The First World War and the Latin American transition from coal to petroleum

Abstract

While it is true that the precise nature of the future energy transition is uncertain, and no standardized transition is expected as such, it is also true that the energy transition phenomenon can only be described as an historical phenomenon. The Latin American early adoption of petroleum as principal energy source during the first quarter of the 20th century challenged the universality of the energy transition observed for the advanced economies and the associated features regarding pace, irreversibility and the sequence within the energy transition. This paper deepens on the analysis of this episode marked by the disruptions created by First World War to show how economic, geographical and political aspects defined the shape and pace of the early switch to oil of the Latin American republics. The aim is to develop a more nuanced understanding of socio-spatial contexts, scale, and the global–local relationships that constitute core elements of socio-technical systems.

Keywords

Energy transition, petroleum, coal, Latin America, path dependence, inertia of energy systems, global-local

Article structure

1 Introduction

As defined by (Geels, 2005) socio-technical systems consist of a cluster of elements, including technology, regulation, user practices and markets, cultural meaning, infrastructure, maintenance networks and supply networks. At times, those elements struggle with specific circumstances that limit their leeway forcing them into alternative courses of action. For the purposes of this paper, the historical contingency of the First World War represents one of those circumstances affecting almost all the elements of the socio-technical system defining the world energy supply.

(Murphy, 2015, pp. 87–88) established that both, technological innovation system (TIS) and multi-level-perspective (MLP) scholars, have highlighted the value of considering space and scale to more effectively capture the complex dynamics through which innovation systems might occur. Therefore, he asked for more emphasis on ‘the precise roles that socio-spatial embeddedness and relations play in determining the path and significance of TIS evolution’. To yield further insights regarding the spatial dimensions and dynamics of socio-technical change, he also appealed to shift the empirical focus away
from the European, North American, and Australian context. Taking up his plead, this paper looks into Latin America's transition out of coal into petroleum.

Rubio et al (2010) established the methodology for reconstructing the historical energy consumption data of Latin America and used their estimates to gauge the economic evolution of the region from 1890 to 1925. (Rubio and Folchi, 2012) extended the database to almost one hundred years to cover 1856 to the 1950s and showed that Latin American early adoption of petroleum as principal energy source, replacing coal, during the first quarter of the 20th century challenged the universality of the energy transition observed for the advanced economies and the associated features regarding pace, irreversibility and the sequence within the energy transition. However, (Rubio and Folchi, 2012) only advanced general hypotheses for the proxy causes of the Latin American particular energy transition, loosely pointing at path dependence, factor endowments, trade energy network and the role of First World War as the probable causes. Building on these, this paper deepens on the analysis of this episode marked by the disruptions created by First World War to show how economic, geographical and political aspects defined the shape and pace of the early switch to oil of the Latin American republics, providing new evidence for the whole subcontinent.

With our analysis, we aim at developing a more nuanced understanding of socio-spatial contexts, scale, and the global–local relationships that constitute core elements of socio-technical systems.

The First World War was responsible for the rapid maturity of the petroleum industry worldwide. While it is true that both the USA and Great Britain began the conversion of their naval fleets from coal to oil burners just before the war started, it is also true that as the war progressed, petroleum use increased, providing fuel for such military innovations as the submarine, the tank and the airplane (DeNovo, 1956). The use of fuel oil and diesel engines as prime movers and as electricity generators in places with either little hydraulic resources or coal, together with the necessary lubricants for the machinery, also increased the demand for petroleum products during the war. These uses superseded kerosene for illumination, the major market in the early days of the petroleum industry (Yergin, 1991). Fuel oil was principally used for bunkering ships and as locomotive fuel, for which coal, supplied largely by Great Britain to the world, was formerly used. Nevertheless, the contribution of petroleum to the world energy supply after the end of the Great War must not be exaggerated. In 1925, solid fuels still supplied 82.9 per cent of the energy consumed worldwide, liquid fuels, 13.2 per cent, natural gas 3.2 per cent and
hydroelectric power 0.7 per cent (Rubio, 2006). Most of the world kept using coal as major energy carrier for few more decades. As it is often explained, the replacement of a technological system (coal and its steam engine) for another one (petroleum and its combustion engine) often happens in a gradual fashion, because the creation of a new socio-technical regime takes time (Geels, 2005). Yet it was not the case in the shift out of coal into oil in Latin America.

