What Bangs for Your Bucks? Assessing the Design and Impact of Transformative Policy

Matthijs J. Janssen

CID Research Fellow and Graduate Student

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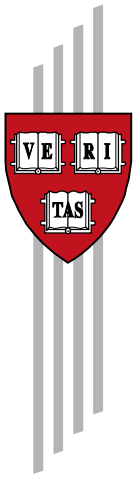

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Assessing the design and impact of transformative policy

Matthijs J. Janssen

Dialogic Innovatie en Interactie.
Hooghiemstraplein 33-36, 3514 AX, Utrecht, The Netherlands. Janssen@dialogic.nl.

Center for International Development, Harvard Kennedy School, Harvard University.
79 JFK Street, Cambridge, MA 02138, USA. Matthijs_janssen@hks.harvard.edu.

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ABSTRACT

After an era of generic support for economic development and innovation, narrowly targeted transformation policy is back on the table. Recent advances in the fields of new industrial policy and transition thinking converge on the idea that achieving structural change requires governments to take an active role in overcoming inertia. Rather than just leveraging R&D investments and setting framework conditions, policy makers are urged to participate in the development of socio-economic systems around particular technologies. Associated policy support typically involves a diverse portfolio of system-specific interventions.

The emergence of transformative policy, in this paper characterized by being selective, process-oriented and multi-instrumental, poses severe challenges to rising standards of public accountability. Evaluation methods for calculating the 'bang for the buck' of R&D-leveraging measures are ill-suited when policy mixes are supposed to enact economic transformation. We argue that, in order to see if aptly chosen policy design is bringing about actual change, assessments should gauge policy contributions to building up technological innovation systems (TIS). The TIS-literature provides a concrete but untapped basis for tracking how policy efforts affect conditions favoring the creation and diffusion of new economic activities. This premise leads us to introduce a scheme for structuring analyses concerned with (the links between) the organization, orientation and aggregate impact of transformative policy. We test it in a tentative assessment of the Dutch 'Topsector approach'.

Besides facilitating continuous policy learning, our assessment scheme also serves to strengthen policy maker's ability to legitimize the adoption of heterodox economic approaches.

Keywords: economic development, innovation policy, policy mix, technological innovation system, structural change, directionality

JEL Codes: O25, O38

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1. Introduction

The interest for narrowly-targeted economic policy is on the rise, both amongst scholars as well as amongst policy makers (Cimoli et al., 2009; Aghion et al., 2011; Naudé, 2010; Mazzucato, 2015; Dheret et al., 2014; Bailey et al., 2015; Janssen, 2015). According to the OECD (2014), several countries have recently launched national strategies targeting specific technologies or industries (e.g. the Netherlands, Denmark, Germany, the UK, Turkey and Canada). Interestingly, the nature of those strategies is often markedly different from classical industrial policy or the generic approach that became to dominate innovation policy. The most distinctive features of emerging policies for structural transformation can be traced back to advances in different strands of economic thinking.

First, the literature on economic development has been redefining its original conception of why to support specific priority areas. Instead of urging policy makers to 'pick winners', it is increasingly believed that the challenge is to explore development trajectories together with the private sector. Policy makers need to identify and alleviate the constraints most severely preventing upscale markets to emerge. As these constraints can be highly contingent on economic environments, it is inevitable that economic development policy gets selective - at least at a certain point (Hausmann & Rodrik, 2006). Rodrik (2004) therefore states that the question is not whether or not to deploy industrial policy, but how. Rather than following top-down decision making, which is typical for the classic way of boosting economic transformation, 'new industrial policy' (NIP) prescribes embedded governance as the key to knowing which portfolio of interventions to develop (Rodrik, 2004; Hausmann & Rodrik, 2006; Rodrik, 2008; Hausmann et al., 2008).

Second, there is a surging belief that governments have a role in steering economic transformation in socially desirable directions. Although such claims are occasionally found in extensions of the NIP discourse (Rodrik, 2014; Mazzucato, 2015), it should be noted that views on directionality of change have since long found their way into economic policy. Especially the science, technology and innovation (STI) literature, with its focus on processes of knowledge creation and dissemination, has significantly changed our understanding of how actual economic transformation comes about. Strategic niche management (SNM), the multi-level perspective (MLP) and studies on technological innovation systems (TIS) are all concerned with explaining (and guiding) the creation of environments in which particular new technologies can emerge (Markard & Truffer, 2008; Smith et al., 2010) Drawing upon those meso-perspectives, Weber & Rohracher (2012, p. 1038) call for "'transformation-oriented innovation policies' which strategically focus on the transformation of whole systems of innovation, production and consumption". Analogous to NIP principles, it is stated that socio-economic evolution requires policy makers to participate in systemic change by organizing interactions and introducing complementary sets of interventions (Chappin et al., 2009; Flanagan et al., 2011; Kivimaa & Kern, 2016).

In sum, a new kind of 'transformative policy' is on its way. We use this unifying term for referring to any kind of policy approach that strives for genuine sophistication of an economy's

industrial structure and underlying capabilities. Rather than trying to enhance R&D and growth across the board, transformative policy supports coordinated attempts for making a leap towards upscale economic activities. Based on the above, it can be characterized with three key properties: it is selective (i.e. it supports collective experimentation related to specific techno-economic pathways), process-oriented (no fixed interventions, but continuous policy adaptation), and multi-instrumental.

One clear example of transformative policy is the Topsector approach, the core of the current national research and innovation strategy in the Netherlands. In order to move forward collectively, nine platforms have been created in which policy makers, science representatives and industry captains of key sectors jointly determine which efforts should be taken to shape ecosystems from which promising new technical trajectories can emerge (e.g. by launching ambitious PPP-research programs, adapting education curricula, altering legislation). Although ultimately focused on improving competiveness – preferably while solving societal challenges -, it is acknowledged that standard indicators of labor productivity and export rates are at most loosely connected to the actual policy inputs that are being provided. In lack of a counterfactual for this coherent and interacting set of interventions, there is no obvious method to assess whether the Topsector approach consists of a policy mix that addresses real constrains, truly alleviates them, and is not crowding out efforts that would have been taken anyway. A similar problem is surfacing for Australia's Industry Growth Centres Initiative (2015-2019), which also is an industry-led approach driving innovation through long-term collective strategies.[1] Given the ongoing diffusion of transformative policy, this paper asks the one big question that has not been answered so far: How do we know if it is working out well?

Despite mostly taking place in parallel, economic development and innovation literature concerned with transformation have posed very similar observations with respect to evaluation practice.

To begin with, it is agreed that evaluation methods traditionally applied to single-goal instruments are not suited to multi-instrumental policy approaches aimed at driving transformation (Pritchett et al., 2012; Magro & Wilson, 2013). Existing studies of policy mix impact are mainly concerned with distilling 'level'-effects of individual interventions and examining their interactions; exemplary is the line of work devoted to the respective effects of subsidies and taxes in raising R&D (Nauwelaers et al., 2009; Neicu et al., 2016). Associated econometrics typically focus on calculating additionality measures, expressed as 'bang for the buck'. For both conceptual as well as methodological reasons, such methods are hardly relevant for modern industrial policy. A series of studies on evaluation of policy systems has resulted in guides for meta-analysis, but at best this serves to check possible contradictions between the impacts (and rationales) of individual instruments (Arnold, 2004; Edler et al., 2008; Miles et al., 2006). Today, a coherent framework for assessing aggregate impact of transformative policy is still very much urged for (Warwick & Nolan, 2014; Mazzucato, 2015; Magro & Wilson, 2013; Quitzow, 2015).

[1] http://www.industry.gov.au/industry/Industry-Growth-Centres/Pages/default.aspx

Furthermore, both focal literatures emphasize that evaluation of process-oriented policy is not just a matter of ex post external accountability. Instead, reflexive learning and dynamic or 'formative' evaluation are part and parcel of a policy approach designed to spur techno-economic developments through close public-private collaboration (Hausmann & Rodrik, 2006; Pritchett et al., 2012; Edler et al., 2012; Voß et al., 2009). Again it is noted that such efforts are in need of a meaningful way of linking interventions to outputs and outcomes.

Finally, the literatures are similar in their ambition to inform policy circles more intensively (Hausmann & Rodrik, 2006; Weber & Rohracker, 2012). Dodgson et al. (2011) point at the paradox that policy makers nowadays might think in evolutionary terms, but still legitimize their policy from a mainstream (market failure) perspective. As long as policy makers operate in structures rewarding them on traditional criteria, they will be poorly incentivized to actually act upon novel insights (Pritchett et al., 2012). We can reasonably assume that better methods for impact assessment are crucial for policy makers to be able to respond to the heterodox ideas they already have started to embrace.

To come up with an assessment scheme for transformative policy, we exploit the observation that the two central literatures we are building on also show significant differences. Whereas the introduction of new industrial policy contains clues on how to orient and organize public support for economic diversification (a first aspect worth to be reviewed), the innovation and in particular TIS literature helps to explain the evolution of socio-technical systems in which new economic activities are embedded (Carlsson & Stankiewicz, 1991; Hekkert et al., 2007). The key insight proposed in this paper is that policy contributions to the building of technological innovation systems are in fact the 'bangs' auditors - be it internal or external - should be looking for. Surprisingly, as it is primarily focused on governance and performance of technological innovation systems, the TIS literature itself has rarely raised the issue of impact assessment. We introduce a framework that structures investigation of the extent to which a multi-instrumental policy approach is effective, decisive and targeted at the system functions most relevant for advancing the TIS (directly, or through interactions with other functions). As the impact framework allows us to connect the policy design review with measures of structural change, it is the heart of the assessment scheme we propose. To facilitate its use, we provide a set of guiding questions and some methodological recommendations for answering them.

The remainder of this paper is as follows. In section 2 we describe which design principles are essential for transformative policy. The third section starts with a discussion of reasons why traditional BftB-methods are not suitable for determining the aggregate impact of modern industrial policy. It continues with our core contribution; the impact framework for determining which changes are being brought about. In section 4 we illustrate of the overall assessment scheme with a tentative case study of the aforementioned Dutch Topsector approach. Section 5 concludes.

2. Principles for appropriate policy design

We regard transformative policy as the collection of policy approaches that aim to drive economic change by targeting sets of (continuously adapted) interventions to selected technological domains. As noted, its emergence can be linked to two trends: the advancement of new industrial policy in economic development literature (Rodrik, 2004; Hausmann & Rodrik, 2006), and the rising interest for insights stemming from (meso-perspectives in) innovation studies (Markard & Truffer, 2008; Weber & Rohracher, 2012; Bergek et al., 2008). Although these developments are rarely linked to each other, notable exceptions being Cimoli et al. (2009), Warwick & Nolan (2014) and Mazzucato (2015), there are striking similarities in their views on how policy can drive upward diversification. Figure 1 shows how it differs from horizontal or 'a-selective' policy. Further details on the characteristics of transformative policy are provided in Appendix 1, and will be discussed as we move to a review of appropriate policy design options.

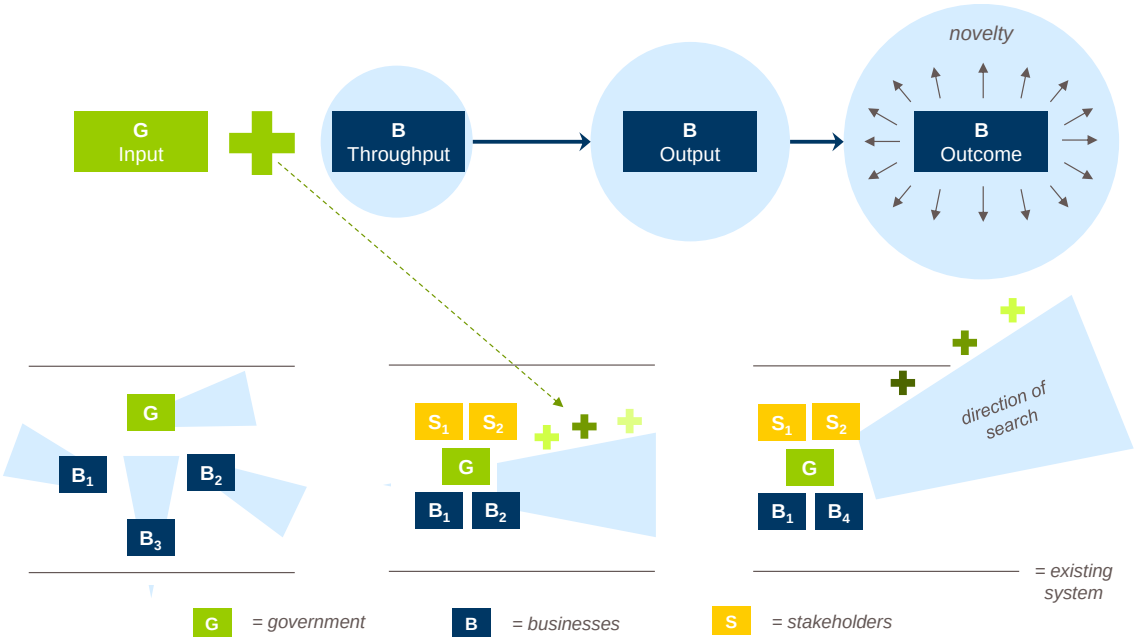

Figure 1: A-selective policy (upper part) versus transformative policy (down). The latter involves joint determination of direction of change, aligning stakeholders/building of ecosystem, and a variety of continuously adapted policy interventions.

