The Changing Roles of Actors in 'Fortuitous' Sustainability Transitions: An Analysis of Brazil's Passenger Vehicles Fuel Technology from 1970 to 2020

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Abstract

Sustainable socio-technical transitions refer to the multi-dimensional shifts societies undergo when they move from one socio-technical system to another that is perceived to be less damaging to the environment. A well-known theoretical framework – the multi-level perspective (MLP) – is often used to investigate the factors that trigger or hamper these shifts. However, to deal with the complexity of sustainable transitions, authors have increasingly complemented it with the multiple stream approach (MSA) in an effort to capture a wider range of factors and contexts. This 'augmented' approach is used to investigate transformations in the fuel-technology used in Brazil's passenger vehicle fleet from 1970 to 2020, with a focus on the actors involved in the transition. In addition to capturing this unusual story through the lens of social-technical transitions, our analyses highlight the changing role regime outsiders and dormant policies played throughout this period, while emphasising the importance of 'fortuitous' windows of opportunity. In doing so, we complement the existing literature on sustainable socio-technical transitions by adding contextual factors that may be particularly relevant for developing economies in their attempts to address persistent sustainability problems. Our approach also delivers new technological forecasting insights that can assist transition planning.

Keywords: Transitions; Multi-level Perspective; Multiple Stream Approach; Passenger Vehicles; Brazil

1 Introduction

Tackling climate change requires shifting our current socio-technical systems to more sustainable alternatives in a process that has become known as ‘socio-technical sustainability transitions’ (Markard, Raven, & Truffer, 2012). Given their importance, many studies explore the complex dynamics that underpin these transitions (Elzen, Geels, Hofman, & Green, 2004; Geels, 2005; van Sluisveld, Hof, Carrara et al., 2018). The bulk of these use a multi-level perspective (MLP) (Geels, 2002) while others apply a multiple streams approach (MSA) (Kingdon, 1984) depending on the weight they assign to technological factors versus political and agency processes.

In recent years, however, an increasing number of authors complement the MLP perspective with the MSA, capitalising on the different insights they offer (Elzen, Geels, Leeuwis, & van Mierlo, 2011; Normann, 2015; Derwort, Newig, & Jager, 2018; Walwyn, 2020). We do so here in an attempt to identify and narrate the events - and the mechanisms reinforcing these - pertaining to the fuel-technology transition of Brazil’s passenger vehicle fleet between 1970 and 2020 (Cornelissen, 2017). In doing so, we find that there are important opportunities for additional insights that have yet to be exploited by existing studies that augment the MLP framework with the MSA. In particular, responding to a call by Kanger, Sovacool, and Noorkõiv (2020), we emphasize insights into the role of the transition’s actors: the people, groups, or organizations which influenced the transition by initiating, supporting, or constraining the occurrence of transformative change at particular intervention point.

We argue that the role played by elements of resistance and secondary actors in the transition process has largely been ignored, as are the lingering effects that national policies continue to exert on transitions actors after the policies have become inactive. Perhaps equally important is the potential for ‘fortuitous’ windows of opportunity for sustainability transitions. We argue that these findings enrich our understanding of sustainable socio-technical transitions, and ultimately facilitate the implementation of systems that address persistent sustainability problems.

The MLP framework distinguishes between three ‘analytical’ levels that need to interact for transitions to occur. These include (i) technological niches for innovations such as incubators, i.e. protected ‘spaces’, (ii) socio-technical regimes – i.e. the set of rules that maintain the socio-technical system, and (iii) the socio-technical landscape which refers to external factors that are largely outside the control of actors but influence their actions (e.g. oil prices) (Geels, 2002). Proponents of MLP stipulate that radical innovations arise when a ‘window of opportunity’ emerges at the regime and landscape levels. While adept at capturing technological dynamics, critics of the MLP argue that it underrepresents the role of political and agency factors thereby reducing its explanatory power (Edmondson, Kern, & Rogge, 2018; Derwort et al., 2018).

Theories of the policy process, on the other hand, are perhaps better equipped at conceptualising the role of power and institutions and explaining how solutions become attached to different problems, even 'wicked' ones involving substantial goal conflicts, technical disputes, and multiple actors (Kern & Rogge, 2018; Köhler, Geels, Kern et al., 2019; Markard, Suter, & Ingold, 2016). Policy process theorists use theoretical devices that focus on understanding how policy-makers coalesce in their interpretation of contextual shocks in the process of policy changes (Sabatier, 2007). Kingdon's Multiple Stream Approach (MSA) synthesised these heuristic devices by differentiating between the three main streams of the policy process – i.e. policy, problem, and politics – thereby capturing the preoccupation of those interested in agency and how political processes promote policy changes (Kingdon, 1984).

In other words, the MLP provides a broader more fundamental perspective that captures interactions between technologies, regime insiders and outside influences through time and in so doing, facilitates the identification of 'transition pathways' (Geels & Schot, 2007; Geels, Kern, Fuchs et al., 2016). MSA complements these accounts by internalising the political factors that underpin these transitions (Derwort et al., 2018; Kern & Rogge, 2018). Unsurprisingly, scholars investigating sustainable socio-technical transitions, or particular technologies within these transitions, are increasingly supplementing the MLP with the MSA in an effort to capitalise on their complementary insights (Elzen et al., 2011; Normann, 2015; Derwort et al., 2018).

We follow their lead by augmenting the MLP framework with MSA insights while honing in on the role of actors in the transition (i.e. their salience and stance in each stage); distinguishing between regime insiders and outside actors. The resulting actor-centered MLP framework is used to 'process-narrate' the fuel-technology transitions of Brazil's passenger vehicle fleet since 1970 (Cornelissen, 2017). This fuel-technology changed three times over the past five decades, providing a rich and interesting setting in which to assess the explanatory power of the combined *actor-centred* MLP and MSA frameworks.

Our application highlights four important gaps and tensions that emerge when using these heuristic devices. Firstly, the findings emphasise the importance of tracking the changing salience of the multiple actors involved in the policy process through time. Secondly, they demonstrate the benefits of looking at actors' shifting political stances (supportive, neutral, resistant), establishing that these can be as important as technologies and policies in capturing the complexities of transitions. In this regard, our study responds to the call by Kanger, Sovacool, and Noorkõiv (2020) for further research into the actors effecting change during transitions. Thirdly, they show the influence national policies continue to exert on the transition process long after they have become officially 'inactive'. Finally, our narrative emphasises how sustainability transitions can be fortuitous, and not necessarily the outcome of deliberate and intentional measures sponsored by sustainability-oriented policies and organised action. This leads to discussions of how both 'problem-fitting solution' and 'solution-fitting problem' approaches can aid the process of policymaking.

The latter is particularly important as it contradicts the view that "sustainability transitions are the outcome of long term goals involving a broad range of actors working together in a coordinated and purposeful way" (Markard et al., 2012, p. 956-957; see also Berkeley, Bailey, Jones, & Jarvis, 2017 and Kern & Rogge, 2018). More concretely, we find that 'fortuitous' sustainability transitions - i.e. those that materialise when an existing economic solution is paired with an emerging environmental problem - provide another conduit for sustainable socio-technical transitions (Kern & Rogge, 2018). We argue that these may be particularly relevant in resources-constrained developing countries where economic concerns tend to be prioritised over environmental ones (Köhler et al., 2019; Walwyn, 2020). Capitalising on their potential requires agile, creative and pragmatic policy entrepreneurs that can recognise and act upon these opportunities.

The paper is structured as follows. Section 2 briefly reviews the MLP and MSA frameworks, documents past efforts to use them concurrently and defines the dimensions proposed to study the role played by transition's actors. Sections 3 describes the sources and methods used in the analysis of Brazil's passenger fuel-technology fleet from 1970 to 2020, while Section 4 presents the narrative and highlights its key findings. A discussion follows in Section 5 while brief conclusions appear in Section 6.

2 Narrating socio-technical transitions

Scholars investigating social-technical system transitions have developed simple heuristic devices that are meant to facilitate our understanding of the policy process in relation to what are essentially very complex phenomena. While these frameworks assemble insights from several disciplines, each tend to specialise on some particular aspect of transitions. However, as the pace and scale of large unforeseen environmental disasters increases, scholars are under pressure to enhance the relevance and applicability of their approaches. Accordingly, recent analyses of social-technical transitions rely on a diversity of frameworks in an attempt to capture a wider range of factors. We present a brief account of studies that combined the MLP and MSA social-technical system transition approaches, the challenges they faced, and how we propose to mitigate these.