Table 1 Latin American modern energy consumption indicators before and after World War I

<table>
<thead>
<tr>
<th>Republics</th>
<th>1912</th>
<th>1922</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total modern energy consumption (Ktoe)</td>
<td>Coal as % of total energy consumption</td>
</tr>
<tr>
<td>Argentina</td>
<td>2429.49</td>
<td>91.89</td>
</tr>
<tr>
<td>Bolivia</td>
<td>5.37</td>
<td>31.76</td>
</tr>
<tr>
<td>Brazil</td>
<td>1652.46</td>
<td>86.60</td>
</tr>
<tr>
<td>Chile</td>
<td>1772.64</td>
<td>78.50</td>
</tr>
<tr>
<td>Colombia</td>
<td>12.13</td>
<td>37.22</td>
</tr>
<tr>
<td>Costa Rica</td>
<td>36.70</td>
<td>80.00</td>
</tr>
<tr>
<td>Cuba</td>
<td>964.76</td>
<td>88.79</td>
</tr>
<tr>
<td>Dominican Republic</td>
<td>12.60</td>
<td>76.89</td>
</tr>
<tr>
<td>Ecuador</td>
<td>15.17</td>
<td>80.70</td>
</tr>
<tr>
<td>El Salvador</td>
<td>0.82</td>
<td>14.62</td>
</tr>
<tr>
<td>Guatemala</td>
<td>30.51</td>
<td>38.32</td>
</tr>
<tr>
<td>Haiti</td>
<td>8.58</td>
<td>65.50</td>
</tr>
<tr>
<td>Honduras</td>
<td>7.07</td>
<td>56.07</td>
</tr>
<tr>
<td>Mexico</td>
<td>1560.24</td>
<td>68.71</td>
</tr>
<tr>
<td>Nicaragua</td>
<td>6.09</td>
<td>27.29</td>
</tr>
<tr>
<td>Panama</td>
<td>488.72</td>
<td>69.62</td>
</tr>
<tr>
<td>Paraguay</td>
<td>na</td>
<td>na</td>
</tr>
<tr>
<td>Peru</td>
<td>3448.86</td>
<td>62.72</td>
</tr>
<tr>
<td>Uruguay</td>
<td>191.39</td>
<td>92.10</td>
</tr>
<tr>
<td>Venezuela</td>
<td>21.36</td>
<td>71.98</td>
</tr>
<tr>
<td>Colonies and Territories</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Barbados</td>
<td>53.13</td>
<td>96.95</td>
</tr>
<tr>
<td>Bermuda</td>
<td>9.95</td>
<td>87.30</td>
</tr>
<tr>
<td>British Guiana</td>
<td>20.46</td>
<td>88.98</td>
</tr>
<tr>
<td>British Honduras</td>
<td>4.21</td>
<td>55.18</td>
</tr>
<tr>
<td>British West</td>
<td>119.16</td>
<td>98.52</td>
</tr>
<tr>
<td>Indies</td>
<td>84.02</td>
<td>99.48</td>
</tr>
<tr>
<td>Dutch Guiana</td>
<td>7.69</td>
<td>84.63</td>
</tr>
<tr>
<td>Dutch West</td>
<td>33.88</td>
<td>97.80</td>
</tr>
<tr>
<td>French Guiana</td>
<td>0.69</td>
<td>24.04</td>
</tr>
<tr>
<td>French West</td>
<td>50.27</td>
<td>96.84</td>
</tr>
<tr>
<td>Jamaica</td>
<td>48.09</td>
<td>90.55</td>
</tr>
<tr>
<td>Trinidad &amp; Tobago</td>
<td>120.77</td>
<td>59.28</td>
</tr>
</tbody>
</table>