When set out to assess if instances of transformative policy are aptly designed to overcome inertia, especially the various studies on new industrial policy (NIP) provide a basis to lean on (Rodrik, 2004; Hausmann & Rodrik, 2006; Rodrik, 2008; Hausmann et al., 2008; Hausmann et al., 2014; Rodrik, 2014).[2] We synthesize this line of work by describing the design principles that are fundamental for adequate policy organization as well as policy orientation.

[2] Readers are advised to also have a look at the Problem Driven Iterative Adaptation (PDIA) policy approach by Andrews et al. (2012). Although focused on building state capability in general, rather than specifically spurring economic development, the approach discuses highly relevant policy principles as well. These are (p.8): (i) aim to solve particular problems in local contexts, (ii) through the creation of an 'authorizing environment' for decision-making that allows 'positive deviation' and experimentation, (iii) involving active, ongoing and experiential learning and the iterative feedback of lessons into new solutions, doing so by (iv) engaging broad sets of agents to ensure that reforms are viable, legitimate and relevant.

2.1. Policy organization

The first set of design principles we distil from the NIP literature concerns institutional requirements for the way policy is governed. Table 1 summarizes them by providing a short description as well as examples of good and bad practices.

Transformative policy is essentially about finding out which interventions have the highest potential of supporting transitions and diversification in genuinely new directions. To retrieve this information, *embeddedness* is indispensable. As knowledge about inertia and potential spillovers is distributed across many parties, Rodrik (2004, p. 18) calls for a "flexible form of strategic collaboration between public and private sectors, designed to elicit information". Policy makers face the challenge of finding a balance between autonomy and being captured by business interests. There are various methods for organizing interactions with firms and other stakeholders. Suggestions made throughout various NIP studies include (self-organizing) deliberation councils, supplier development forums / search networks, regional collaborative innovation centers, investment advisory councils, and private-public venture funds. Although each of these governance forms helps to uncover different kinds of signals, it is not per se necessary to implement all of them. Of main importance is the ability to keep updated about widely experienced problems, and possible ways to actually solve them. Part of this discovery process is to obtain information on the willingness of private parties to make investments.

Discipline is a second design principle for guiding and facilitating change. Rodrik (2004) strongly emphasizes that the art is to 'let losers go' rather than to 'pick winners'. In the first place this requires the formulation of clear objectives and measurable targets, so that it is clear what failure means. Close monitoring is vital for checking if those targets are met. Some developments can be followed continuously, while more analytical reviews typically should occur at an annual basis. Also the more thorough kind of instrument evaluations are part of this design principle.[3] Ultimately, all those learning efforts only make sense when complemented with rules allowing policy makers to adapt or even terminate interventions. While rents are crucial for motivating firms to undertake exploratory action ('carrots'), there also should be mechanisms for aborting support if it starts feeding unproductive activities only ('sticks'). Apart from conditional subsidies, an often mentioned example is a sunset clause for stopping public support after a predetermined amount of time.

Extending the discipline principle, it is also important to monitor policy makers themselves. *Accountability* and legitimacy can be achieved by adopting transparency procedures as well as a pro-active communication strategy with respect to policy choices and policy results. Such communication should provide sufficient information for outsiders (citizens and firms) to distinguish whether positive developments can truly be attributed to policy efforts. It also helps to appoint a high level principle that carries public responsibility for the transformative policy approach as such, or for one of the trajectories it is contributing to. As the exploration of new pathways often is a public-private endeavor

[3] While randomized controlled trials (RCTs) are increasingly common in economic development (Pritchett et al., 2012), policy experiments are still fairly new to the field of innovation policy (Warwick & Nolan, 2014).

(Smith et al., 2010), also the private sector might assign a 'champion' who represents them in the mutual journey.

Lastly, it is evident that policy should be executed by *competent* agencies. When adopting imperatives like embeddedness and responsiveness, the nature of those agencies' activities is different from merely developing and carrying out standardized procedures. It is through arranging interactions with and between third parties that collective needs can be discovered. Instead of a principal-agent relation, policy makers need to assume a form of leadership that permits them to guide developments while being part of them. A potential risk here is that efforts remain restricted to such networking only, without translating into actual policy action. Since it is paramount not to concentrate inputs on a too narrowly defined trajectory, competent policy execution is expressed in the ability to decide which interventions can encourage experimentation and yet still allow for the exploration of competing technological designs and business models.

Table 1: Design principles for policy organization

Design principle	Description	Good practices	Bad practices
Information retrieval (embeddedness)	Mechanisms to obtain information for identifying system-specific problems (and solutions). Requires balance between informational benefits and rent-seeking.	Information retrieval through continuous dialogue with private sector and other parties	Interaction limited to phase in which mechanisms are implemented, or discussion of broad lines only.
Discipline for policy adaptation	Mechanisms for learning about effectiveness and changing the policy course.	Dare to invest in uncertain trajectories, and be sure to recognize failure in time	Inability to stop failing trajectories, or risk-adversity to avoid any failure at all.
Accountability	Accountability requires transparency, a pro-active communication strategy, and visible / responsible leadership (amongst others).	Commitment: show how policy is actually helping to overcome inertia	Window-dressing: select domains that will do well anyway and claim success.
Leadership competence	Effective policy execution requires capable implementing agencies.	Responding to demands, to strongly advance some promising trajectories	Failure to connect and to choose/act (leaving everything open).

2.2. Policy orientation

The second set of four criteria, shown in Table 2, concerns the way how a policy mix aims to bring about change.

A first principle is not to transfer resources to firms directly, or at least to do so very carefully. Granted that firms have incentives to innovate, the objective is to enable them to do so. Support is best to be issued in the form of various types of public *inputs*, together targeting the most inhibitive bottlenecks. Indeed, such a policy mix should go beyond the provision of science, skilled personnel and R&D funding. A cornerstone of transformative policy is the insight that change is a complex rather than linear phenomenon, therefore requiring system-specific inputs also when it comes to factors like legislation and infrastructure. This does not imply a plea for deploying as much inputs as possible. Even when direct inputs are provided in a sensible way (e.g. to facilitate cost-discovery externalities), one criterion should always be that firms themselves exhibit a willingness to invest in experimentation once a particular input is in place.

Another key element of appropriate policy orientation is an *open architecture*. Generally, trade associations and the like are well able to bundle the interests they share. A major reason for transformative change not to take place is that it requires collaboration across sectors. Policy should aim to open up possibilities for experimentation by bringing together input combinations that will not come out of the market's invisible hand. Earlier we already noted that selectivity concerns primarily the collection of activities that is being targeted: which sectors are concerned with this is merely an outcome. When retrieving information from private parties it might of course be efficient to involve firms and organizations who can represent a wider group of actors. However, policy makers should be warned against talking to strong lobbies only. Almost by definition these do not include firms from the type of industries an economy is still lacking. While this issue remains hard to resolve, it certainly does not help to listen only to the incumbents who themselves stand in the way of entry and evolution.

Also the importance of encouraging the exploration of *genuinely novel activities* cannot be underestimated. Transformative policy should enable firms to leap towards new directions, and not just to modify that what they already have been doing. This stance is consistent with a complex-evolutionary policy rationale (Dodgson et al., 2011), stating that intervention is legitimized when it helps to overcome inertia in entrepreneurial experimentation. Such a rationale is a combination of market logic and coordinated logic, implying that policy makers face the challenge of deciding which interventions will give the biggest impulse to innovation activities with a breakthrough potential.

The final design principle is to ensure that *spillovers* will take place. Especially when sustainability considerations are not part of a transformative strategy, spillovers are the main reason for policy makers to support transformation at all. The primary goal is to diversify towards upscale activities, but even within this objective there is a requirement that it is not just a few firms who will benefit from this. Systemic changes resulting from a techno-economic transition should favor a broad range of firms. This requires spillovers either in the form of direct knowledge flows (from policy beneficiaries to non-participants), or indirectly through the possibilities offered by the changed system itself. As for the direct spillovers, this seems at odds with the incentives for firms to invest in change trajectories. Hausmann & Rodrik (2006) challenge this by pointing out that lobbying participants have the opportunity to determine which changes will unfold.

Table 2: Design principles for policy orientation

Design principle	Description	Good practices	Bad practices
Inputs instead of transfers	Discourage transfers to the private sector (e.g. subsidies); at least require co-financing above 'willingness to pay'-level.	Public involvement along a broad range of factors.	Focus on few factors; possibly through linear model of change.
Open architecture	Public support must target activities, not sectors.	Involving diverse parties in dialogue; Chosen pathways broadly backed.	Capture by few parties (usual suspects/sectors) and their goals only.
Genuine novelty	Diversify, don't just back winners in their incremental improvements.	Explore transformative trajectories, preferably several alternatives.	Extending existing trajectories, or narrowing scope to few ones only.
Contrive spillovers	The goal is structural change, not private profits. Ensure that new knowledge is broadly accessible.	Participants co-finance so they can steer research; results spill over to entire system.	Knowledge accessible to policy participants only.

3. A framework for impact assessment

3.1. Limitations of traditional impact assessment methods

Before presenting our approach to assess the impact of transformative policy, we briefly discuss why methods commonly used for evaluating economic (innovation) policy are inadequate here.

Ideally, an impact assessment serves to determine economic progress in terms of productivity growth, employment, added value, exports, etcetera. Because such final outcomes can only be measured after a substantial number of years, appraisals on the shorter term typically resort to econometric analyses that might reveal an elevated level of experimentation. Even if policy is just trying to enhance the general amount of entrepreneurial experimentation in a country, there are many pitfalls to take into account when determining the 'bang for the buck' (BftB). For instance, indicators on R&D investments do not tell how efficiently these are translated into outputs, or how novel these outputs would be (Autio, 1998). Uncertainties of these kinds prevail throughout the entire logical framework for policy intervention, stretching from inputs to outputs to outcomes.

Apart from general difficulties in estimating impact, the number of caveats gets bigger as we move to transformative policy. Characteristic for this type of policy approach is that it aims to align entrepreneurial experimentation around specific technological pathways. Compared to a case where every beneficiary is working on its own innovation, spillovers from collective trajectories are less likely to dilute. Moreover, as transformative policy involves adaptation of elements of the specific environment firms are active in, it leads to systemic change which opens up possibilities also for firms not directly involved. The result is the lack of a good counterfactual. Were we to measure developments taking place in beneficiaries and compare them with those in non-beneficiaries, we would falsely calculate the policy impact as the observed difference between the two. Thus, rather than subtracting positive effects from one another, we should be adding them (see Figure 2 for an illustration of this paradox).

A policy focus on socio-economic change around particular technologies also implies that direction matters. The mere observation that beneficiaries get more innovative does not imply they are all contributing to the transformation that is afoot. Finally, the fact that transformative policy aims to align experimentation also causes problems when it comes to its multi-instrumentality. The sum of narrowly targeted interventions is likely to exceed their individual impacts (Magro & Wilson, 2013), but investigating this requires a possibility to discriminate who has been receiving how much support. Unfortunately, as transformative interventions are explicitly designed to reinforce each other's contributions, this is highly difficult. In Rodrik's (2014, p. 487) words, the applicability of rigorous evaluation techniques is hampered because "program components differ too much across recipients to render comparison meaningful".

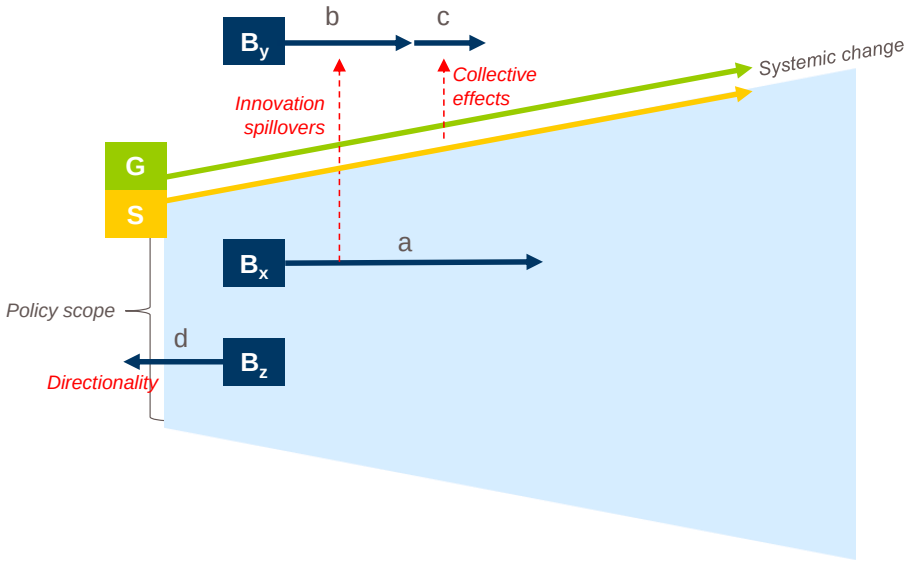

Figure 2: Caveats in calculating impact (Y) of transformative policy. Wrong is Y = (a+d)-(b+c), correct is Y = (a+b+c)-d.