2.1 The Multi-Level Perspective (MLP)

As the name suggests, the MLP explores socio-technical transitions from three different levels - landscape, socio-technical regime, and innovation niche - each framed by concepts adapted principally from sociology, evolutionary economics, and institutional theory (Elzen et al., 2004). The MLP is particularly adept at identifying ‘windows of opportunities’ that can precipitate socio-technical changes and the transition pathways they engender (Geels, 2002; Geels & Schot, 2007). The framework has been used to identify transitions to electric mobility (Berkeley et al., 2017; Mazur, Contestabile, Offer, & Brandon, 2015), teleworking (Hynes, 2016), bike sharing (Ó Tuama, 2015), low carbon urban mobility in general (Moradi & Vagnoni, 2018), in the agro-food systems (Bui, Cardona, Lamine, & Cerf, 2016), and in studies combining MLP with quantitative models to assess sociotechnical system transitions and enrich scenario analysis (Hof, Carrara, De Cian, et al., 2020; De Cian, Dasgupta, Hof et al., 2020). Figure 1 and Table 1 below provide the original and simplified depiction of the MLP framework in which the three levels are independent and the landscape is exogenously determined. More recent contributions examine transition pathways through the lens of endogenous enactment that allow for more nuanced depictions of interactions between actors, technology and institutions and less radical forms of innovations (Geels et al., 2016).

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2.2 The Multiple Streams Approach (MSA)

Another useful tool in socio-technical system transition's toolbox is the MSA. This analytical device focuses more explicitly on policymaking. In particular, it recognises that policymaking operates under conditions of ambiguity characterised by high actor turnover and unclear jurisdictions, not according to a rational and orderly process with clearly defined goals and accountabilities (Kingdon, 1984). It posits that policies are more likely to emerge when events in the three 'streams' – problem, politics, and policy - converge within the same time frame, creating a window of opportunity for the enactment of change. The closer the alignment time wise, the greater the probability that change will materialise.

Figure 2 provides a simple depiction of the MSA. The problem stream is assessed by indicators that measure the extent of a particular condition (e.g. CO_2 emission), focusing events that bring this condition to the attention of society (e.g. crisis, disaster), feedback which can be thought of as interventions that have worked in the past, and load which reflects competing pressures on policymakers. The politics stream consists of factors related to electoral, political parties, and/or pressure groups which together capture 'the broader environment within which policy is made' (Ackrill, Kay, & Zahariadis, 2013, p. 873). Party ideology relates to the political stance of the administrators in power while the national mood represents wider public opinion in the country on a particular set of issues. Finally, the policy stream captures the range and nature of the proposed solutions to identified problems, their acceptability to the public, their technical feasibility, and the extent to which participants in the process interact with one another. Policy entrepreneurs facilitate the alignment of these three streams, articulate policy processes, and ensure that policy outputs materialise (Mintrom, 1997; Bakir, 2009; Timmermans, van der Heiden, & Born, 2014).

Of importance is the recognition by both the MLP and MSA that windows of opportunities are temporary and may appear and close at any time.

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2.3 Combining the MLP and MSA

A number of authors complement the MLP with an MSA component. For instance, in their study of pig husbandry, Elzen et al. (2011) redefined existing MSA streams to 'fit' dimensions of the MLP that were highly relevant to their study (e.g. market and technology) while emphasising the regulatory aspects of innovation and socio-technical regimes, rather than policy per se. Another example is Normann's (2015) study of offshore wind politics in which the three MSA streams are maintained but interpreted sufficiently broadly to include technological niches within the policy stream. Derwort et al. (2018) also uses the two frameworks in their study of energy transition. Although they make no attempt at integrating them, they discuss their respective strengths and weaknesses. In his South African study on decarbonisation, Walwyn (2020) highlights the importance of resource constraints on the transition process by adding a techno-economic stream to the MSA. Together these studies suggest that the MLP is particularly adept at representing the technological aspects from a historical perspective while the strength of the MSA resides in its ability to identify and map out the role of agency and power relations[1].

Process-narrating the fuel-technology transitions of light-vehicles fleet in Brazil is a tall order. Notwithstanding the usual challenges of categorising events, actors, and innovations into niche, regime, and landscape (MLP) or problem, politics, and policy (MSA), the transition we are investigating took place over half a century in a different geography to where most applications of social-technical systems transitions are based (Derwort et al., 2018; Hansen & Coenen, 2015). While this allows for a richer and more complete account of the transition – i.e. one that captures feedback effects of policy outcomes on the process - it also increases the number of actors involved and multiplies the events to consider, heightening the power of the authors over the narration process (Köhler et al., 2019). Acknowledging these caveats and recognising that no individual framework will be sufficient to capture the complexity of the phenomenon under study (Kern & Rogge, 2018), we build on insights gathered from previous attempts at augmenting the MLP with the MSA and provide additional developments.

Our study posits that the MLP provides a 'big picture' integrative approach that accommodates multiple actors and dimensions, and can be used to investigate radical innovations that impact on the whole of society, to more restricted transformations affecting particular sectors (Geels, 2019, p. 11). Appending the MSA streams to the MLP-levels, enriches the analyses by highlighting context specific factors – i.e. the MSA acts as a magnifying glass for the policy and politics

[1] The technological innovation system (TIS) is another approach much used in transition studies. However, the TIS adopts a narrower and more inward-looking analysis that fails to embrace the wider system shift perspective contemplated here (Markard et al., 2012; Walz, Köhler, & Lerch, 2016). See Andersen (2015) for a TIS application of Brazil's sugarcane sector 1900-1973.

elements that are invariably embedded in the MLP. The analysis template we used thus consolidates technological, policy, political, and market forces and provides a consistent frame in which to narrate the several moving parts of this longer-term transition.

More concretely, we supplement the MLP landscape level with the problem and politics streams (MSA) and labelled this the 'Landscape Dimension'. Likewise, we add the politics and policy streams (MSA) to the regime level (MLP) and labelled this the 'Regime Dimension'. Finally, we use the policy stream (MSA) to supplement the niche innovation level (MLP) and named this the 'Technical Dimension'. Dimension is a broader term that comprises concepts of levels and streams used in the MLP and MSA frameworks respectively. The dimensions remain faithful to the traditional MLP framework, but movement inside and between them are influenced by elements of the MSA that capture the dynamics of power and agency in transitions.

The Landscape Dimension captures exogenous pressures that are perceived by regime actors but lie largely beyond their influence. However, through time, the elements embedded in the problem and politics streams can coalesce and help shift the wider strictures of the landscape dimension. The Regime Dimension is the subject of political dynamics that are often considered to be exogenously determined within the time frame of the analysis. Nonetheless – and given the extended time scale of our study - we argue that 'national moods' can become malleable and instruments of regime change. We distinguish between 'insiders' and 'outsiders' national mood with the former capturing the regime incumbent's mood and the later referring to the general public's disposition towards an issue. Forces at play in the politics and policy streams can, with time, influence the national mood thereby altering regime parameters.

The Technical Dimension is only linked to agency elements through the policy stream. The Policy stream is conceived as a 'solutions' stream and naturally aligns with the standard interpretation of niche-innovation (Normann, 2015). Hence the Technical Dimension can be influenced by incumbent actors as well as new entrants (Geels et al., 2016). By allowing the policy stream to straddle both the Regime and Technical Dimensions, we also recognise that policy actors can influence, with time, the regime level as well as the technological solutions. These assumptions implicitly recognise that policy may be enacted by governments but it is influenced by policy entrepreneurs, which can come from both the regime or technical dimensions. For simplicity, we do not categorise market and technology into separate MSA streams as proposed by Elzen et al. (2011) or the techno-economic stream proposed by Walwyn (2020) but retain the 'market/user preferences' and 'technology' variables of the original MLP framework and the technical feasibility of the MSA policy stream. Figure 3 summarises how we consolidated the MSA and MLP into a single template.

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Finally, while the augmented MLP model of Figure 3 provides a more complete tool for the investigation of sustainable transitions, its ability to capture the agency of actors remains limited despite recent progress in developing the micro-foundations of social-technical transitions (Kanger, 2020; Geels, 2020). More concretely, we transferred Mitchell's et al. (1997) concept of 'stakeholder salience' - the degree to which managers prioritise competing stakeholder pressures - to the social-technical transitions context by re-interpreting it as 'actor salience' – the degree to which the social-transition system prioritises competing actor pressures. Since salience is conceived as a function of power, legitimacy and urgency, this allows us to classify niche and regime actors as 'primary' or 'secondary' depending on their ability to exert pressures for change (their salience) during a given period.