Notes and sources: na: data not available; TOE: Tons of oil equivalent. Uruguay data belongs to (Bertoni and Roman, 2006). For all other countries, the methodology established in Rubio et al (2010) indicates that the total energy consumption is estimated as the sum of the import of coal and petroleum products as reported by the main trade partners, net of domestic production and trade. The sources for main trade partners are the following: Germany, Der Auswärtige Handel Deutschlands; US, Department of Commerce, The Foreign Commerce; United Kingdom: Statistical Office of the Customs and Excise Department, Annual Statement of the Trade. The sources for domestic production and trade of coal and petroleum (for the countries where it existed), are listed in Rubio et al (2010) tables 1, 2 and 5. Coal consumption data updated with data in Yañez et al (2013). Hydroelectricity production added using data in Rubio and Tafunell (2014) converted into TOE at heat value. Population data the Maddison Project.
What is special about Latin American transition out of coal? According to (Rubio and Folchi, 2012) first and foremost, that the prevalence of petroleum over coal occurred in Latin America in the 1920s, that is, 30 or 40 years in advance of the industrialised nations (see Table 1). It also happened at much lower level of average income per capita, putting a grain of salt on the energy ladder hypothesis. Second, most Latin American countries made their transitions from coal dominance to oil dominance in a short period of time, within a decade, often in less than 5 years. Finally, Latin American countries present models of energy transition not found elsewhere: revertible and inverse transitions. In revertible transitions countries could go for few years altering between one or the other as principal energy source, taking a while to settle for petroleum as the winning choice. The inverse transitions saw some small Central American republics going from kerosene pre-eminence to a small phase of coal, to finally turn to oil for good. According to (Rubio et al., 2010) ‘the fact that for the Central American countries, coal was mostly irrelevant already by 1925 provides an interesting hint. Had they been involved in the technologies of the first industrial revolution, they would have used coal. It seems these countries never made use of the classic steam engine, but made a jump straight to combustion engines, thus to petroleum products.’

While it is true that the precise nature of the future energy transitions is uncertain, and no standardized transition is expected as such, it is also true that the energy transition phenomenon can only be described as an historical phenomenon. Studying this historical case and boiling down causes and effects to their spare fundamentals, we may be able to understand the hows and whys; It may tell us where to look and where not to look for evidence. It may also help us to identify conditions that are necessary and/or sufficient for past choices and outcomes to influence the present. The next section sets out the scenario of the socio-spatial contexts of the Latin American energy supply in order to understand the changes brought by the Great War, where we argue that geography played a major role. The third section takes up the issues of scale and the question of whether it is possible to distinguish the effect of path dependence from the effect of the inertia of the energy systems. The final section looks at the global–local relationships that eventually also played a role in the early and swift transition out of coal in Latin America. Through the paper we use the databases of Latin American energy consumption and trade compiled over the years - originally constructed by (Rubio et al., 2010), later updated and extended by (Rubio and Folchi, 2012) to provide the evidence required. Minor amendments to the coal consumption data by Yañez et al (2013) and the latest data of the
hydroelectricity consumption by Rubio and Tafunell (2016) converted to equivalent tons of oil at heat value (toe) complete the data used for the estimates of energy consumption used throughout the paper.

2 The socio-spatial contexts of the Latin American energy supply

The coal trade in Latin America began at the end of the nineteenth century. The almost complete absence of this resource in the region made imports necessary, despite the fact that some coal had been produced in Chile and Mexico since 1890, in Peru since 1900, in Brazil since 1912, and in Venezuela in 1913 (Yáñez et al., 2013). Coal external dependence was a regional phenomenon: the sum of production of all the countries the region would not have been sufficient to supply the regional requirements of coal at any point. At best, only about a third of the coal consumption could have been covered domestically (see Figure 1).

[Figure 1: Latin American fossil fuel endowment vs fossil fuel consumption, selected years between 1890 and 1930]

Sources and notes: own elaboration for this paper from the databases behind (Rubio et al., 2010), later updated by (Rubio and Folchi, 2012), except for Uruguay which data belongs to (Bertoni and Roman, 2006). The countries included are those listed in Table 1.

The countries of the Southern Cone which initiated their industrialization process during the nineteenth century, tied their energy consumption patterns to the prevailing technology existing at the time: coal and the steam engine (see for instance (Badia-Miró
and Ducoing, 2013; Bertoni and Willebald, 2016) for Chile and Uruguay respectively). (Badia-Miró and Carreras-Marín, 2008) showed that although coal importation was imposed by the practical absence of the resource, there was some choice over coal suppliers. In the international market of the beginning of the 20th century there were only three large coal exporters: the USA, Great Britain, and Germany. Although German coal had a marginal presence in Latin America. Using a gravity model, (Badia-Miró and Carreras-Marín, 2008) find that transport costs, represented by distance, had the usual negative impact so that countries closer to the USA tended to import their coal from there rather than from the UK. Thus, for example, for Cuba, Ecuador, El Salvador, Guatemala, Haiti, Mexico, Nicaragua and the Dominican Republic, imports from the USA coal represented between 85% and 100% of total coal imports, while in the Southern Cone, the UK occupied a quota close to or above 80% in Chilean and Argentinean coal imports, and somewhat lower (60%) in the case of Brazil. Figure 2 shows the main energy trading partner of the countries of the region by 1913.