3.2. Assessing policy contributions to TIS building

Having established the shortcomings of traditional 'BftB' evaluation methods, the question becomes what then we should be looking at. If embedded policy is in place, leading to the implementation and adaptation of well-targeted policy interventions, how do we know if actual change is underway?

The objective of transformative policy is to overcome the inertia preventing firms to experiment with new technologies and business models. Inertia can be caused by, for instance, legal barriers or a lack of complementary production factors (Hausmann & Rodrik, 2006). Because these sources of rigidity are highly idiosyncratic for each attempt to diversify, policy aimed at economic transformation ends up targeting particular industries and the span of technologies they are working on – if it wasn't already targeted at preferred domains in the first place. A major difference with generic innovation policy is thus that transformative policy is helping to create the conditions that allow specific technologies to be created and diffused. Given that the approach can be oriented towards one or multiple domains, a starting point for assessment is to determine which pathways are evolving out of it.

Once it is clear which socio-technological trajectories transformative policy is addressing, the literature on technological innovation systems offers a rather well-developed basis for understanding how technology matures. Note that a technological innovation system concerns the conditions for creating and applying new technologies, and not those technologies themselves. An observed lack of radical new technologies or fast-growing start-ups in itself is not a definite sign of failure (Rodrik, 2004). More important is if the socio-technical systems around the focal domain show signs of adaptation. Essential in this respect is the notion of key processes, or functions (Johnson, 1998; Bergek et al., 2008; Hekkert et al., 2007). Although there is no full consensus on what the most relevant functions are, all proposed sets contain more or less the ones depicted in Figure 3 (retrieved

from Hekkert et al., 2007). A TIS is believed to be strong when those functions are strongly developed for the technology in question. Studies on TIS diagnostics have suggested ways to measure this, typically by combining quantitative and qualitative methods (Hillman et al., 2011; Hekkert et al., 2011). Besides efforts to determine the performance of a TIS, many scholars have provided ideas on how its evolution should be governed (e.g. Wieczorek & Hekkert, 2011). It is therefore remarkable that so far no attempts were done to assess the impact policy actually has.

Our suggestion is to gauge the impact of transformative policy by disentangling the contribution of policy efforts to the strengthening of technological innovation systems. A basis to do so is provided by the reform analytics laid out by Hausmann et al. (2004). Although their work was mainly developed for the purpose of identifying why growth is stagnating, its characteristics synchronize very well with the principles underlying the TIS concept. Both schools of thought base themselves on a bottleneck principle. According to reform analytics the objective is to find out which market distortion is the most detrimental to productivity increases. The analogy in TIS thinking is that it also urges policy makers to address the function most severely holding back further evolution (Wieczorek & Hekkert, 2011).

Importantly, in reform analytics as well as in TIS governance it is acknowledged that modifying a certain wedge or function might affect another wedge or function (respectively) in turn. For the case of TIS, this point is stressed by for instance Bergek et al., (2008) and Hekkert & Negro (2009). Taking into account such complexities, Hausmann et al. (2004) distinguish different reform modes for spurring growth. Translating this type of reasoning to TIS building, policy makers could choose to do as much as they can, support the functions that generally have the largest positive influence on other functions, support only functions not having any negative influence on other functions, or target the functions that are most binding themselves. The reform analytics approach would argue for the latter type of strategy, as it is hard to know interdependencies in advance. In the context of socio-technical transitions this also recognized by Smith et al. (2010).[4] In an *ex post* assessment, however, the situation is different. Looking back upon the dynamics that have led to the current status of the TIS, it might well be possible to determine which functions have been most critical both directly and indirectly.

Recognizing the similarities between reform analytics and TIS governance leaves us to model the effect of public inputs $\{n1 \ldots N\}$ as shown in Figure 3 (for mathematic specification, see Appendix 2). Both the impulses P_j generated by public inputs as well as the impulses M_j caused by other inputs can affect one or multiple functions $0 \ldots k$. For some functions, public inputs are more decisive (α_j) than for other functions – the classical example being regulation which only can be altered by the government itself. Whether public inputs are essential rather than replace other inputs is commonly referred to with the term 'additionality'. It is increasingly acknowledged that the TIS literature

[4] At the same time, the authors do suggest it is possible to develop 'informed expectations' about the actual contributions policy interventions can make (Smith et al., 2010).

typically neglects the issue of stringency (Markard et al., 2015). The imperative of solving actual inertia implies that policy efforts only pay off when there are reasons to believe that the market itself will not set evolution in motion. Besides focusing on functions where policy can truly make a difference, the challenge is also to concentrate inputs on functions which are of crucial importance λ_j during the assessment period. As a TIS matures, the importance of one function can diminish by increasing the importance of another. To understand the impact of a given policy mix, a final parameter to look at is the interactions β_{ji} between the functions.

Central to the model is that it provides a structure for checking whether policy efforts are aligned with bottlenecks where public intervention is most urgent. When the government invests significantly in a function that is important (high λ_j) but that can also be performed by others (low α_j), total policy impact will be disappointing. Then again, in theory this reduced effect can be offset when enhancing the strength of that function impacts heavily upon the other functions (high β_{ji}'s).

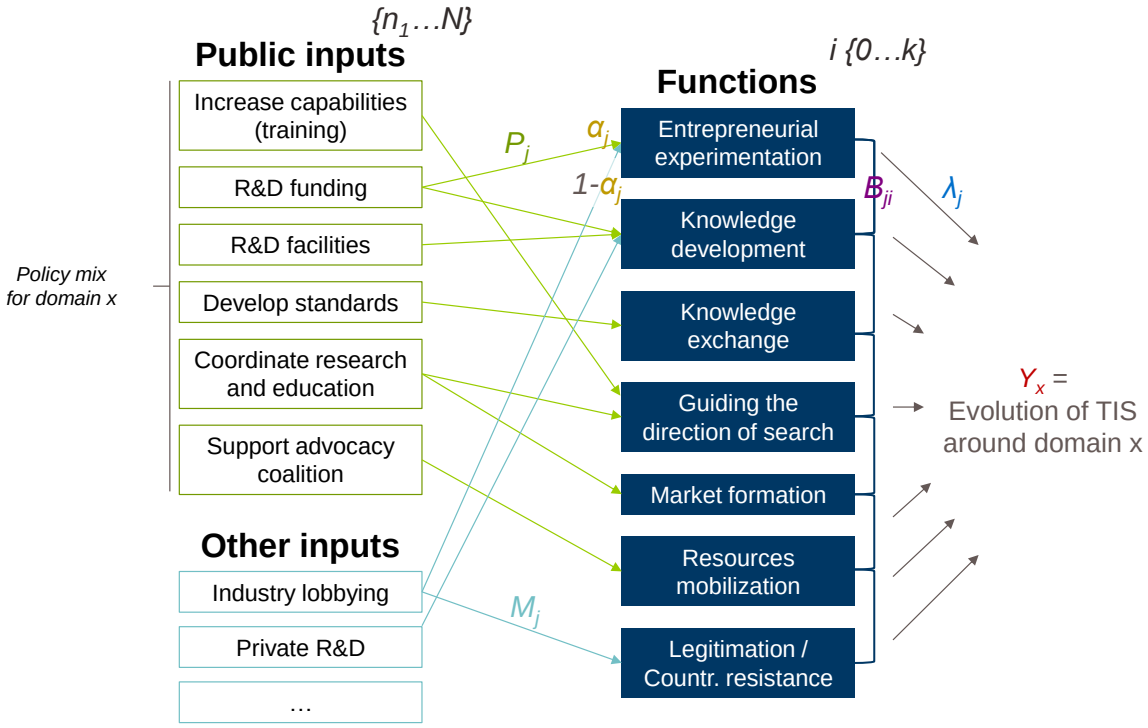

Figure 3: Components of a model for linking policy contributions to TIS building (functions by Hekkert et al., 2007).

A subtle but important distinction concerns the difference between inputs and impulses. While inputs *{n1…N}* are the bare resources that are being invested, impulses P_j, and M_j, refer to the actual force that is exercised on a function. It probably is far from obvious how interventions in a policy mix relate to the rather abstract system functions. To track these relations, it is helpful to recognize the concept of blocking mechanisms (Bergek et al., 2008). These mechanisms entail the underlying reasons for functions to be weak. An example provided by Bergek et al. (2008) is a lack of standards. The absence of such standards might affect the direction of search as well as market formation. Identifying which mechanisms are responsible for weak functions is a way to discover which type of intervention is really needed. Essentially, such an analysis of finding concrete explanations for abstract problems is highly similar to setting up a growth diagnostics tree (Hausmann et al., 2005).

The assessment principles outlined so far are now ready to be synthesized. Table 3 presents our impact framework. The rows consists of TIS functions, in this case again the ones proposed by Hekkert et al. (2007). On the columns we find the collection of key variables. The questions in the cells should guide reviewers in forming a judgement, per function, for each of those variables:

- λ_j : How important was function j for the success of the TIS? Determining how significant a particular cause of inertia has been requires a reconstruction of how a TIS evolved. A timeline exercise might be helpful here, especially to get a sense of how the importance of a function has been changing as the TIS matured. Rather than having a fixed value, parameter λ_j is an integral taken over the investigated period.
- *{n1…N}:* What did the government do to strengthen function j? Which actual interventions (projects/programs/institutional changes) did she implement? How substantial were they?
- P_j: How effective was policy in strengthening function j? One way to assess this is by examining the relation between inputs, blocking mechanisms and functions.
- α_j : How decisive was policy for strengthening function j? Are there reasons to believe private firms or other stakeholders would not be strengthening function j? What are the main reasons for these parties to refrain from (refraining from) providing essential inputs?
- β_{ji}: Did solving function j strengthen other functions? Also the interactions between functions can be expected to be dynamic. Estimating average 'values' for this multiplier in hindsight, however, is easier than making conjectures into the future.

Table 3: Impact framework, including guiding questions

		λ_j	{n1…N}	P_j	α_j	β_{ji}
F	Function	How **important** is function j for the success of TIS x?	What did government do to strengthen function j?	How **effective** was policy in strengthening function j?	How **decisive** is policy for strengthening function j?	Did solving function j **strengthen other functions**?
F1	**Entrepreneurial experimentation**	Which notable opportunities are not yet explored?	(E.g. attracting foreign firms, training centers)	What new firm capabilities / which firms settled?	Why no market for training, or for technology itself?	In the review period, which were the most pervasive dependencies between the functions? Did strengthening a function have a positive or negative effect on other functions?
F2	**Knowledge development**	What knowledge was missing / insufficient?	(E.g. targeting public science)	What research results? (quality and topics)	Why is interest for certain new technologies low?	
F3	**Knowledge exchange**	Which particular connections were weak?	(E.g. vouchers, joint R&D, TTO, platforms)	Which new interactions have been facilitated?	What mechanisms were blocking interactions?	
F4	**Guiding direction of search**	Which goals were not shared or recognized?	(E.g. publish joint vision / agenda, studies)	In which way have interests been alligned?	Why did interests use to be divergent?	
F5	**Market formation**	Which suppliers / demand are crucial?	(E.g. public procurement / public goods)	Which signals given to market parties?	Why were up- or downstream markets missing?	
F6	**Resource mobilisation**	Which activities hampered by lacking resources?	(E.g. innovation funding, R&D facilities, HR)	How much increase in R&D funding / fte?	Public resources matched by private expenses?	
F7	**Legitimation / counteracting resistance**	Which changes did lobby / laws used to block?	(E.g. adapt legislation, lobby, do assessments)	Did policy change discourse? Less legal barriers?	What hindered acceptance and compliance?	

4. Tentative case study

The past two sections provided criteria for reviewing the design of policy, as well as an impact framework for studying if actual change is coming along. In this section we apply them to a case. Besides demonstrating how an actual assessment could look, it also serves to clarify how both assessment elements are linked to each other.

4.1. Case selection and methodological remarks

The case selected for illustrating our assessment methods is the Dutch Topsector approach. A first motivation for taking specifically this case is that it is a research and innovation policy approach designed with many of the principles of new industrial policy in mind (OECD, 2014). Indeed, it is selective, process-oriented, and multi-instrumental.

Second, because the Topsector approach has been introduced in 2010/2011, it has been running a sufficient number of years to perform a meaningful assessment. Five years is a common period for governments to order an assessment, whereas it is clearly too early for significant economic change to take place. The Topsector approach is thus exactly at a point where analyses of systemic adaptations can be informative for both formative as well as summative purposes.

The main sources for our case analysis are country reports prepared annually for the Research and Innovation Observatory of the European Commission's Institute for Prospective Technology Studies. The country reports, the latest Dutch one being Janssen & Den Hertog (2016), build on a highly extensive set of policy statutes, policy visions, strategy documents, evaluations and consultations to describe (policy) developments in the research and innovation system. This information is highly suitable for describing the Dutch Topsector approach and assessing its policy design.

