investments associated with *(i)* effluent and emission regulation (waste water treatment, refineries' emissions into air of SOx, NOx, and particulate matter, etc.) and to *(ii)* clean fuels regulation (mostly regarding the permissible sulphur content of gasoline, diesel, etc.). These two represent the most relevant areas of environmental regulation affecting EU refineries, and were reported by industry (e.g. Europia 2010) as being particularly burdensome for the competitiveness of the sector.

The Lukach et al. (2015) analysis of the industry data (2000 to 2012, also collected by Solomon Associates) conveys a mixed picture: for effluent and emission control EU refineries have on average invested less than their competitors in the two US regions, and—in the most recent years—about the same as refineries in the Middle East (p. 264). At the same time, EU investments were clearly above the level observed for refineries in Russia and also in Singapore & Korea. For the second cost item, i.e. investments for achieving clean fuel regulation, one has to first point out that this type of product-related regulation affects all refineries—whether inside or outside the EU—producing fuels for the EU market, and hence should a priori have an only limited competitiveness impact. Reflecting this, the investment data indeed shows that regions with increasing export orientation—e.g. in recent years Russia and Middle East—also undertook significant investments into clean fuel capacities, even above the level observed in the EU (p. 215). The data also shows that the average US refineries' clean fuel investments were again equal or above the EU's in all considered years. Therefore, the general picture is consistent with the central finding of our analysis that EU environmental and energy regulation has likely contributed to the negative demand side effect, but was of minor importance for the overall erosion of competitiveness.

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[33] Note that the three time series shown in Figure 6 vary in their definition of refining margins, e.g. BP's European average margin is based on a North-West Europe light sweet cracking refinery, whereas the IEA's represents the average of different Mediterranean and North-West Europe cracking and hydroskimming refineries. This, to large extent, explains their dissimilarity.

CONFLICT OF INTEREST STATEMENT

All three authors declare to have no financial interest, such as personal or professional relationships and affiliations, in the subject matter discussed in this manuscript.

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