We also transfer Neville and Menguc's (2006, p. 387) suggestion to determine "which stakeholders are supportive of the organisation's activities and which are not..." by considering the direction, strength, and synergies of actor pressures, or more generally their 'stance' which can be supportive, neutral or antagonistic. Accordingly, and in addition to actor salience, we introduce the notion of actor stance, which can be categorised as supportive, neutral, or resistant to change in technology or in policy. We suggest that key actors, those which substantially shape transitions, have high salience (they are primary actors) and a non-neutral stance.

These features are added to the standard model in what we propose is an *actor-centred* MLP and MSA framework. Figure 4 highlights insider and outsider national actors' 'salience' using textured lines while their respective stance toward a social-technical system transition is represented by colours (red-resistant, blue-supportive, and grey-neutral). As in the original MLP template from Geels and Schot (2007) (see Figure 1), the long dotted arrows represent the strong influence of existing regimes and landscape on the niche level, the short diverging arrows denote uncertainty and differences of opinion, the longer full black arrows represent ongoing incremental processes and the orange arrow[2] represents the incremental processes prompted by regime insiders.

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3 Methods and data sources

We follow a process-model theorizing approach (Cornelissen, 2017) to investigate the fuel-technology transition of Brazil's passenger vehicle fleet since 1970. Brazil provides an interesting case study given its history of investing in ethanol (National Alcohol Programme, *Proálcool*) which, unbeknown to policy-makers at the time, proved to be a much greener alternative to other fuels and a more sustainable approach for the development of the sector.[3] By supplementing the MLP with the MSA, our approach is reminiscent of parallel process theorizing (Cloutier & Langley, 2020). We argue that doing so enriches the narrative by empirically identifying elements that improve understanding of stage-level and cross-level dynamics and resulting process outcomes. More concretely, the structure and components of Figure 4 guided how we gathered and extracted the information contained in the corpus of documents collected through a systematic search of government, academic, practitioner, and journalistic publications published over the past 50 years.

We used a three-pronged approach to our document search to ensure that we had adequate representation from experts, policy-makers, policy entrepreneurs and the wider public. Firstly, we collected documents that explicitly referred to the sugar-ethanol industry using *Proálcool* (and relevant variations[4]) in the Scopus platform. This exercise yielded 44 documents, most of which were of a historical nature and produced by scholars and industry experts discussing some aspects of the *Proálcool* investment programme launched by the Brazilian government in 1975. Secondly, we used the same terms to search the National Archive Information System (SIAN) and legislation

[2] Note that in reference to Geels et al. (2016), the orange arrow was added to capture the incremental processes prompted by regime insiders.

[3] CO2 emissions of ethanol cars are significantly lower than those fueled by gasoline (see Cadernos NAE / Núcleo de Assuntos Estratégicos da Presidência da República. Biocombustíveis (*Nucleus of Strategic Affairs of the Presidency of the Republic. Biofuels*). No 2 (jan. 2005). Brasília: Secretaria de Comunicação de Governo e Gestão Estratégica (*Brasilia: Government Communication Secretariat and Strategic Management*), 2005).

[4] *Proálcool* is short for "national alcohol programme". Other search terms included (in English and Portuguese): 'National ethanol programme', 'Brazilian ethanol programme', 'Brazil's alcohol programme'.

databases to gather government documents on the subject of ethanol. This produced 1,172 and 11 additional documents respectively. Finally, we used the same terms to search the archives of a popular and widely distributed national newspaper in Brazil, the *O Globo*. For consistency, we also examined the archives of two other popular national newspapers (*Folha de S. Paulo* and *O Estado de S. Paulo*). This produced an additional 2,612 documents. The original corpus of data was thus composed of 3,839 documents.

Since the initial search was likely to collect documents with little relevance to our research (e.g. adverts referring to ethanol, job listings, etc.), we searched document titles (and abstracts for documents listed in Scopus) and eliminated those that had little connections to the themes of this study. As expected, a large number of documents found in the SIAN and *O Globo* archives had little relevance to our research subject. The corpus of documents was reduced to 102 documents following this cull. Table 2 provides additional details of our searches.

We delineated five distinct periods in the transition based on the occurrence of pressures on the main landscape (1970-1980, 1980-1986, 1986-1990, 1990-2000, and 2000-2020). These periods are also identified in previous studies (e.g. in Oliveira, 2002; Bennertz, R., 2014, Bennertz and Rip, 2018). Transition actors were identified using sources reviewing these distinct periods. We then used the combined *actor-centred* MLP and MSA model (Figure 4) to track how the stance and salience of the actors evolved in each of these periods and the events that hampered or enhanced the transition. We also used the framework to guide our interpretation of the transition and form an overall impression of whether it progressed, regressed, or stagnated during the period under study.

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4 Brazil socio-technical fuel-technology transition

While we used Figure 4 to guide what information we extracted from the documents, we recognised that actors can be inconsequential for several periods before emerging or re-emerging as agents of change (Jawahar & McLaughlin, 2001). Hence, to identify the elements (actors, events, policies) whose influence persisted in some form or the other throughout the 50-year period, the application of our template required an initial reading of all the documents irrespective of publication date. Once this identification was completed, we revisited each decade using documents produced by governments, experts, and newspapers to describe the elements at play during the specific period.[5] What follows is a brief account of these findings.

4.1 Stage 1 – Transition triggers (1970-1980)

The first catalyst in Brazil's fuel-technology transition is linked to the drastic change in the landscape that followed the 1973 oil crisis. At the time, Brazil was importing most of its oil (80%) such that the increase in the price of oil led to a 225% sudden rise in expenditures for Petrobras, Brazil's state-owned monopoly energy supplier (Santos, 1985; Santos, 1993). Brazil was also heavily involved in the export of sugar which were regulated by the Sugar and Ethanol Institute or IAA[6] (Brazil, 1933). Around the same period (mid-1975), the world supply of sugar increased leading to a substantial fall in the international price of sugar (Szmrecsányi & Moreira, 1991).

The confluence of these two 'landscape' events (the sudden rise in oil price and fall in sugar price) created a window of opportunity for the ethanol industry to increase its production and led to the establishment of the National Ethanol Programme (*Proálcool)* in 1975 (Brazil, 1975). The policy stream was activated and regulation authorising a rise of anhydrous ethanol rate from 5% to 20% in the gasoline blend was enacted. These developments did not require major technological adaptions of car engines or filling stations infrastructure.

The national mood was mainly driven by Brazil's military government (i.e. the executive power was controlled by the military but legislative authority was held by elected party members) and by sugar and ethanol producers who had sufficient power to influence policy and policymakers (SIAN, 1988). Copersucar and Coperflu, two major sugarcane producer cooperatives, are on record as supporting the transformation policies with enthusiasm and even criticizing the low production targets set in the first phase of *Proálcool*. Other incumbents, including Petrobras and some automakers, were more indifferent or resistant to these changes. However, in the face of an economic collapse and with the population generally supportive of the ethanol policy and its promises of cheaper fuel and economic stability, their complaints had relatively little impact, relegating them to the role of secondary actors in this particular period (Oliveira, 2002).

In addition to actors located within the political sphere, we note that there were also experts, academics, and social groupings operating outside this network. At the time, these secondary actors had very little influence on the transition process but evidence suggests that they were

[5] These references are listed in the online appendix.
[6] The *Instituto do Açúcar e do Álcool* (IAA) in Portuguese.

generally in favour of a national strategy aimed at reducing Brazil's dependency on oil by increasing its use of ethanol (Calmon, 1978).

This first phase is characterised by a transformation transition pathway with low-level and more restricted incremental change – i.e. the technology did not require major disruptions - and 'endogenous' enactment by the government. It is strongly associated with the president of the time (Ernesto Geisel) and his Ministry of Industry and Commerce (MIC) who acted to prevent an impending economic crisis (Santos, 1993). Other insider actors were also instrumental in supporting ethanol-based fuels. While outsiders were less influential during this period, evidence suggests that they too were in favour of these developments. The pre-existence of the sugarcane and automotive sectors meant that ethanol-based fuels were technically feasible and their use during the interwar years rendered them socially acceptable and marketable.