[Figure 2: Maps of countries with the US as major energy trade partners by 1913 vs countries that had made the transition to oil by 1925]

Sources and notes: as Table 1. The alternative to the USA as major energy supplier was in all cases the UK.

Coal reigned unchallenged as the major energy carrier in Latin America through the first decade of the 20th century. In 1910 Latin America consumed almost seven times more coal
than oil (see Figure 1). Most of it consumed in the Southern Cone and therefore massively imported from the UK (about 60 per cent of the total coal imports of the region came from the UK). Exceptionally, some very small energy consuming countries of Central America were at that date already consuming more petroleum than coal (see Table 3 in Rubio & Folchi, 2012).

The outbreak of the First World War was a watershed for Latin America, as for the rest of the world (Bulmer-Thomas, 2003; Thorp, 1998, 1989). The first months of the war brought a temporary collapse of most of the familiar infrastructures of commercial exchange. In the first year of the conflict the exports of the five largest economies (Argentina, Brazil, Chile, Colombia and Venezuela) decreased on average 23 percent according to (Kuntz Ficker, 2014, p. 121). The coincidental opening of the Panama Canal in 1914 hastened a change in transport patterns (Schuler, 2017). Generally speaking, the economies closely linked with the European markets –the UK, mainly, but also Germany and France- suffered the most the Great War. This was the case of all the large South American economies –Brazil, Argentina, Chile, and Uruguay-, and for some smaller countries in Central America, and the Caribbean. Mirroring the war economy developments in Western Europe, these economies faced increasingly poor economic conditions and skyrocketing insurance and freight rates. A number of economies, however, enjoyed positive growth during the war years: Honduras, Nicaragua, Venezuela, Dominican Republic, El Salvador, Mexico, Trinidad & Tobago, and Peru. All of which tended to have a more oriented trade towards the USA before the war (see Figure 2).

The war also had deep impacts on the energy markets. First, the war severely disrupted maritime routes. Coal was by far the dominant seaborne good in terms of weight (Klovland, 2017, n. 15). The coal export trade during the war was characterized by two key factors: a falling output of coal and a controlled redirection of exports in favor of the contenders. There was consequently much less coal available for other countries. Figure 3 shows that the imports of coal into Latin America continuously decreased from the start of the conflict, hitting bottom by 1919 when imports of coal had fallen to 40 per cent of the pre-war level. In fact, the pre-war levels of coal consumption and imports in Latin America did not recover before the Great Depression.

The second impact of the war into the energy socio-technical system developed partly because of the coal shortage. The incumbent energy technologies of the time, electricity and petroleum, increased their appeal. Both encountered incentives for applying steadfast improvements in their associated technological developments, the expansion of their infrastructure and supply networks and a widening market during the war and right afterwards. While electricity, and particularly hydroelectricity, started off from a trivial
level and will remain relatively small in the Latin American energy mix for few more decades (except in Brazil and Costa Rica, (Rubio and Tafunell, 2014)) it increased by 50% its weight in the energy consumption of the region over the war years (see Fig.3). By its part petroleum production swollen in the region during the war and the immediate postwar, tripling its level of consumption in the region (see Fig.3).

Before the War, the USA produced about 60 per cent of the petroleum produced in the world (American Petroleum Institute, 1937, p. 56). The distortions introduced by the War, the Soviet Revolution – halting 20 per cent of the world’s oil production, the cold winters of the end of the 1910s, plus the war effort, produced the first petroleum shortage of the 20th century (Rubio, 2006). The scenario for a worldwide rush for oil was set. Seven Latin American countries became producers during the period considered, and those that were already producing crude before the war, become exporters (see Table 2). Subsequently, domestic oil production in Latin America surged during World War I (see Figure 1 above, and (Philip, 1982; Wirth, 2001)). Of these countries, Mexico remained as the main oil
producer outside the USA until the end of the 1920s when Venezuela first (1928) and the Soviet Union later (1931) overtook that position.