Also the impact assessment is performed on the basis of publicly available documents only. While the consulted sources might be sufficient for a preliminary but informed judgment, we are aware that especially this assessment ideally requires a much more rigorous analysis than the one presented here. To be as thorough as possible, we restrict the impact assessment to one out of nine Topsectors only. Our choice for the Topsector Energy is based on availability of secondary sources. Apart from the type of documents available for any Topsector[5], the Topsector Energy has recently been examined in a study relying on extensive interviews with 19 stakeholders (Van Son, 2015). Nevertheless, we emphasize that the analyses reported here should be interpreted with utmost caution. At this point an actual in-depth analysis has not been performed, as this very study is in fact a call for policy makers to reconsider the type of review they request. What matters here, in order to give an appropriate impression of the envisaged assessment approach, is the kind of signals that are identified and how these can be interpreted. Despite methodological limitations we are confident that our case analysis does serve this purpose.

[5] The website http://topsectoren.nl/documenten-en-publicaties lists almost 200 publications. For the Topsector Energy this includes an overview of the Topsector's ecosystem, annual reports, key priorities, strategic plans and a progress report.

4.2. Description of the Dutch Topsector approach

In 2010, with the onset of Cabinet Rutte II, the Dutch Ministry of Economic Affairs and the Ministry of Education, Culture and Science launched their Enterprise Policy. The primary goal of this ongoing strategy is to strengthen the competiveness of the Dutch economy. Apart from generic measures like reduction of regulatory burdens, SME funding and (existing) major R&D tax schemes, the Enterprise Policy also included the newly conceived Topsector approach. This policy approach is commonly seen as the successor of the Innovation Program approach (2006-2010). Whereas the latter was selective because of an industry-specific policy strategy (i.e. the 10 key domains were appointed top-down), the Topsector approach started with an open call. Over the course of 2011, firms and research institutes had the opportunity to unite themselves in so-called topteams. A total of nine topteams were finally selected for becoming a Topsector. Later, also three cross-over domains were added.

Contrary to the bureaus managing an Innovation Program, the topteams do not receive subsidies for funding their collectively organized research and innovation activities. Instead, the Topsector approach entails a varied package of interventions. To discuss its content it is important to explain the institutional setup. For each domain, the topteam (see Figure 4) decides what innovation and human capital priorities are for the firms and research institutes it is representing. Every two years, the topteams make agreements with authorities and societal organizations as for what joint activities will be undertaken. The last Knowledge and Innovation Contracts, for 2016-2017, were signed in October 2015. Joint research activities are performed in the Topconsortia for Knowledge and Innovation (TKIs). Topsectors can have one or multiple TKIs. While there were 19 TKIs in 2011, the number is now back to 12 due to some consolidation. Besides those centers for applied research, also the Centers for Expertise and Craftsmanship are an important part of the institutional setup. These centers tune their educational programs to the human capital priorities of the respective Topsectors.

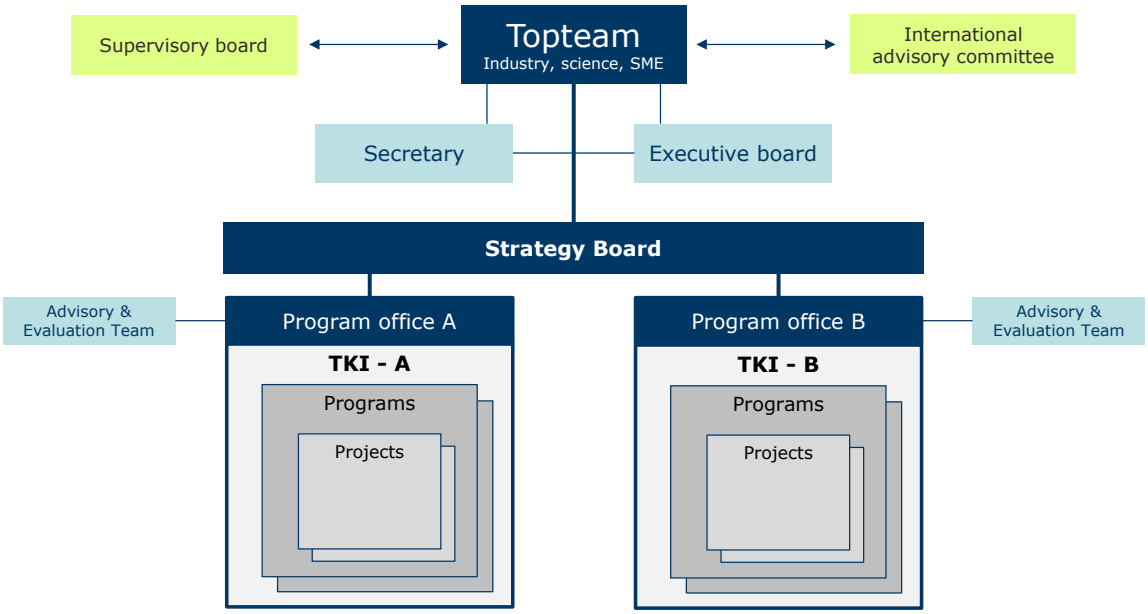

Figure 4: Organogram of governance structure around a topteam. Details and number of TKIs may vary per Topsector.

Figure 5 shows the institutional components of the Topsector policy mix (central) and the main interventions related to this. A first actual policy measure is the TKI-surcharge. This measure provides a top-up of 25% for every euro firms are spending on public-private research collaboration. The TKIs also receive direct funding for some of their networking and advising activities. In order to ensure SME involvement, there is an additional measure called the MIT. Each Topsector had the opportunity to select one or more of five possible types of interventions (advisory projects, feasibility studies, R&D collaboration, knowledge vouchers, and TKI-networking activities). The policy approach also aims to spur techno-economic developments by adapting regulations, facilities and infrastructure customized to the specific needs of each Topsector.

Finally, it is important to note that the Topsector approach also serves as a mechanism to align policy interventions not strictly related to economic development. On the science side, a substantial share of funding for fundamental research got redirected exclusively to Topsector topics. Likewise, also the research activities of existing research centers like TNO and the Large Technological Institutes (together forming TO2) have partially been shifted to Topsector topics. These changes indirectly contribute to the research taking place in the TKIs. Firms can also benefit from the fact that Topsectors are used to strengthen the profiling of the Dutch scientific and economic strengths, which helps to attract funding from European R&I programs as well as international trade.

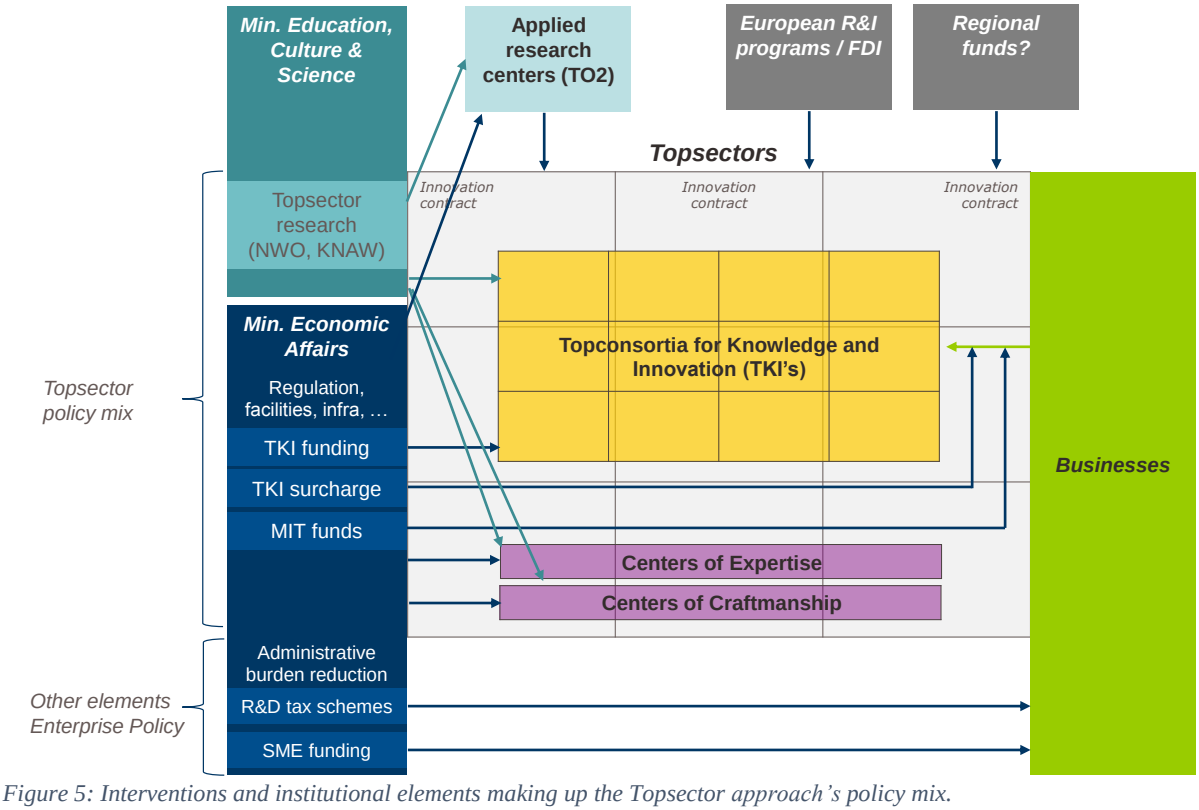

Figure 5: Interventions and institutional elements making up the Topsector approach's policy mix.

One important reason why the Topsector approach qualifies as transformative policy is that it truly embodies an effort of policy makers that embark on collective paths to overcome inertia and unleash change. To clarify this, consider two ways one might conceptualize the policy strategy. A

traditional perspective is that it is nothing more than a bundle of policy interventions all targeted at specific industry sector (upper part of Figure 6). In reality, however, the topteams of diverse representatives have the power to affect other policies, institutions and firm behavior as well. The lower part of Figure 6 depicts this is the indirect but no less important influence of the Topsector approach. At least from the outset, the governance structure seems in line with PDIA-principles (Andrews et al., 2012) of engaging broadly-backed bodies in experimental learning with respect to solutions for their context-specific problems. But how well does it qualify as transformative policy?

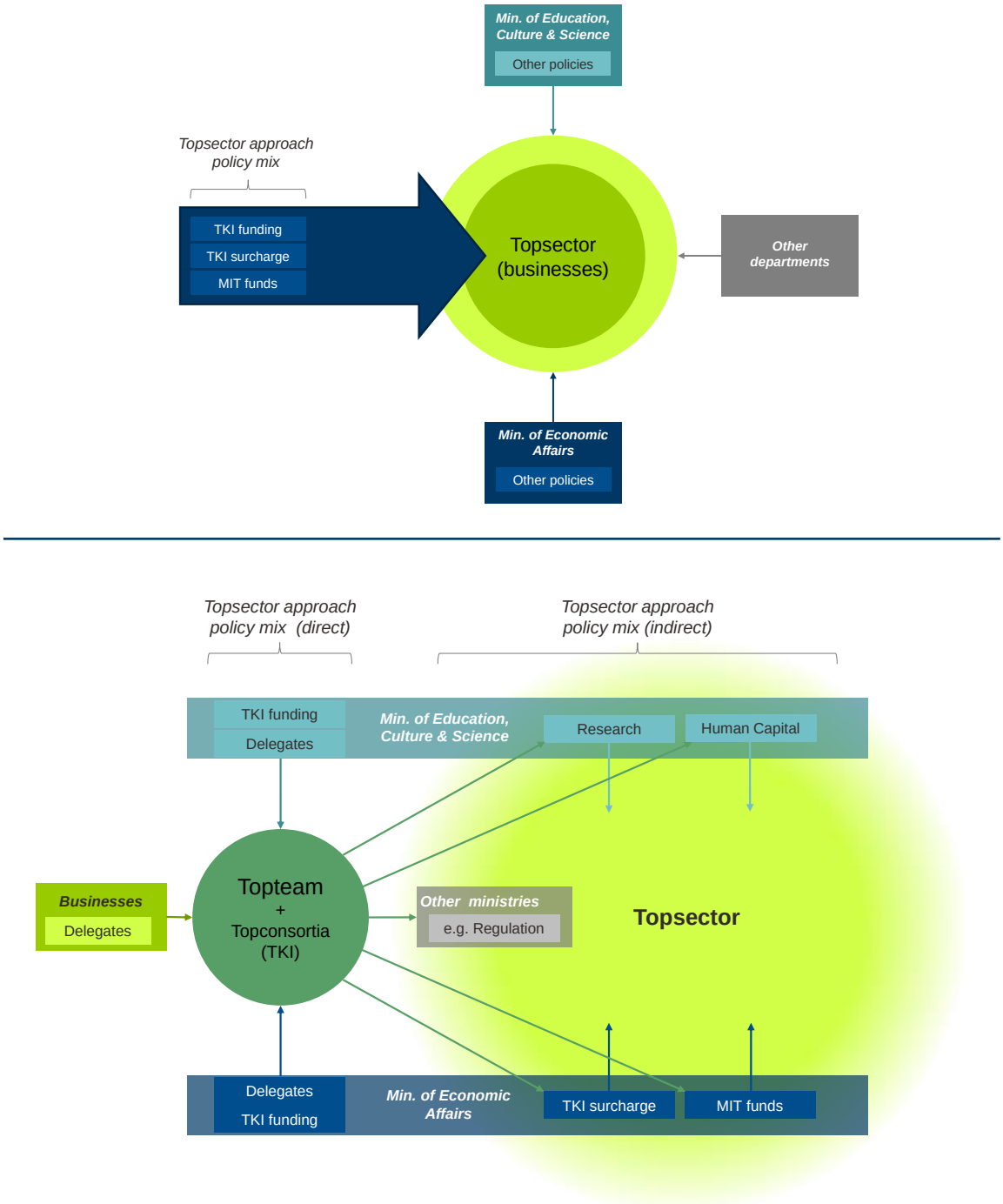

Figure 6: The upper part represents the Topsector approach as a policy mix offered to a clearly defined industry sector which also receives support from other departments. The lower part of this figure highlights the interactive nature of the policy approach; an important part of the policy mix is the collection of policy adaptations resulting from joined strategy development by businesses, science and economic policy delegates.