4.2 Stage 2 – System reconfiguration (1980-1986)

The second oil price shock of 1979 gave momentum to initiatives that would allow Brazil to further diversify itself away from petrol (SIAN, 1986). Headlines claiming that 'ethanol will substitute gasoline' became regular features of media outlets and support for *Proálcool* was widespread (Globo, 1980b, 1980a). There were technological challenges however, as the infrastructure required to accommodate the increased ethanol production and appropriate tanking and distribution facilities was lacking (Moraes & Zilberman, 2014). Petrobras was not an incumbent ethanol producer but changed its stance and took on a leading role as a distributor, using its extensive tanking and distribution to gain market control (Santos, 1985). Universities, research centres, and private sector firms were also encouraged to collaborate and ethanol-based cars started appearing on the market (SIAN, 1986). The World Bank credit loan of US$250 million further increased international interest in the *Proálcool* programme (SIAN, 1984).

Hence, by deepening economic and energy security concerns, the second oil crisis reinforced the window of opportunity for a socio-technical transition to ethanol-based fuels for passenger cars. The reorientation towards new technologies within the transformation pathway was only partial since several incumbents had started producing both gasoline and ethanol-powered cars, but it nonetheless represented a higher level of incremental change. Reconfiguration pathways, characteristics of new alliances, emerged as regime actors united in favour of the shift, and encouraged by government subsidies, they produced (i) higher volumes of hydrous ethanol, (ii) specialised tanking and distribution facilities, (iii) ethanol-fuelled vehicles, and (iv) equipment for filling stations. Records indicate that the car industry was in favour of the programme. It was hit very hard by the oil crisis (SIAN, 1988) and lobbied intensively for the government to develop an export market and provide incentives to facilitate the transition to ethanol-based fuels (Hira & de Oliveira, 2009). Encouraged by the National Association of Motor Vehicle Manufacturers (ANFAVEA), the government introduced consumer incentive schemes including (i) ethanol-fuel subsidies to attract new customers, (ii) 'weekend fuel sales' events, (iii) lower highway tolls for ethanol-fuelled automobiles, (iv) long-term financing schemes for ethanol-fuelled car purchases, (v) attractive ethanol pricing, and (v) limiting ethanol price to 55%-65% of that of gasoline (Moraes & Zilberman, 2014; Globo, 1982). The government also announced that ethanol production would be commercialized at a price above the minimum price (Oliveira, 2002). Incentivised by these various schemes, consumers embraced the new system wholeheartedly and by the end of 1983, the millionth ethanol car was sold. By 1985, automakers sales were at a peak of 99% (Surrey, 1987). Events were held to celebrate what was deemed to be a spectacularly successful public-private partnership (Globo, 1983).

It is worth noting that agricultural producers in Brazil's northeast region were less favourable to the *Proálcool* programme and raised concerns about its impact on farming, referring to it as the 'food versus fuel' dilemma. Many felt the sector was unable to produce ethanol in the quantities required to fuel pure ethanol cars across Brazil while also catering to other domestic and export markets. The following quote by a mill director from the State of Pernambuco (translated from Portuguese) captures the intensity of the debate: "(i)deological or philosophical, the fight for Proálcool in the northeast has become an eminently political and administrative issue" (Globo, 1980d). Rosillo-Calle and Hall (1987) argued that although there were few "limited and confined" negative effects on food production, this issue would be better framed as one of crop production for the export versus the domestic market. The programme addressed these concerns by further accelerating the modernization of the agricultural sector that began in the 70s after the creation of Embrapa (the Brazilian Agricultural Research Corporation) which famously introduced soybean crops that could thrive in tropical climates (Cabral, 2021). In the 70s, Brazil's agricultural production started increasing faster than its population growth (Rosillo-Calle & Hall, 1987). Part of the infrastructure for oil transport was adapted for the transport of ethanol while tanks were redesigned to accommodate the new fuel. Nonetheless, while impressive and substantial in terms of investments, these developments are considered to be 'add-ons' to an existing socio-technical system that was in the main managed by Petrobras. In other words, we argue that the sum total of these changes do not constitute a niche-driven substitution (pathway) per se. This period is thus characterised by an active policy stream, stringent targets enacted by the government, supporting actors located inside and outside the political sphere and relatively little dissent. It constitutes a moderate shift in the transition pathway towards reconfiguration.

4.3 Stage 3 – Transition stagnation (1986-1990)

The oil price suddenly fell in 1986, in what became known as the 'oil counter shock', marking the end of the expansion phase for *Proálcool* (Surrey, 1987; Santos, 1993). Petrobras was hit particularly hard by this sudden reversal in price. Since it owned 80% of the ethanol distribution infrastructure, it had to buy ethanol at a relatively higher price than it was obligated to sell it in its fuel stations. Moreover, the ethanol consumer price freeze (see above) exacerbated the growing deficit, reducing Petrobras' oil exploration investments and further weakening its overall financial position (FOLHA, 1986; SIAN, 1986). It also led to ethanol producers experiencing substantial productivity decreases and the closing down of many local distilleries. The IAA lobbied for the government to adjust its price (as opposed to providing subsidies) which they did towards the mid-1988. In the absence of a strong consumer demand, this decrease further aggravated Petrobras' revenues and led them to delay ethanol collection and minimize stocking levels (Santos, 1993). By 1989, the international rise in sugar prices created additional incentives for sugarcane producers to move away from the domestic market and redirect their production to export markets. (Alves & Vogel, 1996; Chagas, 1997; Moreira & Goldemberg, 1999).

The combined effect of these price changes contributed to a shift in the mood of national insiders by making them more resistant to the use of ethanol as a fuel. This reduced the overall appeal of *Proálcool* (Globo, 1986). These intensives and sudden landscape pressures weakened the regime, highlighting a de-alignment and re-alignment pathway as incumbents struggled through the crisis. Car manufacturers were relatively less affected as they were able to adapt their cars to whatever fuel was in demand. From 1984-1988, ethanol consumption had increased by 116%, while its production increased by 25%. This was the first severe supply crisis (Ordoñez, 1989). Consequently, ethanol-powered car sales dramatically declined, from over 95% to 4% of all vehicle sales in 1990 (Santos, 1993).

Theory predicts that due to path dependencies, when landscape pressure events revert as they did here, the system tends to return to its old ways (Elzen et al., 2004). Hence, with the price of oil plunging and the price of sugar rising, the trend away from fossil fuels stalled, and by the end of 1989, the country was experiencing major ethanol-fuel distribution shortages. The programme of transition to an ethanol-based regime became under serious threat (SIAN, 1990; Nogueira, 1989), to the frustration of the 4.5 million consumers who purchased ethanol-only fuelled cars (Chacel, 1989; Ordoñez, 1989). Progress along the transformation pathway stalled and the system was in danger of reverting to its original petrol-based state.

4.4 Stage 4 – Transition reversal (1990-2000)

In the 90s, Brazil underwent a major political shift, moving from a military to a democratic regime intent on market reforms and economic liberalization. The IAA was shut down in 1990, and Petrobras monopoly ended in 1997. This the de-alignment and re-alignment pathway created opportunities for new entrants and new players, including a number of multinational companies, started entering the arena and incumbent actors were forced to adapt.

This period is characterised by a drastic change in the 'mood' of national actors, away from the ethanol programme and back again. As consumers feared new supply shortage, ethanol-vehicles lost their market appeal. Consequently, the production share of pure ethanol car fell from 96% to 0.2% by 1996 (Alves & Vogel, 1996; Chagas, 1997 – see the online appendix). The gradual return of the gasoline-powered cars was inevitable. More concretely, consumer preferences re-established the predominance of gasoline-powered vehicles. While automakers were generally content to accommodate these preferences, they also became subject to regulations linked to the new Programme for Control of Air Pollution by Motor Vehicles (PROCONVE) introduced by the National Environment Council in 1989 (CONAMA, 1989). This incentivised the industry to align with a minimum requirement of 22% anhydrous content. There were thus clear signs that the transition was reversing back to gasoline.