Table 2 Starting dates of oil production and exports in Latin America

<table>
<thead>
<tr>
<th>Country</th>
<th>Production begins</th>
<th>First export reported</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peru</td>
<td>1896</td>
<td>1897</td>
</tr>
<tr>
<td>Mexico</td>
<td>1901</td>
<td>1911</td>
</tr>
<tr>
<td>Argentina</td>
<td>1908</td>
<td>1915</td>
</tr>
<tr>
<td>Trinidad &amp; Tobago</td>
<td>1909</td>
<td>1911</td>
</tr>
<tr>
<td>Venezuela</td>
<td>1917</td>
<td>1920</td>
</tr>
<tr>
<td>Ecuador</td>
<td>1917</td>
<td>1925</td>
</tr>
<tr>
<td>Colombia</td>
<td>1922</td>
<td>1926</td>
</tr>
</tbody>
</table>

Sources: (Rubio et al., 2010)

In the middle of the first historical oil shortage created by the final months of World War I and its aftermath, Mexico became the world's greatest exporter and second largest oil producer in 1921. By the end of the war Latin America produced more than half of the world's oil produced outside the United States. The region produced by 1920 more than three times the oil it consumed (see Fig. 1 and Fig. 3). Indeed, regional petroleum trade played a very important role within Latin America, especially oil from Mexico and Peru. In fact, Mexico supplied around 40 percent of all the petroleum imported by the Latin American countries by 1925. Peru, the third largest producer in the region, supplied 7 percent in the same date. It should be noted that Venezuelan production, more important than the Peruvian, passed unnoticed in the region's trade. Venezuelan production got almost entirely exported as crude oil to the Netherlands Antilles, where it was refined and re-exported to the United States and Europe. Still the USA were the origin of more than half of the tons of petroleum products imported by the Latin American countries during the first quarter of the 20th century.

In the Americas, the merchant fleet and the railways started the switch to fuel oil engines. If by 1914 only 15 per cent of the cargo on board of USA flag fleet shipped using oil as locomotive fuel; by 1924 it was 62 per cent and 71 per cent in 1934. The USA were well ahead of the rest of the world: in 1914 only 3 per cent of the tonnage shipped in the world was on an oil burning ship, 31 per cent in 1924 (American Petroleum Institute, 1937). The USA championed petroleum production and the combustion engine associated to it
embedded in ships, railways, planes, tanks, and of all kinds of motor vehicles. The 26.5 million vehicles registered in the USA by 1929 represented 78 per cent of the estimated motorcars in the world (Yergin, 1991). The USA were the leading supplier of motor vehicles in Latin America, although its hegemony became greater with the passage of time. In fact, before the World War the flow of automobiles imported from Europe was not negligible (Tafunell, 2009). This helps to partly explain the relationship shown in Figure 2, which demonstrates that the Latin American countries that had the USA as major energy supplier before the war made faster transitions to petroleum than those countries traditionally linked with the UK—the sponsor of the steam engine and coal trade.

As a final point related to the socio-spatial contexts of the Latin American energy supply, one may consider the role played by long-range transport costs in the choice between coal and petroleum. One ton of crude oil contains approximately 1.5 the energy of a ton of coal, taking less volume in any ship’s hold. We have seen that the suppliers of coal and oil were different and at different distances, long in most cases, from Latin American consumers. (Bertoni et al., 2009) provided evidence for Uruguay confronting far more favorable freight rates for the imports of oil than for coal. Transport costs could take up to half of the final price of the coal bought while for petroleum it would be around a third of the final price. Transporting British coal to Uruguay was much more expensive—more than twice—than transporting it to places within the European continent like Spain according to (Bertoni et al., 2009). We presume, the cost advantage of transporting oil versus transporting coal applied to most ports in Latin America. Which seems to be a good justification for undertaking an early transition to oil. This section signals that geography and historical contingency must be considered as important factors in the transition to oil in Latin America. In the next section, we explore other plausible explanations for understanding the (fast) pace of this transition.

3 Temporality and scale: path dependence vs the inertia of the energy systems

For most of the first half of the 20th century, over 90% of the total primary consumption of modern energy in Latin America was accomplished by just six countries: Argentina, Brazil, Chile, Cuba, Mexico and Uruguay (see data in Table 1 above). Yet, it is also important to establish at front that at the dawn of the 20th century Latin America consumed far less modern energy per capita and, in particular, far less coal than industrialized countries. This general observation hides the huge differences in the amount of modern energy available across the Latin American republics. In 1890, a Chilean consumed on average about 370 times more energy (specifically coal) than the average Guatemalan. The four largest consumers of energy in the region—Argentina, Chile, Cuba and Uruguay—consumed on average 17 times more modern energy per capita than
the rest. These striking differences did not happen in Europe: the UK (the largest modern energy consumer in the world at the time) consumed 40 times at much modern energy per capita as Portugal one of the poorer countries in Western Europe (data from (Kander et al., 2014).