4.3. Policy design assessment

The characterization provided above allows us to assess how well the Topsector approach meets the design principles for policy organization and orientation. Because the institutional implementation is relatively uniform across Topsectors, it is possible to make statements about the policy approach in its entirety. For the sake of brevity, we discuss only the most relevant policy actions when reflecting on a design principle: exhaustiveness is not pretended. In case a policy aspect is found not to be clearly in line with a design principle, our critique should merely be seen as an urge to investigate those particular issues in more depth. Note that this holds for virtually everything in this assessment, as it aims to support policy learning just as much as making a conclusive analysis of policy contributions to TIS building.

As for policy orientation, *embeddedness* seems to be a rather strong point. The topteams were formed bottom-up and continue operating as self-organizing entities. By representing the firms in their Topsector, the deliberation council-like topteams are empowered to negotiate widely supported innovation contracts with government authorities. Also, the TKIs and especially the Centers of expertise and craftsmanship are highly sensitive to local innovation dynamics. Collaboration is at the heart of all their activities. Investments advisory councils are largely absent, as the Topsector approach refrains from making big economic investments at all (not counting expenditure on fundamental and strategic science). At the regional level there are Regional development companies (ROMs), but it is unclear how much they are aligned with the Topsector approach. The same holds for the recently launched venture funds 'Future Funds'. All in all, the policy design appears to be configured in such a way that information retrieval is possible. What kind of information that will be is the subject of other principles.

For most of the elements listed under *discipline,* policy design appears to be adequate as well. The overall objectives and targets of the Topsector approach are complemented by the detailed goals of the TKIs. From the beginning, the responsible ministries have been coordinating extensive monitoring procedures. These are largely in hands of Statistics Netherlands (CBS), whereas more analytical reflections are primarily provided by the Councils for Science, Technology and Innovation (AWTI) and the Social and Economic Council of the Netherlands (SER). The ministries themselves also publish a progress report every year, in which they respond to the consultations. Furthermore, they commissioned a study on how to set solid evaluation standards. The resulting report became highly influential, and provided concrete suggestions for econometric techniques suitable for upcoming assessments. Interestingly, the report did not manage to design a method for evaluating the Topsector approach as such. One discipline element perhaps not so present is concerns well-designed rules. On the basis of public documents it is hard to see how Topsectors or topteams can fail (for particular TKI programs/projects this is clearer). Adaptation and termination rules are important, because all other discipline elements become irrelevant if there is no way to act upon negative signals.

A pro-active communication strategy for the sake of *accountability* is clearly present. Apart from publishing the progress reports, which provide strategic considerations as well as analytical capita selecta, the responsible ministries host a variety of websites devoted to the approach. This includes dashboards for monitoring purposes, online portals for information on policy measures platforms for announcing and coordinating community activities, etcetera. Also the Topsectors and TKIs themselves are communicating visions and progress updates frequently and in detail. The trait of visible leadership is placed in the appointment of topteams. Having a high public visibility, it is clear which firm representative, researcher and top official are responsible for each Topsector.

Execution of the approach's underlying policy interventions like the MIT is mainly done by the Ministry of Economic Affair's own agency RVO.nl. It is generally known as an experienced and *competent* agency, just like the National Science Foundations (NWO) allocating the research funding. Judgments about competency of the Topsector's executive and strategy require more examination.

Table 4: Assessment of policy organization. Dark items seem best in line with design principles, light items are questionable.

Policy organization	Topsector approach
I: (Self-organizing) deliberation councils	Topteams formed bottom-up; Innovation contracts
I: Supplier development forums / search networks	Topsectors + TKI's
I: Regional collaborative innovation centers	TKI's, Centers of expertise / craftsmanship
I: Investment advisory councils	Not at TS-level. But: Regional development companies (ROMs)
I: Private-public venture funds	Future Funds aligned with Topsector approach?
D: Formulating clear objectives	Overall objective: competitive + 'green'. Detailed goals per TKI.
D: Formulating measurable targets	Overall target: 2.5% GERD. Detailed targets/KPI's per TKI.
D: Close monitoring (incl. annual diagnostic)	Annual monitors, Progress Report BB, AWTI balance, SER
D: Proper evaluation (incl. RCTs)	Evaluation of individual measures. No policy experiments yet.
D: Well-designed rules (e.g. sunset clause)	TKIs programs managed strictly. But can Topsectors/TKIs also fail?
A: Pro-active communication strategy	Progress reports (include rationale), dashboard
A: Visible / responsible leadership	Involvement high-level officials, topteam 'captains'
L: Leadership competence	Partially carried out by RVO.nl / NWO. Quality of TS-boards ok?

The overall picture for policy orientation is somewhat less positive. *Prioritization of public inputs* is still in order, as the Topsector approach abolished any direct transfer of resources. The most substantial budget item is the TKI-surcharge, but this concerns contributions to public-private research only to be awarded as a top-up to actual firm investments (in accordance with the willingness-to-pay requirement). Whether the government truly undertook significant efforts to address non-financial barriers is unknown at this stage.

What choices have been made for the *openness* of the approach's architecture is more visible. The label 'Topsectors' strongly suggest that the approach adheres to an industry-focus rather than an activity-focus. Of course it would be bold to base our judgment just on the approach's name. A focus on nine Topsectors jointly representing 87% of national R&D-investments (CBS, 2014) does indeed not seem to involve any selectivity at all: it might just be a starting point for helping public-private consortia to organize themselves. In practice, many policy inputs get directed exclusively to the priorities defined by the topteams. What should be safeguarded is thus that those topteams concentrate

their influence on a number of clearly defined domains that offer, when supported, innovation possibilities for a wide variety of parties. In this light it is striking how much the government is reporting on developments that concern the entire collection of firms active in industries that can be grouped under a Topsector.[6] For instance, the official annual monitor provides, for every Topsector, statistics on the average R&D investments (used to calculate the figure mentioned before), amount of patents, exports, etcetera. Also the percentage of firms in a Topsector involved in TKI-activities is carefully monitored. Clearly, a more relevant issue is whether the right parties are involved for making major transitions: these are not necessarily the firms who tend to find their ways to policy makers easily ('usual suspects'), and neither are they necessarily part of the industry classes classified as making up the Topsector. The extensive monitoring of sectoral statistics does suggest that socio-technical activities are not a primary concern, or at least the monitor's output is hardly useful for analyzing if change is afoot.

Following up on these considerations, there are also some concerns to be expressed for the focus on *new activities*. The fact that the Topsector approach is highly focused on innovation does not imply that it only supports radical experimentation. Particularly interesting here are the risks lurking in the demand-driven mechanism for organizing TKI research. Although this mechanism helps to tune research to actual needs, it does increase the possibility that joint experimentation gets targeted at rather immediate issues - and therefore incremental change only. This would be against the imperative of targeting transformative policy at long term developments that could truly alter industries and social practices. Also, coming back to the issue of architecture, we remark that a focus on new activities does not always benefit from involving as many parties as possible.

Finally, careful attention should be paid to the extent to which *spillover effects* are ensured. Due to the aforementioned demand-orientation, there is a great risk that research results remain accessible only to the firms contributing to the TKI projects. While they are indeed the ones making investments, the publicly funded surcharge suggests results should transcend the TKI's boundaries. When the Topsector approach aims to be transformative rather than only R&D-boosting, the question is whether participating firms buy themselves exclusive research or just the position to determine what the TKI research projects will be about (recall the remarks on lobbying by Hausmann & Rodrik, 2006).

Table 5: Assessment of policy orientation. Dark items seem best in line with design principles, light items are questionable.

Policy orientation	Topsector approach
Inputs instead of transfers	TKI-surcharge and HR instead of subsidies. But what about (domain) specific interventions? In innovation contracts?
Open architecture	Strongly framed around *sectors*, but funding for *activities?*
Genuinely novel activities	Focus of support measures is innovation (and HR). But radical?
Contrive spillover effects	Support mostly for public or public-private research. But does it transcend beyond TKI-boundaries?

[6] The official methodology for determining which firms belong to a Topsector does include some customization beyond industry class boundaries. Also, it acknowledges that some industry classes belong to multiple Topsectors.

In sum, the Topsector approach meets most of the policy organization principles but does less well on the policy orientation criteria. Note that this does by no means imply failure per se: the critiques (or rather questions) pertain only to the specific bar we use to form a judgment. The analysis suggests that the Topsector approach might not be as transformative as some would suggest; perhaps it is just a resource-extensive R&D spurring policy after all. This would not be problematic in itself – the Topsector approach might be quite good in bolstering existing ecosystems - , but it seems inconsistent with aspects of the policy design that do appear to be attuned to driving transformative change. Once again, we stress that our preliminary analysis only highlights points of concern. In-depth follow up studies should verify the actual state of affairs.

4.4. Policy impact assessment

Transformative policy causes structural change by opening up innovation possibilities for firms concerned with a certain span of economic activities and technologies. The policy interventions making up the policy mix can contribute in various ways. As there is no clear counterfactual, the impact of these interventions is to be determined by filling out the impact framework introduced in section 4.3. Ideally this is done for every technological innovation system the transformative policy eventually helped evolving.[7] In this empirical illustration we limit ourselves to the Topsector Energy only. While this Topsector used to cover no less than seven TKIs, restricted space requires us to treat the Topsector as if it constituted one single TIS.

There are two ways to fill out the impact framework. If the policy mix is entirely clear, it is intuitive to start with listing all policy efforts and identify what functions they impacted upon, how much, etc. In practice, transformative policy might also take the form of interventions not coming to mind directly when making an overview of the relevant policy mix. In that case it makes sense to start with the functions and ask for all of them what public inputs were relevant.

As mentioned before, the analysis presented here is rather tentative. It is primarily based on statements expressed in one single source (Van Son, 2015), where possible triangulated with publicly available documentation.[8] The results summarized in Table 6 strictly serve to illustrate how an assessment would look if, after more rigorous examination, all the preliminary findings were indeed found to be true. More details on our judgments are provided in the table in Appendix 3. Here, we restrict ourselves to interpreting the key observations.

[7] Defining the TIS in focus is the first step of Bergek et al's (2008) scheme for analyzing the functional dynamics of a TIS.
[8] The website http://topsectorenergie.nl/documenten/ provides a rather extensive set of strategy and progress reports.

Table 6: Assessment of policy impact. The intensity of the shading in the cells corresponds with the value for the parameters in the columns: a darker color stands for a higher effectiveness, decisiveness, or importance.

		λ_i	{n1…N}	P_i	α_i	β_{ii}
F	Function	How **important** is function j for success of TIS?	What did government do to strengthen function j?	How **effective** was policy in strengthening function j?	How **decisive** is policy for strengthening function j?	Does function j **strengthen other functions?**
F1	**Entrepreneurial experimentation**	Various options being explored, but not in depth	TKI projects (aimed at sector demands), MIT	Demand driven TS-activities spur innovation	Particular sector is innovative by itself already	
F2	**Knowledge development**	Technological uncertainties hamper progress	Redirecting research to Topsector topics	TKI research not radical, some topics dropped	Vested parties focus on current practices	
F3	**Knowledge exchange**	Poor link with customers blocks acceptation a bit	Topteam / Topsector	Diverse parties involved (but some missing)	Normally mostly same parties in networks	
F4	**Guiding direction of search**	Stagnation due to competing tech. options	TKI vision, Innovation contracts	Strong project focus, including soc. challenges	Scattered field, but not ignoring major options	Setting directions spurs innovation (but limits variety)
F5	**Market formation**	New techn. later depend on new ecosystem	?	Missing: Min. of I&M, certifiers, insurance prov.	Governments can solve missing markets	
F6	**Resources: financial capital**	Still too early for big investments	TKI-surcharge	Still low finance availability	Long-term infra = scarce funding	
F6	**Resources: human capital (HC)**	Lack of HC not a bottleneck yet	HR agenda	Better skilled HC (in the future)	Beta-studies unpopular	
F7	**Legitimation / counteracting resistance**	Scarce licenses for space limit off-shore wind	Listening to Topsector firms (but also acting?)	Some laws still hampering; CCS low acceptation	Especially regulation is pure policy issue	

Whenever functions have dark-colored cells in both the P_j-column and α_j-column, this means that underlying policy interventions gave an impulse to TIS-elements were public involvement was decisive. In the case example this concerns especially the future availability of resources like appropriate human capital (F6b). However, as the light-colored cell in the preceding λ_j-column indicates, this particular function was (in the period under study) not crucial for the performance of the system. By the same token, it hardly matters that at this point policy was limitedly effective in countering resistance by adapting regulation (F7), or in acting as a leading customer to provide signals that drive market formation (F5). Both these functions typically do require some policy involvement (high α_7 and α_5), but generally many of the Topsector's TISs are in a too early phase for those functions to be of crucial importance. A low policy impulse for financial capital (F6a) might thus testify of correctly placed policy priorities (assuming it is not due to inputs failing to translate to impulse in the policy implementation stage) if public inputs are not decisive and capital is not even a bottleneck for the moment.