As the decade progressed, prices of sugar and anhydrous ethanol, hydrated ethanol, and gasoline were deregulated in 1997, 1998, and 1999 respectively. As Petrobras' monopoly ended in 1997 (Brazil, 1997), several parts of the oil market – i.e. exploration, refining, transportation, import and export of petroleum and oil products - were now operating in more competitive settings. Hydrated ethanol deregulation was damaging to producers since from their perspective, its production could not compete with gasoline (Moraes and Zilberman, 2014). The reduction in the demand for ethanol-related fuels led to major overproduction and revenue crisis, which hit the sugarcane agroindustry hard. This incentivised workers in the sugarcane industry to unite and voice their discontent with the reversal. They unexpectedly became primary actors in this restricted transition, remarkably adept at influencing public sentiment by publicising the devastating effects this reversal was having on their livelihood. Manifestations multiplied in size and scope and reverberated through the system, eventually refocusing the mood of national outsiders on employment and job security. An "employment pact" between the federal government, car producers, and the sugar-alcohol sector was signed in 1999, reinstating incentives for the production and consumption of ethanol-fuel vehicles and subsidies for R&D in related technologies (Cioccari, 1999; Olmos, 1999; Moraes, 2011; Moraes & Zilberman, 2014).

Hence, while the transition to ethanol fuels was in serious jeopardy following the fall in oil prices and the deregulation of fuel markets, pressures from national insiders (e.g. producers) and outsiders (e.g. commercial associations, shopkeepers) mitigated some of the effects of market liberalisation, reinstating incentives to producers and consumers to remain in the ethanol industry. The transformation pathway was struggling but still unfolding.

4.5 Stage 5 – Transition resurgence (2000-2020)

Automakers already had to comply with the basic PROCONVE emission regulations which considerably reduced emissions from gasoline fueled cars. Nonetheless, new, more stringent requirements were introduced for vehicles enhancing the comparative advantage of ethanol in terms of emissions reduction (Phase L4, 2005; Cadernos NAE 2005). The realisation that ethanol is a more environmentally-friendly fuel gained momentum and policy initiatives were launched – such as 'Green Fleet' - that established a gradual substitution of the government's official fleet to ethanol-powered alternatives on favourable terms (Brazil, 1998).

More concretely, gasoline-powered cars did make a comeback but resistance from sugarcane incumbents, societal pressure, and an emerging environmental movement created a window of opportunity for the introduction of the flexible fuel vehicle (FFV) (Vogel, 2002). This was a genuinely new technology that would give consumers the flexibility of fuelling their cars with ethanol and/or gasoline to any extent they chose, thereby facilitating the cohabitation of the two fuels. Awareness and endorsement of FFV technology quickly grew amongst automakers, suppliers, academia, and R&D institutes attracted by its potential to service consumers wanting to alternate between petrol and ethanol depending on their relative price and availability. Marked by the ethanol crisis of the 80's, Brazilian agricultural producers also saw the new technology as an effective way of managing turbulence in ethanol markets. Governments thus welcomed FFV technology as it would help them cater to demands from both the petrol and ethanol sectors. Accordingly, the development of FFV cars received widespread government support in the form of reduced car taxes, R&D subsidies to industry, and support to agricultural bodies in the development of more robust and abundant sugarcane crops (Hira & de Oliveira, 2009). Finally, we note that the existing system infrastructure was also conducive to the emergence and diffusion of FFV.

What is particularly striking about this period is the societal consensus that emerged around FFVs. Moreover, this consensus was principally enacted by incumbent actors (auto-parts industries, automakers, technology companies) and not by government insiders as was the case with the original *Proálcool* initiative. The market fully embraced FFVs and they now represent over 95% of new passenger car sales (ANFAVEA, 2022). While perhaps too modest to be labelled as a radical transition, the country nonetheless witnessed widespread adoption of this dual-fuel technology by incumbent actors. This resulted in FFVs successfully reinstating ethanol as a major competitor to gasoline.[7]

5 Analysis and discussion

In terms of characterising the nature of Brazil's fuel technology system transition, we argue that it shares features associated with the 'transformation' pathway. While some reconfigurations did take place over the 50-year period - i.e. those linked to ethanol fuel tanking and filling stations, most of the changes were add-ons to existing technologies, as opposed to radical innovations, and perhaps best described as 'symbiotic'. In more recent years, however, the system experienced a major technological substitution in its primary fleet engine (FFV technology) by allowing the cohabitation of ethanol and petrol, and FFVs became the dominant type of passenger car in Brazil.

[7] We note that FFVs did not create a captive market for biofuel producers (which have other options) but proved vital for their production expansion. The estimated proportion of hydrated ethanol used as a fuel in the FFV fleet in recent years fluctuates between 30-40% - i.e. not the majority (oil dominates) but considerable nonetheless. We also recognize that while the period saw a resurgence of ethanol-based fuels, mechanization, changes in agricultural practices (such as prohibitions on sugarcane burning) and the effects of climate change led to stagnation in other parts of the Brazilian sugarcane industry. We thank our reviewers for pointing this out.

Brazil's fuel-technology transition was undoubtedly spurred by the windows of opportunities the various oil and sugar price shocks created, and pressures exerted by insider enactment and regime incumbents. In Stage 1, the government (a military regime) was the main instigator of change thereby acting as its own 'endogenous enactor'. In Stage 2, the government supported and encouraged scientists and engineers in their efforts to promote *Proálcool*. This national policy had an impact on the transition at the niche level, by accelerating biofuel production, and at the regime level, by consolidating efforts to launch ethanol-based vehicles (Kanger et al., 2020). Stages 3 and 4 are characterised by a lack of tangible progress in the transition as the system went through a reorganisation of regime actors. Attempts were made to shift the system towards ethanol-only vehicles (Stage 3) but these failed and it reverted to old petrol-based technologies (Stage 4). It is only in Stage 5 that regime insiders experienced strong pressures from outsiders, which lead to the launch and widespread adoption of FFVs.

This narrative also highlights a number of interesting elements that were important to the transition but not fully captured by the MLP or the MSA add-on. Firstly, we note how actors' support (*stance*) for, and importance to (*salience*), the transition fluctuated through time depending on their interests and position in the regime, increasing the complexity of the process. In Stage 2 for instance, Petrobras migrated from an oil company intent on protecting the petrol-based system to an energy company that headed the transition to ethanol. By Stage 3, after suffering considerable losses, Petrobras changed its stance back to petrol and away from ethanol. It also lost much of its influence (salience) on the transition after the deregulation of the oil sector. Similarly, consumers alternated their stance towards ethanol and petrol-based cars depending on the respective price and availability of fuels and their salience on the transition increased through time. Hence, our analyses demonstrate that across periods, actors can change *salience* by acting as primary or secondary agents to the transition, and *stance*, by shifting between being supportive, resistant or neutral towards non-fossil fuel technologies or related policies. These changing roles affect the speed and extent of transitions.

Secondly, the narrative demonstrates how national policies enacted in earlier stages of the transition can have lingering effects decades later. While path dependencies linked to infrastructure developments are central features of the transition literature, policy 'residues' that can either enable or constrain transformations are less visible (Markard et al., 2016). We argue that in Brazil's case, both infrastructure path dependencies and policy residues played a critical role in the diffusion of FFVs (Bennertz & Rip, 2018). We also showed how some periods saw no distinct progress but were nonetheless instrumental to the process as they allowed actors to consolidate, regroup and reposition themselves, thereby highlighting the potential for policy rebound effects.

Finally, our study demonstrates that sustainable transitions may occur 'fortuitously' when a pre-existing technology is given a sudden and unexpected advantage by new environmental research, consumer preferences, and/or social concerns. In Brazil's case, the initial shift to biofuel was driven purely by energy security concerns, not environmental imperatives. Hence, while *Proálcool* began as a programme intent on reducing Brazil's dependence on oil, it morphed decades later into one that addressed the nation's growing environmental preferences and objectives (Brilhante, 1997).

In other countries, however, energy security concerns were combined with environmental preoccupations at a much earlier stage. For instance, greenhouse gas (GHG) reductions were a main driving force for the adoption of alternative fuels in Germany (Hake, Fischer, Venghaus, & Weckenbrock, 2015), Sweden (Johnson & Silveira, 2014), Korea, Japan, and California (EU, 2016). It is also the case that policies and strategies introduce specifically to encourage transitions to sustainable technologies can have a negative impact in the longer term (Benvenutti, Uriona-Maldonado, & Campos, 2019).