Practically nothing changed in the first third of the century (the ratio was 12 times in 1900, 13 times in 1913, 12 again in 1925) (Rubio et al., 2010). Compared with other parts of the world, the citizens Argentina, Chile, Cuba, Mexico and Uruguay consumed more modern energy per capita than Spain before 1925. Which implies that they were more advanced economies than the Spanish in those moments. This view agrees with both the known macroeconomic data and the migratory flows of those decades.

Do the differences in the scale of energy consumption across Latin America and with respect to the industrialized world played a role in the pace of the transition out of coal? (Rubio and Folchi, 2012) interpret that the countries that began the process of industrialization early (Argentina, Chile, Uruguay and Brazil), tended to maintain the classic pattern of energy consumption based on coal. This may be a manifestation of path dependence, wherein switching to petroleum may be impeded by the existence of previously installed coal-burning machinery that is still in good condition. For instance, Argentina and Brazil had a noticeable capital stock in machinery circa 1913 (Tafunell and Ducoing, 2016). In the less-industrialised countries, fossil fuel consumption was small, coal was present in fewer productive sectors and was likely the result of decisions by a smaller number of companies. They show that the smaller the level of coal consumption, the faster and the earlier the transition to oil was, possibly because the replacement costs were minor when few machines/factories/sectors were involved. In other words, the largest consumers of coal took the longest to leave it behind.

The problem with this explanation is that it makes indistinguishable the effects of “path dependence” from the “inertia of the energy systems”, or whether these two are different effects after all. Path dependence has become a sort of umbrella category for all theories that explain why institutions, technological standards, or firm capabilities tend to persist. But also experts in energy transition refer to the “inertia of energy systems” when trying to explain how difficult, painful and slow is to alter a given course (Fouquet, 2016; Grubler, 2004; Smil, 2017). Both concepts are as difficult to pinpoint theoretically as they are to prove in empirical case studies. (Vergne and Durand, 2010) go at lengths trying to figure out what conditions are necessary to single out path dependence to clearly distinguish it from other ‘history matters’ kinds of theoretical constructs. They propose to narrow down path dependence definition to its logical core, recognizing that not every historical process is path-
dependent, but also that path-dependence can explain phenomena that other theories cannot. As such, they define that the necessary conditions for a process to be path dependent are contingency of the initial conditions and self-reinforcement. They defend that path dependence has a true theoretical substance that basically says: when contingently selected paths undergo self-reinforcement, then, ceteris paribus, lock-in will occur on one single path as alternative options are selected out (owing to negative externalities). Lock-in is a state of the system that cannot be escaped endogenously. According to these authors, because paths are selected contingently, lock-in can happen on any path, i.e. not necessarily on the optimal one. By his part, (Page, 2005) distinguished between phat and path dependent outcomes. If the history of outcomes matters, but not the order in which they occurred, he defined the process as being phat-dependent. However, for Page a process is path-dependent if the outcome in any period depends on history and can depend on their order. In other words, for Page, temporality matter in path dependent processes.

The inertia of the energy systems does not have, to our knowledge, a literature grounding the concept theoretically. There exists a literature on the inertia of organizations initiated by (Hannan and Freeman, 1984). Applied to the energy system, implies that large organizations are less likely than small ones to initiate radical structural change. Which is the same place one would arrive if one were to stick to the physic definition inertia: the tendency of an object to resist changes in its state of motion (including speed and direction). A more massive object has a greater tendency to resist change in its state of motion.

Recapitulating, while path dependence has to do with the weight that past choices have in limiting present and future decision making, the inertia of the energy system has embodied a scale effect not necessarily present in the former. Path-dependency literature help us understand lock-in, but it results less helpful to understand 'lock-out' or predict the pace of change. In that sense, inertia may be a more useful concept to investigate pace of change: changes in the energy system occur faster in systems with lower inertia.

Besides, there exists no empirical way to measure, compare, and contrasts whether one entity endured more or less path dependence than another. On the contrary, researchers could eventually attempt to proxy inertia by the size of the energy system undergoing transition by looking at the stock of capital related to energy usage, the amount of energy consumed, or any other measurable variable. Yet, such a measure is beyond the scale of this paper.