What is relevant for the current state of TIS building is that research activities involve a high variety of parties (for the sake of diversity and applicability/acceptation), and that the knowledge exchange allow results to find their way to parties willing to use them in the development of novel products/services (F3). In turn, the TKI-projects and MIT give a positive impulse to entrepreneurial experimentation (F1). Although policy efforts are not entirely decisive in these respects (low α_3 and

α_1), they unmistakably contribute to the longed-for (moderate λ_3 and λ_1) in-depth and customer-sensitive exploration of new technological opportunities.

In the end, however, the most important functions to be boosted (high λ_j) were knowledge production (F2) and guidance of the search (F4). Because policy was effective and decisive especially in the latter aspect - overcoming stagnation by facilitating the selection of specific directions, including long term goals -, it is likely that more radical research will accelerate. This can in turn lead firms to explore the more novel options in more depth (high $\beta_{4,1}$). On the other hand, knowledge development might be steered further away from some topics (high $\beta_{4,2}$).

To summarize the impact assessment of our test case, inertia was mainly overcome by concentrating joint research efforts on directions firms appear willing to invest in (which was more a matter of adding focus than of formulating new long term targets). The provided policy inputs yielded impulses of varying magnitudes, but not all of them seem to be addressing necessitous functions were policy intervention is indeed the only way to set further TIS development in motion.

4.5. Overall assessment

So far, policy design and policy impact have been assessed independently from each other. In reality the design of a policy approach is likely to explain many of the policy outcomes. When policy is a-selective, firms themselves have relatively a lot of freedom in deciding how they will use public inputs. A transformative policy approach is - by definition - more selective in the development opportunities it offers. At the same time the policy design space is also far more extensive. That is, policy makers have to consider relatively many policy design options when configuring their intervention. Whereas generic policy typically requires one standard implementation procedure, transformative policy is characterized by multi-instrumentality, system-specificity and reflexivity (continuous adaptation). All of these imply that any instance of this approach, like the Topsector approach, will be exercising significant influence on the direction of change. The resulting strong link between intervention and outcome can be used to strengthen the validity of our findings.

Cross-framework linkages

Figure 7, below, gives an impression how such an analysis could start. Some of the policy design choices related to embeddedness, e.g. the formation of topteams and Topsectors, contribute to positive developments on the accounts of knowledge exchange (F3) and - as they help policy makers to identify priorities - guiding of the direction of search (F4). Also discipline-aspects like formulating targets and reporting progress serve to steer developments. One could furthermore argue that all the attention for Topsectors, for the sake of accountability, provides signals to markets (F5) and helps to attract foreign R&D funding and talent (F6). Reversely, the occasionally questionable design of policy orientation might explain on what accounts policy impulses were less strong. The preference for demand-driven TKI projects could reasonably linked to signals of incrementalism in the Energy Topsector's research activities (F2). And the observed difficulty to involve outsiders and customers in

processes of knowledge exchange (F3) is perhaps embedded in some of the spillover-inhibiting features of the Topsector and TKI project's institutional design.

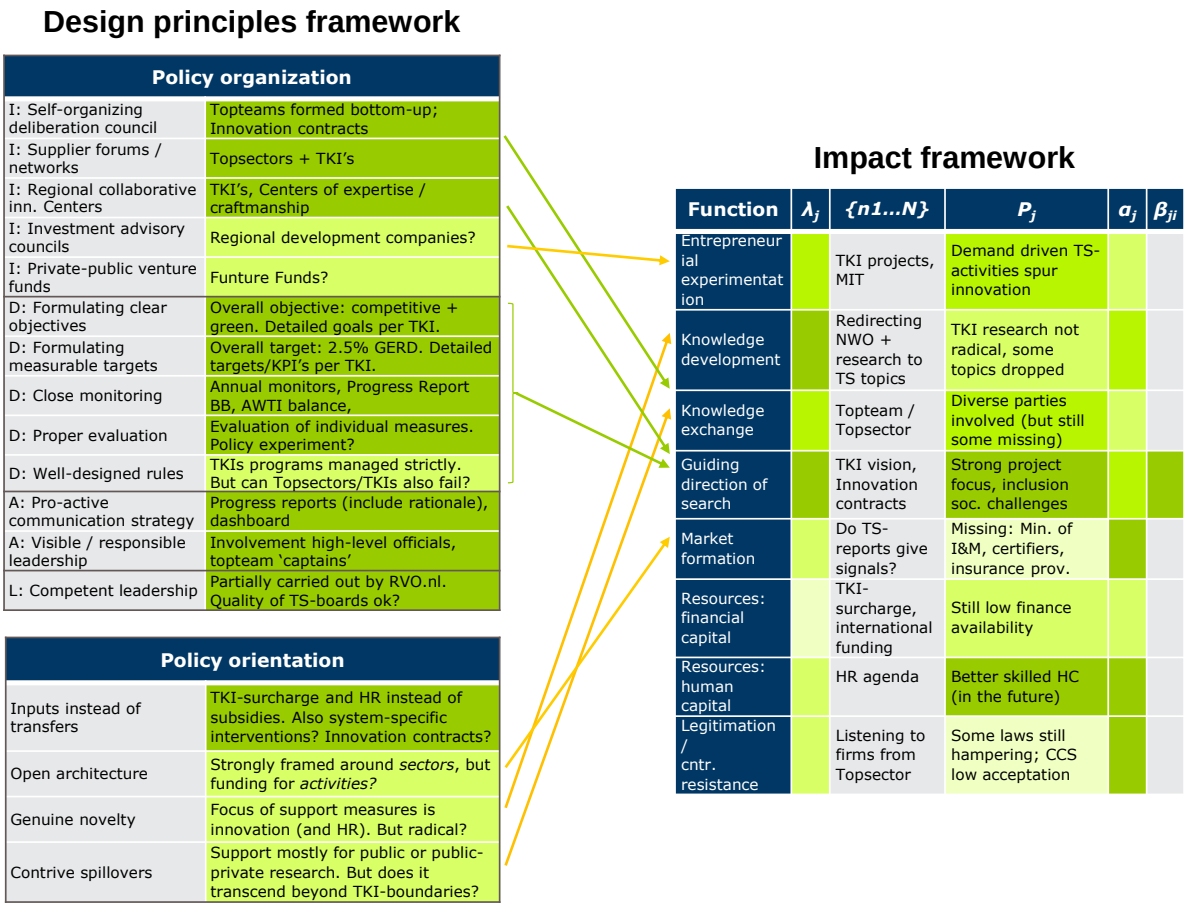

Figure 7: Exploration of linkages between policy design choices (left) and policy impulses in the impact framework (right).

Our brief cross-framework analysis suggests that strong points in the policy organization seem responsible for successes found in the impact assessment. Similarly, some of the possibly shaky elements of the policy orientation are related to parts of the TIS that could perhaps have been stronger.

The presented analysis only captures impact in the sense of 'contributions to conditions that allow for the creation and application of activities that can enable a leap in economic transformation'. Additional investigations should indicate the economic potential of the emerging trajectories as such. To anticipate on such follow-ups, we sketch how a comprehensive assessment could include the examination of actual economic changes.

Economic transformation

Throughout this study the term 'economic transformation' has been used for referring to a *process* of adaptation. In the final stage of an impact assessment it is desirable to also have an *outcome* definition of economic transformation. There are many ways to operationalize this. The most obvious candidate is probably structural change, i.e. modification of an economy's industrial tissue. In practice this often boils down to the rise of activities in industry classes so far unpopulated. However, our understanding of economic transformation clearly goes beyond this. Socio-economic transitions

related to the development and/or deployment of new technologies can significantly alter the competiveness and sustainability of an economy without manifestations of activities in new industry classes. Inspection of patenting and publishing activity in previously untrodden domains could be just as informative. The same holds for the emergence of new products and services, educational curricula, or any other indicators on knowledge-related phenomena ultimately underlying structural change.

Regardless the type of indicator chosen for assessing transformation, it is important to acknowledge that conceptually there are multiple kinds of 'new'. Transformative policy aims to enforce transitions by bringing together inputs and conditions that market players themselves would not (or much slower) manage to coordinate. This begs the question which type of diversification is new but adjacent, and which type is genuinely novel. Particularly informative in this respect are the lines of literature on economic complexity (Hidalgo et al., 2007) and related diversity (Frenken et al., 2007). Both of them stress that economies, whether it is at a national or regional level, tend to diversify incrementally (Hausmann & Klinger, 2006; Boschma et al., 2014). Firms, for example, generally explore activities in which many of their knowledge and capabilities (attuned to specific infrastructural and institutional elements in their economic environment) can be leveraged. In case industries are highly similar in the assets or knowledge base on which they rely, the 'distance' between them is said to be small. This can be measured by inspecting co-occurrence patterns in for instance exports, patent citations or labor flows. Figure 8 shows the type of network that can then be constructed. If it were an industry space, the nodes would be industries of different sizes and the ties would represent the extent of relatedness. Blue dotted notes make up the portfolio of industries currently present in an economy. In the provided example, density-measures (Hausmann & Klinger, 2006) would confirm that industry X is more related to the economies existing portfolio than industry Y. These different types of development feature centrally in recent studies on related and unrelated diversification (e.g. Boschma & Capone, 2015). Such concepts are important to build on when determining if actual leaps are taking place.

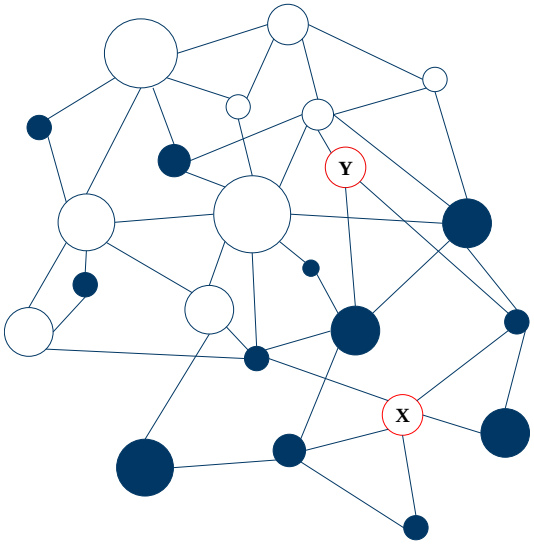

Figure 8: Conceptual illustration of a relatedness network (e.g. industry space). Node x is more related to existing portfolio (blue colored dots) than node y.

The last step of the assessment scheme we envisage is thus to answer the questions: did diversification in the policy's key domains become more unrelated, and can this be linked back to TIS building the policy approach has been contributing to? It normally is only after a couple of years that we can determine what kind of alterations in the course of knowledge and economic development are coming along. Generally such final changes originate from complementary developments within the TIS as a whole. Nevertheless, some type of changes can be associated with particular system functions.[9] The production and export of new products (goods/services) is a manifestation of successful entrepreneurial experimentation. Likewise, publications result from knowledge development and patents from probably the first three functions. Using a variety of indicators for changes in economic and underlying knowledge structures, our overall assessment scheme would look as follows:

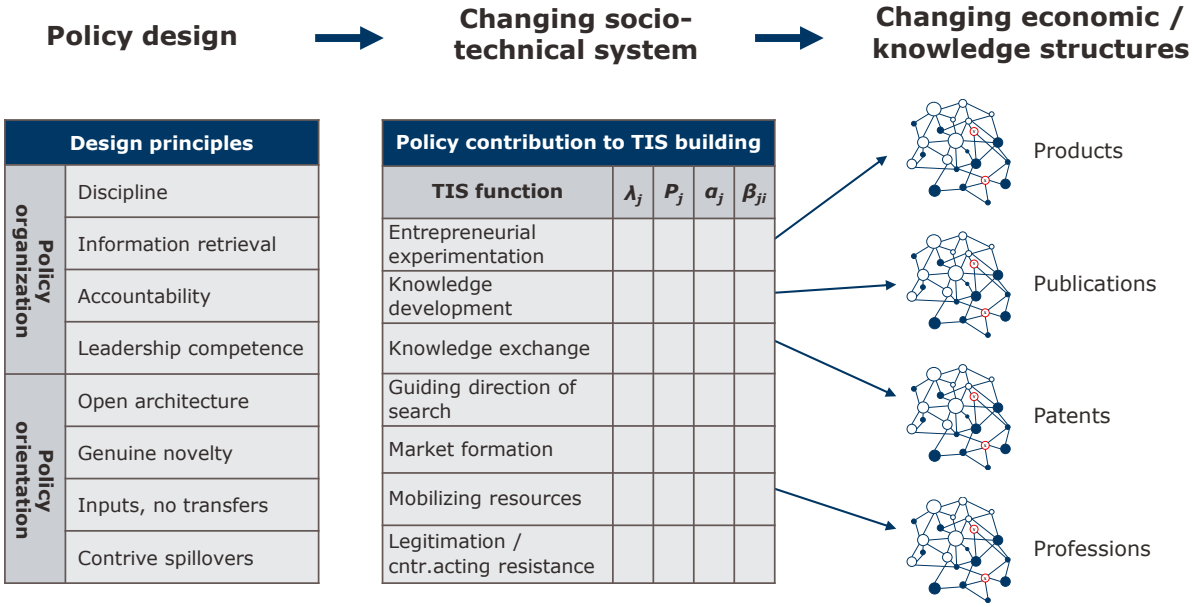

Figure 9: Overall assessment scheme

5. Conclusions

In the fields of economic development and innovation, currently unfolding policy changes and accountability demands do not go hand in hand. As policy makers try to strengthen their grasp on the complexity of socio-economic and technological change, they reduce possibilities for actually demonstrating effect. Traditional techniques for determining impact tend to reduce the concept of effectiveness to a single number. Such additionality calculations, like the infamous 'bang for the buck', falsely suggest that results of innovation policy are a unidimensional and linear phenomenon. In the case of transformative policy, there clearly are significant dynamics to take into account other than just the government failure of crowding out private investments. Nevertheless, it does remain fair to ask for the ultimate impact that policy intervention achieved.