As our analyses demonstrate, the diffusion of FFVs in Brazil is attributed to long-standing policies for fuel security, support by carmakers, and pressures from workers in the sugarcane industry. Although environmental concerns were already gaining momentum, evidence suggest that they were not the catalyst for this transformation in fuel-technology (Goldemberg, Coelho, & Lucon, 2004). Fortuitously, however, the advent of FFVs coincided with a growing endorsement of environmental policies by Brazilians (e.g. PROCONVE L4). Moreover, FFVs provided Brazil with a significant comparative advantage in dealing with emerging international pressures to meet environmental targets (EU, 2016). Such developments strengthen the transition to biofuels by aligning it with a wider set of actors and national interests (Benvenutti & Campos, 2019). The importance of these dynamics is exemplified by the new federal programme (*Rota 2030*) which creates incentives to enhance R&D within the automotive chain (Brazil, 2018), and the new national biofuel policy (*Renovabio*) which helps Brazil meet its National Determined Contributions (NDCs) of the Paris Agreement (Brazil, 2017).

We posit that these fortuitous windows of opportunities are likely to become more frequent features of socio-technical sustainable transitions, perhaps even more so in developing countries where economic concerns dominate environmental ones. Ongoing socio-technical transitions that have yet to be perceived through a sustainability lens can gain momentum once positioned as solutions to both an economic and environmental problem (Kern & Rogge, 2018). As environmental events multiply and disrupt existing patterns of production, consumption, and governance, synergies between sustainable and economic concerns will increasingly coalesce.

Moreover, the concept of 'fortuitous' windows of opportunity is relevant to discussions of problem-solution sequencing in the policymaking process (Béland & Howlett, 2016). In Brazil's case, biofuel (i.e. the solution) existed before sustainability concerns (i.e. the problem) were considered important political and policy priorities. Our findings suggest that there may be merits in adopting hybrid approaches to policymaking that combine 'known problem and unknown solution' traditional sequencing with 'known solution and unknown problem' alternatives. This reversal in optic could encourage actors to visualise sustainability issues in more innovative and productive ways and help keep policies under greater scrutiny as they compete against a wider set of potential problem-solution combinations. We argue that doing so could ultimately accelerate the pace of sustainable transitions.

Figure 5 and Table A1 use the proposed framework to process-narrate key developments in the fuel technology used in Brazil's passenger vehicles in the past 50 yrs. Together they highlight the different and changing stances of actors in each period of the socio-technical transition and track their ability to influence policy and/or technological development and outcomes (i.e. their salience).

As with other such studies, our approach is subject to a number of caveats. In particular, considerable discretion was exerted in selecting the start and end of each period, in identifying primary and secondary actors, and in determining their salience through time. We also note that ethanol use in FFVs is only one part of the entire system of ethanol production and consumption (see Moraes and Zilberman 2014 and Oliveira (2002) for a wider perspective) – in that sense, our analyses are limited. Moreover, we recognise that the adoption of FFV technologies does not eliminate the dependence on petrol. Nonetheless, since Brazilian FFV cars can be driven using 100% ethanol (E100) – competing technologies found in other countries vary in a range of 50-

85% - we argue that these can be interpreted as a social-technical sustainable transition, albeit perhaps not a radical one (Geels et al. 2016).[8]

Our narrative is also based on documents available through search engines. If earlier documents remain undetected by these searches, our accounts are underrepresenting their content. Results should be interpreted accordingly.

________________________________ Insert Figure 5 __________________________________

6 Conclusion

This study contributes to the literature on socio-technical transitions in four important ways. Firstly, it provides an alternative and richer way of inserting the MSA into the MLP framework to process-narrate socio-technical transitions. In particular, it recognizes that actors' salience is dynamic, they may be primary in one period but secondary in another. It also allows actors to change their stance towards the transition in line with changing events. Our proposed amendments thereby allow actors to exert different levels and types of influence at different stages of the transition. We argue that introducing actors' salience and stance to the MSA augmented MLP framework allows the narrator to capture a more dynamic version of the transition, one that reflects evolving power relations in a changing landscape.

Secondly, our amended framework emphasises the important long-term effects policies exert on socio-technical transitions even decades after they have become inactive. We argue that these lingering effects or 'policy residues' can potentially be as powerful as infrastructure developments in creating path dependencies, whether as enablers or constrainers of future sustainability transitions. This suggests that accounting for past national policies and investigating potential 'policy rebound effects' could improve our understanding of sustainable transitions.

Thirdly, our analysis highlights the circumstances leading to 'fortuitous' sustainability transitions. Sustainable transitions can become feasible even in situations where environmental concerns are not the primary driver of change. More concretely, certain technologies originally conceived and developed as solutions to economic or other problems may become more attractive when seen through the lens of mounting environmental pressures, as was the case with Brazil's

[8] We are grateful to one of our reviewers for highlighting this caveat.

fuel technology transition. The emergent and unplanned nature of some transitions had been observed before but we contribute to a better understanding of the processes underpinning them.

Our final contribution is in producing a process-narration of the 50-year socio-technical transition experienced by Brazil's passenger vehicles fuel-technology fleet. This adds another data point to the growing number of such analyses, eventually allowing others to meta-analyse the features of successful socio-technical sustainability transitions.

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[9] Brazilian references to documents used in the historical analysis appear in the online appendix.

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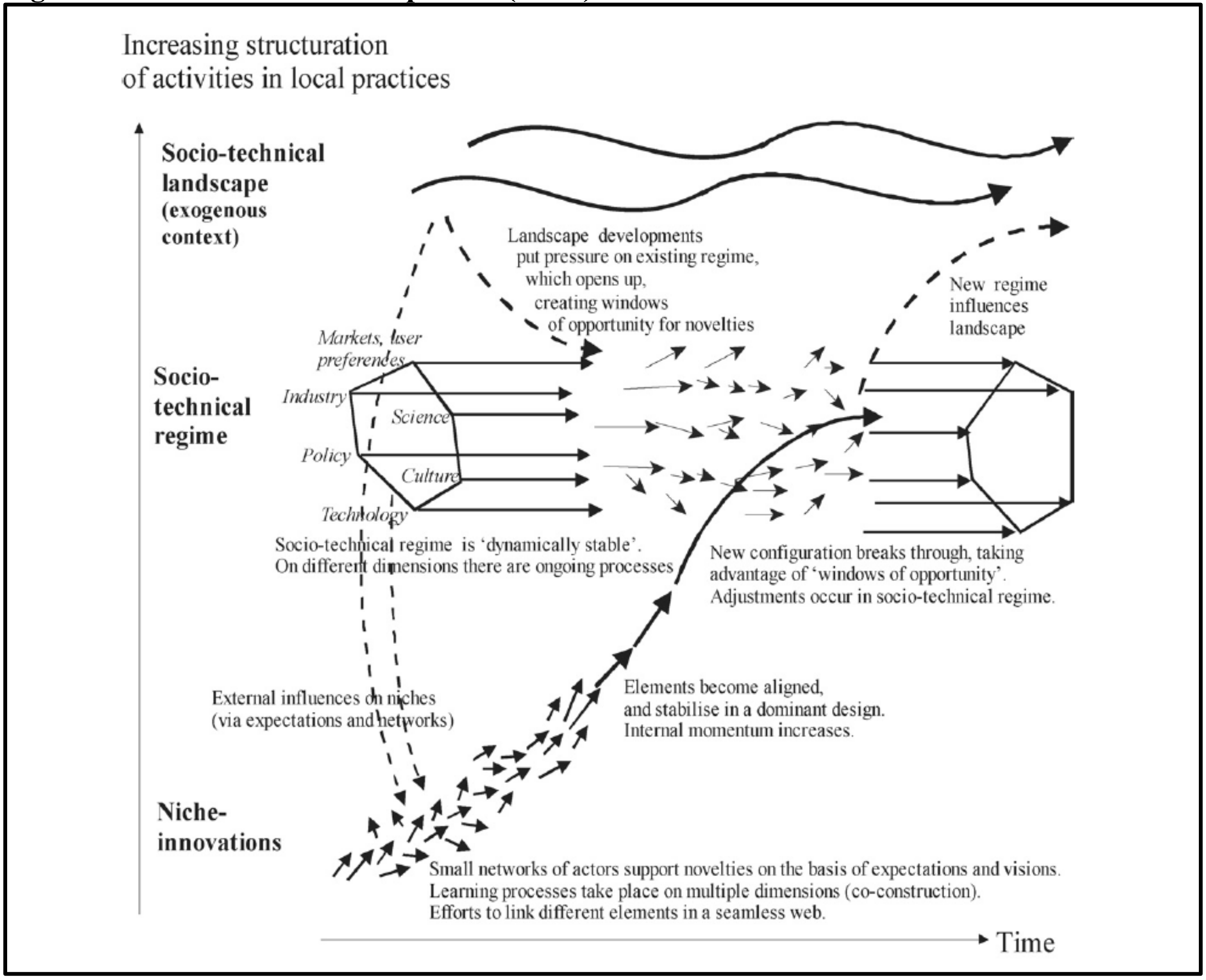
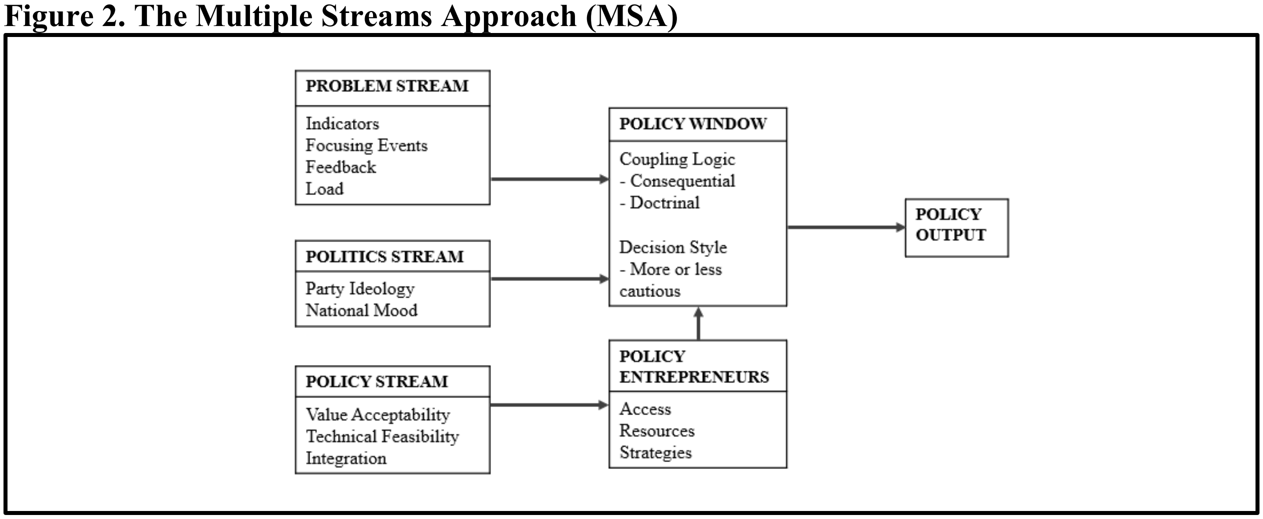
Figure 1. The Multi-Level Perspective (MLP) Framework.