Thus, if we apply these reflections to the case of Latin American energy transition where does they take us? The transition out of coal was slower for the more developed
economies in Latin America, which were at the same time early adopters and large energy consumers. Their early choice of energy source was contingent to the time when it happened, the nineteen century, which limited the choice to coal and steam engine. It was not arbitrary or aleatory, but it was time contingent. As time went by, it allowed a deeper penetration the technology, a larger market share and larger sunk costs. There appeared the self-reinforcing mechanism, making the prevalent technology more and more dominant over time. Thus, for these economies one can identify both a path dependence effect (time contingent and self-reinforced) and an inertial effect (due to the size of their energy systems).

The latecomers, however, had a wider set of choices at their disposal when they arrived to configure their energy systems few decades after the early comers. Furthermore, even if they had some previous investment made on coal technologies, these were small and were rapidly outpaced by the adoption of the incumbent technologies. It was their smaller inertia what allowed most Latin American economies to switch swiftly from coal into oil, within socio-spatial contexts and the historical contingencies explained in the previous section. Then, some other aspects related to the global-local relationships played a role too in the early transition out of coal.

4 The global-local relationships

The dynamics of socio-technical change evolve within a global economy which has different repercussions at the local level. According to (Dicken, 1994) the most commonly held position is the one which sees the nation-state as the fundamental building block of the global economy. The state is seen as both the container of economic (and other social) processes and the primary regulator of such processes both internally and across its national borders. From this perspective, therefore, the global economy is a set of interlocking national economies. The conventional approach is that exchanges (of goods and services, investment, people, knowledge, etc) take place between states/countries. Although that is statistically correct it is, in functional terms, an illusion. For the most part, companies exchange goods and services, investment, and knowledge, not states. The forgone sections of this paper adopted the nation-state as the unit the unit of analysis. This last section, attempts to mitigate that bias by considering the changing nature of the global–local relationships over the period.

Firms and states are the two major shapers of the global economy; they are involved highly embedded interacting networks consisting of firm-firm, state-state and firm-state relationships (Stopford and Strange, 1991). This nexus of relationships constitutes the framework within which organizational and technological changes occur. States attempt
to regulate the inter-firm transactions that cross their borders. In so doing, they adopt and implement policies designed to regulate trade and investment. Such regulatory behaviour brings states into particular kinds of relationships with firms (both domestic and foreign) and with other states. Relationships that may favour one technological system over another if they exhibit strong national biases (as we saw in section 2 above with the UK championing coal vs the USA as major oil exporter). The centrality of international firms and nation-states in shaping the changing geography of the global economy (Dicken 1986, 1992a) is a question of where power lies, and it is a central problem facing both firms and states. This section ponders whether the shifts of power balance as a consequence of the First World war was likely to impact on the Latin American energy system. It concentrates on the oil producers within the region as paradigm of the power struggle between firms and nation-states.

At the dawn of the twentieth century most Latin American economies based their economies on the primary sector. The globalisation of world trade that had been slowly taking place from the mid 19th century, allowed Latin American economies to follow a pattern of typical export economies, which depended upon increasing exploitation of natural resources with cheap labour and foreign capital and technology to expand production for overseas markets. The oil industry added to the ‘export-led’ pattern of the early part of the century, just displacing some traditional products such as coffee and cacao in Venezuela and silver in Mexico (Rubio Varas, 2015).

The globalizing era tilted the balance of power in favour of the companies, but the First World War changed the scenario. Before 1911 foreign companies found extensive liberal legislative facilities to search for oil in Latin America, even if it was only commercially exploited in very few of them before that date (see section 2 above). In Mexico the Petroleum Law (1901) allowed the granting of concessions on public lands, and the Mining Law of 1909 reaffirmed the rights of landowners to develop their subterranean assets. Multinational firms from U.S. and Great Britain bought much of the land securing their stake in Mexican oil. The War (and the coetaneous Mexican Revolution) awoke a spirit of nationalism in all countries, which involved the ideas of self-determination, self-preservation and national security (Rubio, 2006). The latter idea immediately suggested the importance of conserving the natural resources and raw materials of any given country.