[9] Previous studies on TIS diagnostics occasionally use observations of these types as indicators for TIS building. We stress again that the TIS itself concerns *conditions for the creation and application of new technologies/activities*; actual changes in e.g. patenting and production structures are thus an outcome we would like to disconnect from the throughput (i.e. interactions/transactions in the TIS that lead to these results).

5.1. Practical contributions

The current paper has set out to develop a scheme for assessing the design and impact of emerging forms of narrowly-targeted policy. To do so we brought together two unconnected but highly complementary (and occasionally overlapping) bodies of literature. Our concept of transformative policy unites principles from new industrial policy on the one hand, and perspectives from science, technology and innovation studies on the other hand. While the first helped defining how policy organization and policy orientation should look, the latter supplied the basis for determining whether change is afoot. Both literatures have been advancing ideas on what structural transformation really entails.

A major contribution of this study is the development of an impact framework; the centerpiece of our assessment scheme (both literally and figuratively). Fundamental to the suggested way of measuring impact is the belief that, essentially, transformative policy is about adapting socio-economic systems in such a way that it opens opportunities for collective exploration of a set of set of technologies and/or business models. The impact framework provides a structure for gathering and analyzing information needed to assess how much policy inputs jointly contributed to changes in a certain domain. For every function in the framework researchers should ask if there are any verifiable problems (not just claims, but preferably hard evidence), which efforts are taken to solve them, what has this led to, whether those efforts were additional to existent dynamics, and how they affected overall system dynamics. Filling out the impact framework thereby is a means to uncover whether there is any logic in the combination of efforts that are deployed to reinforce the creation of a TIS.

Ideally, the first use of the impact framework (and policy design framework) occurs already before the implementation of newly formulated policy. Such an ex ante specification prevents ex post rationalization of how policy is working out. In case there is divergence between planned and realized events, it is essential to determine whether this can be attributed to policy failures or unanticipated changes in the socio-economic environment. Finding such a justification does not just serve to make a judgement about policy impact, but is primarily a way to learn why changes are unfolding as they do. For some it will be uncomfortable that quantitative estimations are only limitedly applicable. However, even via qualitative methods the proposed approach is likely to generate a comprehensive account of the actual (and perhaps ideal) role played by policy. Such an account is likely to be richer than the results of solely quasi-experimental econometric techniques, and it yields insights useful for future policy efforts. After all, continuous assessment is key for a process-oriented policy approach (Hausmann & Rodrik, 2006; Edler et al., 2008; Andrews et al., 2012).

Having a practical orientation, this paper also contains a tentative case study. The presented empirical analysis should not be taken as absolute truth, as it is too preliminary for making final judgments. It mainly acts as a demonstration of how a policy review according to our propositions could look, analogous to the step in scale development where the external validity of a new metric is

examined by applying it to actual data (but without intentions to make strong claims about the data itself).

As far as our assessment scheme is used to assess the Dutch Topsector approach in a formative way, it does its job by pointing out what in-depth follow-up assessments should be paying extra attention to. The Topsector approach was found to adhere to most of the design principles for transformative policy organization, while some elements of its policy orientation are questionable (notably: open architecture, focus on new activities, ensuring spillovers). Our cross-framework analysis suggests that the design configuration can be linked to observations on the actual policy impulses that were provided in the Energy Topsector. By filling out the entire impact framework we were able to construct an overview of how supportive the policy interventions have jointly been. This exercise highlighted that it is paramount to check if a policy mix is decisively contributing to functions where impulses are truly needed.

5.2. Theoretical contributions

Transformative policy is believed to be emerging out of recent contributions in economic development and innovation studies. Our efforts to unite insights from those fields could help advancing either side. The first line of literature has for instance been criticized for focusing too much on explaining a lack of private investments (e.g. Felipe & Usui, 2008): more attention for the variety of potential policy inputs and roles in managing socio-technical dynamics of change could be useful in this respect. On the other hand, the streams of innovation studies we relied on (notably TIS, but in extension also SNM and MLP) have been accused of neglecting the fact that policy budgets are constrained (Bening et al., 2015). The TIS perspective has also omitted asking what impact is achieved through policy, and it is acknowledged that closer links with other bodies of literature could make the field stronger (Bening et al., 2015). The impact framework embodies our answer to these critiques, as it draws upon a modification of a complexity-based growth model and it introduces stringency.

The availability of a first basis for assessment contributes to the call for bringing new industrial policy and innovation studies to policy circles (Weber & Rohracker, 2012; Bening et al., 2015; Hillman et al., 2011). Apart from structuring ex-post assessments, it is also relevant for experiential learning and thereby increasing rather than only gauging the impact of the policy interventions (Pritchett et al., 2012; Andrews et al., 2012).

5.3. Limitations and further research

The limitations in the tentative case study have been expressed extensively already. In order to strengthen the suggested assessment approach, an actual in-depth application is urgently required. Such a follow-up should start with assessing policy contributions to the evolution of a single TIS, perhaps followed by a comparative study across multiple TISs. Repeating this exercise would ideally lead to some standardization of qualitative and quantitative methods for filling out the policy design and impact frameworks. Nevertheless, an adequate assessment will always requires a profound understanding of the way systemic change took place. To determine how much policy efforts have

been leading the way, and alleviated bottlenecks, the challenge is to reconstruct an account of the forces that were at play in the evolution of the TIS under study. Suitable methods in this regard are process analysis and event mapping (e.g. Chappin et al., 2009; Hekkert & Negro, 2009). We like to stress that also econometric techniques can be of great use when filling out the impact framework. Their limited ability to determine the aggregate impact of a policy mix does not imply that they should be excluded when assessing, for instance, the decisiveness of policy inputs for a certain function.

Another apparent weakness of the suggested assessment scheme is that it seems to assume that a TIS needs to be developed entirely within national borders. How TISs develop or should develop in an international perspective is a topic some scholars already started struggling with (Binz et al., 2014). What should be noted here is that our impact framework does not request reviewers to check which function is strongest or weakest in absolute terms: it only asks which function is relatively most in need of additional support. There is no instruction to determine this by looking at only the national state of affairs. However, we do acknowledge that an international orientation is highly relevant when finding a policy response to the identification of necessitous functions. Instead of immediately investing public inputs, it might be worthwhile to verify which missing inputs can be retrieved through international collaboration. Particularly interesting in this respect is the topic of 'STI diplomacy', as a variation on economic diplomacy (UN Task Force on Science, Technology and Innovation, 2004) or extension of science diplomacy (Flink & Schreiterer, 2011). Further investigation of this largely overlooked phenomenon is a promising avenue both for researchers and policy makers.

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Appendix 1: An ontology of transformative policy

Key characteristics of transformative policy

As noted, the emergence of transformative policy can be linked to two trends: the advancement of new industrial policy in economic development literature (Rodrik, 2004; Hausmann & Rodrik, 2006), and the rising interest for insights stemming from (meso-perspectives in) innovation studies (Markard & Truffer, 2008; Weber & Rohracher, 2012; Bergek et al., 2008). Although these developments are rarely linked to each other, notable exceptions being Cimoli et al. (2009), Warwick & Nolan (2014) and Mazzucato (2015), there are striking similarities in their views on how policy can drive upward diversification. A review of these similarities leads us to speak of transformative policy when a policy approach meets three key characteristics.

Selectivity

According to the OECD STI Outlook (2014), many countries stimulate entrepreneurial experimentation by providing generic support measures. Such *a-selective* or horizontal measures spur innovation without giving any explicit preference to specific types of industries or technologies. Examples are the widely used tax schemes for deducting R&D costs. The opposite of horizontal policy is vertical policy.[10] One kind of vertical policy is the type a government uses to establish a certain industry, for instance through support of inwards knowledge mobility, FDI and trade protection. A famous example is Chile's decision to invest in salmon-farming (Hausmann et al., 2008). This case shows that an *industry-specific* development strategy can be very successful, but of course there are also many examples of less prosperous attempts to pick winners. The alleged inability of governments to make champions is indeed a major explanation for why industrial policy got so contested (Rodrik, 2004).

What is confusing about the horizontal-vertical distinction is that it neglects the fact that economic policy can also be selective in other ways. New industrial policy is considered novel because of redefining the way policy makers target their interventions (Hausmann & Rodrik, 2006). New industrial policy 'in the small' refers to the approach where policy makers interact with other actors to identify which policy efforts could help new industries to emerge. It is through this dialogue that policy makers discover which experimental pathways to support best, and how to do so. The strategic challenge is to alleviate business constraints in such a way that firms can collectively enjoy the new business possibilities this yields - and take it in different directions. In this case, the consequence rather than starting point is that policy gets organized around domains who share particular constraints (i.e. all the activities benefitting from the complementary of publicly produced inputs). New industrial policy 'in the large' involves strategic bets, meaning that policy makers are more explicit in setting the directions of transformative change. As long as firms are in the driver's seat of entrepreneurial experimentation, however, this strategy is still very different from the industry-

[10] In reality, of course, it is inevitable that horizontal policies back some type of firms more than others (Rodrik, 2004).

specific approach in which the government itself is planning how a yet to be developed industry will look.

Our notion of *selectivity* is consistent with either version of new industrial policy. At the same time, we acknowledge there are more reasons why governments get to opt for a narrowly targeted approach. Important for our definition is that governments commit themselves to facilitate experimentation in specific domains, be it because of their potential to spur competiveness or for sustainability considerations, but do not dictate how exactly techno-economic developments should unfold - unlike in those 'smart specialization strategies' (Foray et al., 2009) where resources get devoted to innovation in top-down selected focal domains. The domains policy makers might select do not necessarily match with the boundaries of a particular industry. Instead, as relieving common constraints is supposed to let new activities emerge, the most likely scope is a technological domain like smart industry (based on the Internet of Things), smart grids or bio-energy. Whereas some technologies naturally get explored by firms from different industries, others might have a latent potential for creating connections between firms from very different industries. Doing so is in fact the cornerstone of 'cross-specialization' strategy (Janssen, 2015), which suggests spurring breakthrough innovation by exploiting the local presence of strong yet *unrelated* specializations in an economy. Rather than reinforcing the specializations themselves, this example of a selective strategy aims at creating platform-like interfaces (around particular technologies or societal challenges) that help firms to let their disparate knowledge bases converge.

Pathways towards new economic activities are typically explored by a varied mix of parties who jointly develop and apply technologies so far not available (at least locally) (Schot & Geels, 2008). The higher the novelty of those technologies, the more development gets the character of socio-technical transitions (Markard & Truffer, 2008). That is, in case a new technology is still in its infancy, it is likely that its maturation (ultimately leading to structural change) requires relative intense adaptations of knowledge flows, capital flows, infrastructures, institutions, etcetera (Hekkert et al., 2007). We understand transformative policy as the approach which sets out to support firms and other stakeholders as they deal with such uncertainties.[11] Looking at the OECD's (2014) examples of national STI strategies involving new industrial policy, countries typically target between 6 and 16 key priority areas.

Process-oriented / participatory

In order to support firms in their exploration of technologies and business models that can result in new industries, policy makers are advised to continuously monitor the bottlenecks those firms are encountering (Hausmann & Rodrik, 2006). The bottlenecks might change as firms advance the particular technology they are developing (Hekkert et al., 2007). As a result, it is no use to spur development by implementing a few instruments designed to eliminate major structural problems in

[11] Selectivity thus does not necessarily mean policy singles out individual industries or technological solutions; essential is that it helps firms in a certain domain to discover which way of designing a technology is most viable.

the economy or innovation system. To provide public inputs effectively it is key to keep adapting interventions to the progress made in experiments in the pre-selected domain. Such a process-oriented or participatory approach requires policy makers to engage in embedded governance, focused on retrieving information on what exactly is the most binding constraint at a particular moment in time (for a particular transformation). In this respect it should be noted that also end-users can be in the position to point out severe constraints. Studies by Dewald and Truffer (2011) have shown that new technologies or even industries can evolve from innovation and activism by those users themselves.