Source: Geels and Schot (2007).

Figure 2. The Multiple Streams Approach (MSA)



Source: Adapted from Zahariadis (2007).

Figure 3: Augmenting the MLP with the MSA

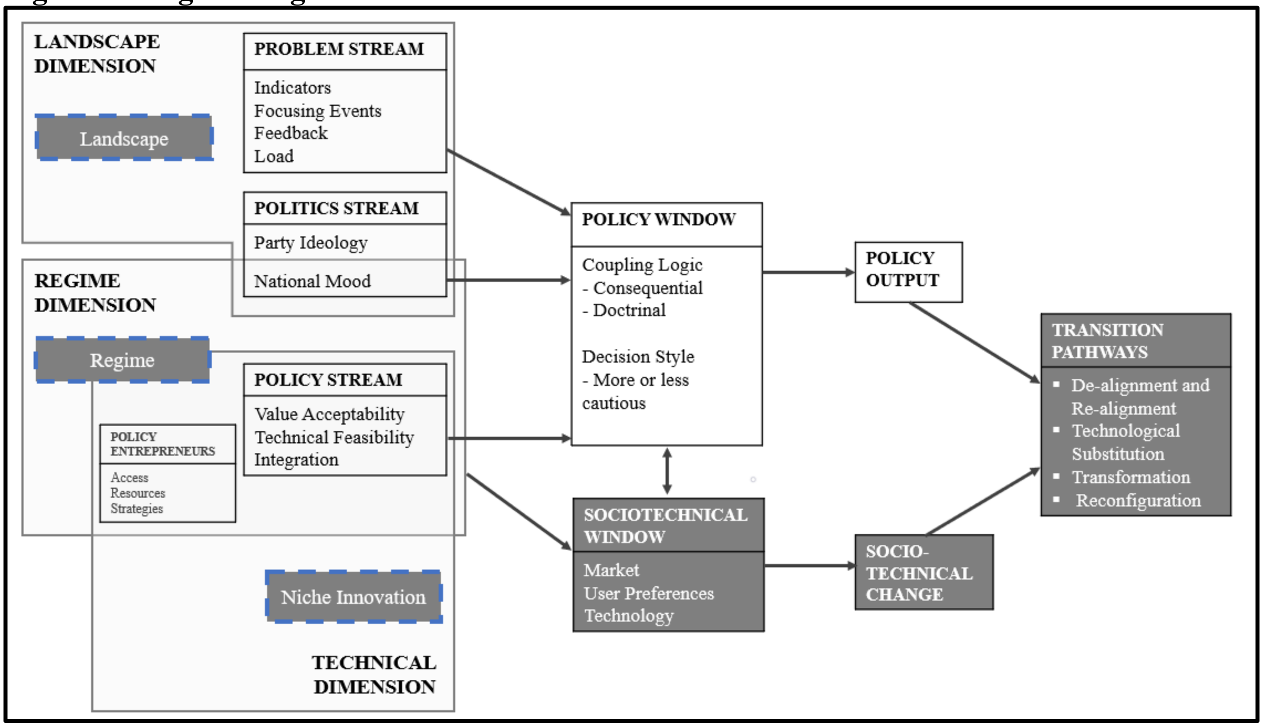


Table 1. MLP Transition Pathways

Transition pathways	Main scenario	Main outcome
De and re-alignment	Intensive and sudden landscape change that weaken the regime	Rise of multiple niche-innovators
Technological substitution	Intensive landscape pressure combined with existing niche-innovations	Radical innovations substitute incumbent firms
Transformation	Niches already developed and adopted by the regime	'Add-on' to existing technologies with no major system architecture disruption
Reconfiguration	Niches already developed and adopted by the regime	Substantial change and disruption to the basic system architecture disruption

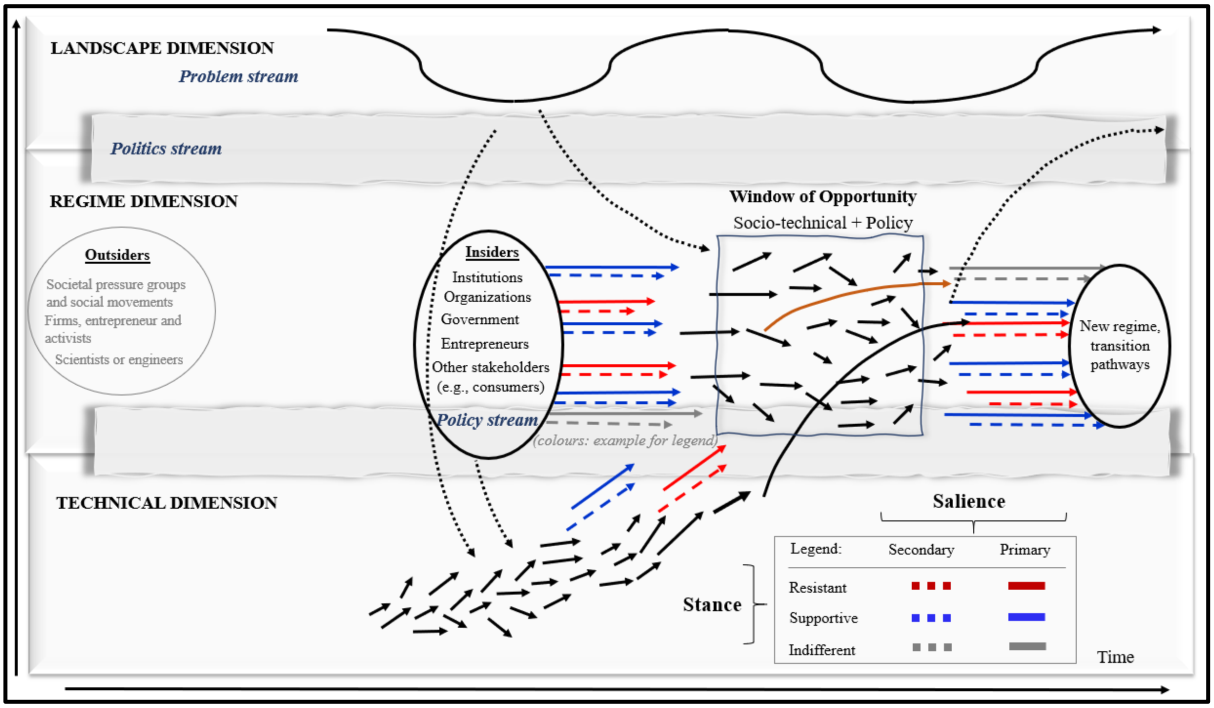
Source: Adapted from Geels (2002, 2005, 2006a, 2006b).