Argentina was the first Latin American country to establish a national oil company, YPF in 1907, and one of the first to pass strict legislative measures limiting the activities of private oil companies (see Philip (1982)). In Mexico, oil companies managed to isolate production from the effects of the Revolution and continue to produce for the war effort so
that output in 1921 was fifty-three times greater than in 1910 (Rubio, 2006). Until 1911, the Mexican government gave extensive facilities to the companies, granting concessions without for instance imposing specific taxes to oil production. This attitude slowly changed, partly due to the nationalism arising from the Revolution, but also owed to the increasing economic importance of oil for Mexico. Rather than utilizing oil for the benefit of the companies and foreign nations, the path towards economic success should be through affordable energy for the country. These ideals received their most famous – though not necessarily their most efficacious- assertion in the article 27 of Mexican Constitution of 1917. The article reverted the ownership of underground substances to the state. Foreigners could lease the underground privileges but never actually own them. Conservation and distribution issues were at the core of the article that would provide the constitutional basis for the oil expropriation few decades later in 1938. From the companies’ side, the government's increasing nationalist tendencies paralysed exploration and reduced production. The creation of national reserves –i.e., the retention of land for further exploration and potential exploitation by the state- exemplified the point made by the companies. As a consequence, capital started to flow away from Mexico, particularly to Venezuela (Brown, 1993, 1985). Nonetheless, the immediate post-revolutionary governments maintained a hands-off policy with regards to USA property, and the potential threat posed by the 1917 Mexican Constitution was not taken very seriously in the 1920s (Thorp 1989). Nevertheless, it influenced other Latin American nations. From 1919 and for the first years of the 1920s, both Colombia and Ecuador tried (but mostly failed) to enforce petroleum laws inspired on the Mexican legislation. Despite several modifications to the original laws, the foreign companies argued that the legislations of both countries were far from satisfactory for their interest. According to (Wilkins, 1974) in Peru and Bolivia the problems were no so much legislative over property and concessions, as fiscal. Long running conflicts about tax evasion and fraud affected the development of oil production in both countries. From this account, it appears clear that the very few countries that offered open door policies, such as Venezuela, were exceptional among the oil producing countries of Latin America at the end of First World War. But even in Venezuela, criticism with the liberal policies towards oil companies existed: the oil concessions were nothing but the ‘surrender of national sovereignty to the imperialist capital’ (Allen, 1977)). Oil had become part of the national strategies for economic development. Furthermore, even among the countries lacking oil, we can identify some changes that took place in the same period and that also fall within this category of the global-local relationships affecting the energy socio-technical system in Latin America. For instance, in
the case of Uruguay, Bertoni et al. (2009) report that the government pursued a strategy to favour American capital investors to “shake off the British yoke”. Such promotion included the construction of infrastructure, such as paved roads, to facilitate the adoption of motor vehicles. The US Consul in Montevideo reported in 1912 of the ‘persistent efforts of an agent of an American company […] who has kept the good qualities of the car he represents constantly before the public. The appearance of American automobiles on the streets attracted widespread attention, and when it was shown that they were at least the equal of any European car sold here, and the cost was much below that of the European makes […] there arose a demand for more cars than could be supplied’ (US Bureau of Manufactures, 1912). As a result, during the war and its aftermath Uruguay became the second largest relative importer of cars from the USA per 10,000 habitants in Latin America after Cuba, as shown in Figure 4. In total, Uruguay had accumulated a number of motor vehicles per capita that doubled at the time the number of European countries like Spain.

[Figure 4 Accumulated imports of motor vehicles from the USA in selected Latin American countries by 10,000 habitants]

Sources and notes: data on trade of motor vehicles from the USA from the (U.S. Department of Commerce, 1915), annually accumulated for the period, divided by national population from (Maddison, 2003).
The anecdotal evidence provided in this section suggests that the shifts of power balance in the global-local relationships because of the First World impacted on the Latin American energy system favouring the adoption of oil. Truly, these were slow changes which effects continued to influence the decades ahead.

Conclusions

This paper deepens on the analysis of the early transition from coal to petroleum in Latin America, an episode marked by the disruptions created by First World War. The revisited evidence shows that geography and historical contingency stood as important factors in the transition to oil in Latin America. We identified that both a path dependence effect (time contingent and self-reinforced) and an inertial effect (due to the small size of their energy systems), explain the rapid pace of the transition toward the incumbent technology. And finally, that the changes on the global-local interacting networks consisting of firm-firm, state-state and firm-state relationships favoured one technological system (petroleum) over another (coal).

By concentrating on the economic aspects this paper offers bits and pieces for understanding the dynamics of transitions, but also have drawbacks and makes limited cross-sections of other aspects affecting the socio-technical systems. Yet it is hoped that it helps to show the role that history can play in the analysis of the theory and policy of sociotechnical transitions. The case of Latin America highlights the value of considering space and scale to better understand the intricate dynamics through which innovation systems might occur. Particularly, the value of looking outside the Western economies. For the policy makers, one message can be taken away: to be aware of the opportunities that historical contingencies might represent for changing the status quo of the sociotechnical systems.

References

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