Table 2. Documents per Source*, **

Source	Total	After selection	1970s	1980s	1990s	2000s	2010s
Scopus (title, abstract, keywords) (https://www.scopus.com/)	**44**	**30**	0	10	2	6	12
Federal legislation (https://legislacao.presidencia.gov.br/#)	**11**	**11**	7	4	0	0	0
National Archives Information System*** (http://sian.an.gov.br/)	**1172**	**15**	2	10	2	1	0
O Globo*** (https://acervo.oglobo.globo.com/)	**2612**	**46**	10	21	12	2	1
Total	**3839**	**102**	**19**	**45**	**16**	**9**	**13**

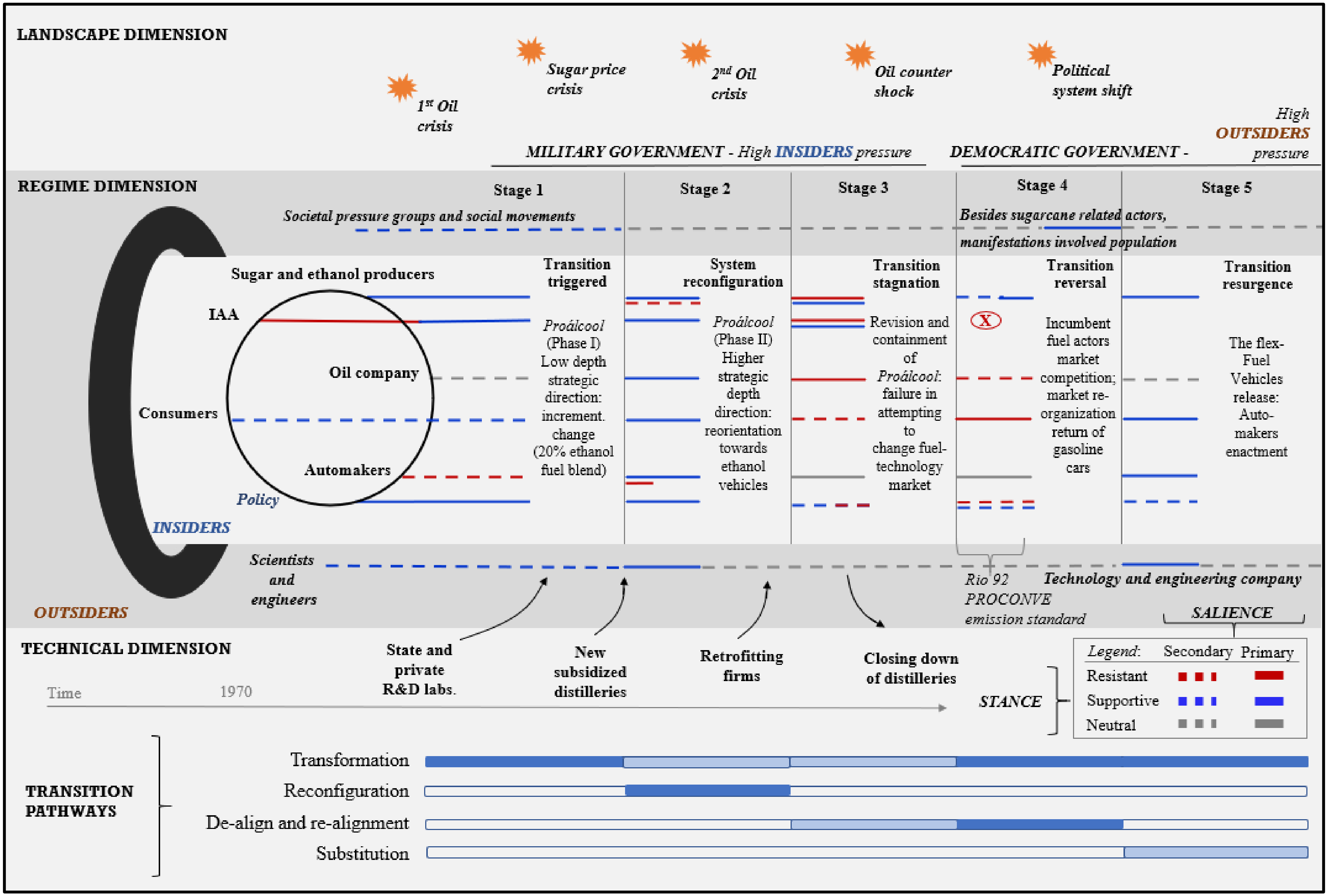
*Search terms for Scopus: 'Proálcool', 'National ethanol programme', 'Brazilian ethanol program', 'Brazil's alcohol programme'.
*Search term for the rest: 'Proálcool'.
**Final date of access: 15 July 2020.
*** This search provided several results unrelated to the theme.
**** See online appendix for references appearing in the text.

Figure 4. The *actor-centred* MLP + MSA framework.



Source: Based on the iconography of Geels and Schot (2007, p. 401) but adapted to an *actor-centred* approach.

Figure 5. The *actor-centred* MLP + MSA framework applied to the Brazilian passenger vehicles case study (1970-2020).



Appendix A

Table A1. *Actor-centred* MLP and MSA dimensions and streams in Brazil's sociotechnical fuel-technology fleet transition (1970-present)

Adapted MSA streams	Stage 1	Stage 2	Stage 3	Stage 4	Stage 5
Problem Stream					
Indicators	High oil prices Oil scarcity predictions Import oil dependency	Economic crisis Energy security concern Sugarcane surpluses	Oil prices dropped** Oil production rise** Sugar price rise**	Ethanol-car sales decline Petrobras' deficit rose	High oil prices Sugarcane industry crisis
Focusing events (landscape shocks)	1st Oil crisis Sugar crisis	2nd Oil crisis	Oil counter shock Sugar market rise	Political system shift Protests	Residue from prior stages
Feedback: path that worked before	Ethanol infrastructure and know-how	Ethanol previous use as fuel	Economic recovery plan working	Gasoline-powered vehicles return	Dual fuel infrastructure in place
Politics Stream					
Party Ideology	Military government	Military government	Military government	Democracy	Democracy
National actors' stance (mood): **resistant** to change*	Automakers IAA (at first)	Automakers at first Northeast producers	Petrobras, IAA, ethanol producers, consumers	Policy (deregulations), consumers, Petrobras	
National actors' stance (mood): **supportive** to change*	Government, sugarcane sector, population in general	Government, sugarcane sector, consumers, oil company, scientists	IAA, ethanol producers, policy stream	Sugarcane industry, policy, societal groups	Overall acceptance from regime actors
National actors' stance (mood): **neutral**	Oil company	Outsiders	Automakers, outsiders	Automakers, outsiders	Outsiders, oil company
Policy Stream					
Value acceptability	Industrial development National security	Reduce oil dependency	Low: profitable oil and sugar	Environmental awareness growing	Industry recovery Environmental value
Technical feasibility	Higher ethanol rates previously used	Ethanol-powered vehicles able production	Shaken: ethanol-powered vehicles lost credibility	Minor action, know-how already in place	Common incentives type
Policy Output					
Fuel (ethanol content in gasoline blend)***	1-5% to 20%	15-22%	18%-22%	20-24%	20-27%
Technology, policy, infrastructure	*Proálcool* (phase I)	*Proálcool* (phase II) Ethanol-based vehicles Ethanol tanking, stations	*Proálcool* (still phase II)	Green Fleet, deregulations, PROCONVE L3	FFV, *Few initial tax incentives,* PROCONVE L4, L5, L6

* Change from less to more sustainable fuel/energy sources.
** The national energy strategy was jeopardized by the sudden changes in oil and sugar prices.
***Source: MAPA (2015).
Legend: Green - Landscape Dimension; Blue- Regime Dimension; Purple- Technical Dimension.