Portfolio of interventions

Almost by definition, process-oriented policy leads to the implementation of a multitude of interventions targeting the same development. Theoretically it is possible to replace one instrument for the other, but in practice we see governments stacking instruments on top of each other or modifying existing ones (Kivimaa & Kern, 2016). The result is referred to as a policy mix (Flanagan et al., 2011), policy system (Magro & Wilson, 2013), or policy portfolio (Miles et al., 2006; Edler et al., 2012; Rodrik, 2014). Policy mixes resulting from process-oriented policy are probably not a combination of relatively standard types of interventions, like R&D subsidies, tax holidays and an IP protection regime. The point of being sensitive to signals concerning particular bottlenecks is to provide inputs that are specific for the innovative transformation that is being boosted. This also involves, for instance, creating the right networks, involving relevant stakeholders, providing customized infrastructures, adapting legislation, and creating legitimacy (Bergek et al., 2008).

Figure 1 in the main text showed the key differences between an a-selective policy instrument focused on leveraging a particular type of outcome (e.g. R&D investments), versus the type of policy approach we regard as transformative policy. The latter does not simply aim to increase the extent firms are innovating, but is designed to effectuate modification of the industrial structure more directly. As this often involves the development and application of new technologies, meso-perspectives like TIS are useful in understanding the processes at play. Transformative policy facilitates processes of socio-economic adaptation by setting directions and continuously updating the inputs and laws relevant for the building of a technological innovation system in which the new economic activities can thrive. This kind of approach ultimately does rest on a number of single-goal interventions like the one depicted in the top of Figure 1, but it is important to note that these are part of a narrowly targeted structure of interventions. As we will see later on, a policy mix based on selective measures requires an assessment methodology different from the ones used for a-selective measures.

Rationales for transformative policy

No discussion of policy approaches can be without touching upon the rationales legitimating their existence. This is not less true for a study on impact appraisal, as effectiveness is measured by the extent policy is solving the problem it is targeted at. A good understanding of rationales for

transformative policy is crucial for the development of an adequate assessment scheme. We discuss this by describing the three legitimization logics introduced in Dodgson et al. (2011).

Market logic

The fact that a government can govern the creation of new techno-economic paths does not automatically imply that it should (Markard et al., 2015). Mainstream economists legitimize policy intervention by referring to market failures like positive or negative externalities, information asymmetry, coordination failures, or incomplete markets. All of these can hamper firms from engaging in transactions that might involve novel activities or technologies. Hausmann & Rodrik (2003) extend this line of thinking by pointing at another barrier to exploring new activities. Their notion of self-discovery is a variation on the better-known positive externalities. It basically describes the tension firms experience with exploring the viability of switching to a modern industry. Firms active in traditional industries might learn of this and follow rapidly, thereby dampening the return on the first-mover's exploration investments. In a similar vein, Rodrik (2004) notes that coordination failures are another reason why modern industries might sometimes not take off. In case markets themselves are unable to provide all the inputs required for activities in the modern industry, policy intervention is legitimate. This view on transformation is still consistent with orthodox economics.[12]

It is a strong assumption that every innovation attempt is affected equally and persistently by the market failures present in an economy. Hausmann & Rodrik (2006) therefore advance an argument leaning more towards heterodox economics. They plea for embedded governance, allowing policy makers to identify what exactly is hampering firms to jump towards a *particular* new industry. The natural tendency of firms is to explore economic activities similar to the ones already represented in an economy (Hidalgo et al., 2007). In order to make a 'jump' towards upscale industries, a wide range of factors need to be in place. Some of these are inherently public, like legislation, but policy also has a role when markets are unable to bring about the simultaneous deployment of absent inputs. As the range of 'productive complementarities' required for a new activity is highly specific for that activity, implementing generic interventions is not enough to boost economic transformation. On this basis policy makers might be legitimized to take the lead and provide missing inputs. Although these inputs are understood as more than production factors only (e.g. legislation), the underlying perspective is still very much one of production functions.

Coordinated logic

A different line of arguments is provided by innovation studies, starting with the literature on (national) innovation systems (Freeman, 1988; Lundvall, 1992). Economies are believed to be adaptive when the present ensemble of actors, institutions, interactions and infrastructures favor activities of knowledge production and application. Referring to possible shortcomings on these accounts, studies concerned with innovation systems are quite persistent in stressing the importance of

[12] The same holds for Rodrik's (2014) discussion of carbon (mis)pricing as an extra policy motive for green industrial policy.

acknowledging system failures or 'system problems' that can block technological and (therefore) economic change (Smith, 2000; Arnold, 2004; Weber & Rohracher, 2012). Already since the early days of innovation system thinking, such system failures are opposed to free market logic (Malerba, 1996; Metcalfe, 1992; Bergek et al., 2008; Mazzucato, 2015). Some scholars take a more integrative approach by acknowledging the complementarities in both ways of thinking (see Bleda & Del Rio, 2013). Transformative policy tends to follow this last line.

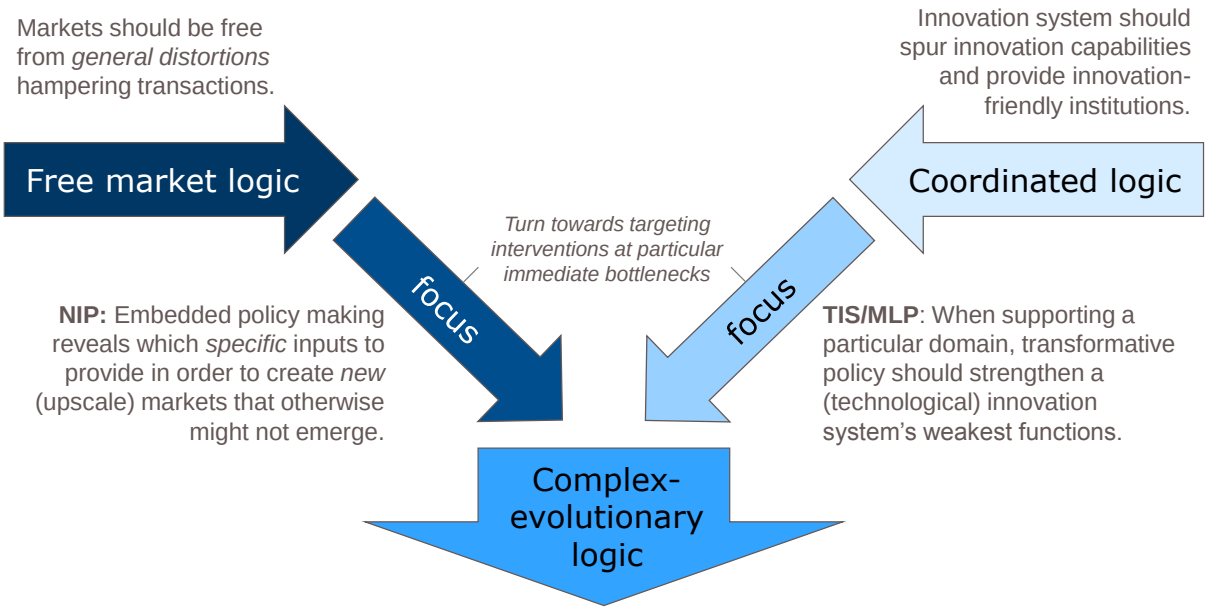
There is no need to doubt that unhampered market transactions alone are suboptimal for major economic transformation to take off. Less consensus exists if it comes to what this means for the justification of policy intervention. According to so-called coordinated logic, policy makers have a crucial role in governing the socio-economic processes that lead new activities to emerge (Dodgson et al., 2011). This interventionist view allows for the implementation of widely stretching spectrums of interventions, addressing R&D funding, interactions, legitimization, etcetera.

By concentrating on innovation capabilities and institutions in general, as if they were stationary, the national innovation system literature is "less suited for strategic challenges of transforming systems of innovation" (Weber & Rohracher, 2012, p.1039). Just like the free market logic, also the coordinated logic has generated views that emphasize the high degree of 'granularity' required for effective transformative policy. In particular according to the technological innovation systems perspective, governing the creation and application of new technologies is a matter of providing the right stimuli at the right time rather than (only) implementing generic innovation policy (Bergek et al., 2008). What exactly is malfunctioning in an economy is determined by diagnosing key processes known as system functions (Hekkert et al., 2007).

Probably due to their focus on socio-economic dynamics around transformative change, TIS scholars acknowledge that they have somewhat neglected the fact that budgets are constrained and policy must be stringent (Markard et al., 2015). Coming from a free market logic, intervention is only legitimized when it is solving some sort of distortion (be it in existing markets or in the creation of novel ones). A major critique on systems thinking is that it allows policy makers to intervene in a wide range of change aspects without asking the question if public intervention is really setting things in motion which aren't occurring already (Bleda & Del Rio, 2013).

Complex-evolutionary logic

In sum, free market logic is critical on the need for policy makers to be involved in change, but tends to focus on 'production function' interventions when the answer is yes. Coordinated logic, on the other hand, is sensitive to a wide set of particular factors influencing techno-economic change, but compromises on stringency when formulating policy. The respective merits of the two logics clearly can enrich each other, especially as they move from a generic appreciation of innovation conditions to a scope focusing on developments in particular domains. At the intersection of the allegedly contrasting views we find what Dodgson et al. (2011) call complex-evolutionary logic.



Relation between various rationales for policy interventions with respect to economic transformation (based on Dodgson et al., 2011).

Characteristic for complex-evolutionary logic is that it sees a prominent role for policy intervention in bringing about new economic activities, while at the same time emphasizing that in the end entrepreneurial experimentation is in the hands of firms. As firms strive for profits, or even just sustained existence, they have a strong incentive to look for new ways to create (and capture) customer value. Attempts to innovate, however, are limited by the fact that the existing industrial and institutional set-up favors activities related to what is already there.

To let relatively novel industries emerge, policy needs to help overcoming path-dependent incrementalism. Such a view, combining entrepreneurialism with meta-coordination, is agency-centered as well as institution-centered (Borras & Edler, 2015). Striking is Dodgson et al.'s (2011, p. 1153) claim that "innovation policy should present a coherent approach addressing crucial systems issues which go beyond market interactions alone". It aptly points out that complex-evolutionary logic is a blend between market logic and coordinated logic, as it urges for systemic policy only when markets are not delivering. The imperative following from this synthesis is that markets should not be free from distortions, but from inertia. Thus, reasoning from this rationale, transformative policy allows for intervention when there are clearly identifiable barriers preventing industries from evolving.

Appendix 2: Mathematical expression of marginal policy gains

The variables and relations shown in Figure 3 allow us to express TIS building as a function of public and private contributions. The formula below essentially describes how the total improvement in the performance of TIS x (= Y_x) relates to the extent to which a function j is being strengthened:

$$Y_x = \sum_j \left(\left(\left(P_j^{\alpha_j} + M_j^{1-\alpha_j} \right) * \lambda_j \right) + \sum_i \left(\beta_{ji} \left(P_j^{\alpha_j} + M_j^{1-\alpha_j} \right) * \lambda_i \right) \right)$$

Starting with the left-hand side, the impulse to function j caused by public inputs is denoted by P_j, while M_j marks the impulse brought about by inputs of another origin. The relative importance of each type of impulse (for a given function j) is determined by exponent α_j, ranging from 0-1. When impulses can only be public, like regulation, α_j approaches 1 and additional non-public impulses (e.g. through private expenditure on regulation) would cease to contribute at all, as $M_j^{1-\alpha_j}$ remains 1.

How much Y is affected by the public and other impulses for function j depends also on how important that function is to bring about systemic change. This 'weight' is represented by multiplier λ_j, which is likely to depend on the values for P_j and M_j (i.e. the relative importance of a function can alter as P_j and M_j rise).

As noted, the importance of a particular function also depends on the status of other functions. This is captured by the right-hand side of the equation. Impulses for function j affect the total societal benefits via the other functions i (with i being a Lagrange multiplier stretching over functions $\{0 \ldots k\}$). The strength of these interactions depend on the weight of each function i (λ_i), but also on the extent changes in impulses for function j carry over to function i. Multiplier β_{ji}, also a weighting factor, ranges between -1 and 1 as interactions between functions can be both positive and negative (Hekkert & Negro, 2009).

Based on our general formula for modelling TIS building, the contribution of just the policy impulses can be denoted as follows:

$$Y_x(P) = \sum_j \left(\left(P_j^{\alpha_j} * \lambda_j \right) + \sum_i \beta_{ji} * P_j^{\alpha_j} * \lambda_i \right)$$

The marginal contribution of policy impulses, basically the derivative, is then expressed by a formula highly similar to the one presented in the work on reform analytics (Hausmann et al., 2005):

$$\frac{dY_x}{dP_j^{\alpha_j}} = \lambda_j + \sum_i (\beta_{ji} * \lambda_i)$$

It should be noted that this formula does not shed light on the importance of parameter α. Because we are interested in the marginal gains yielded when increasing P_j with one unit, a more suitable notation is shown below. In words, it stresses that those gains are determined by a combination of impulse magnitude, additionality, constraint size, and interaction effects.

$$\frac{dY_x}{dP_j} = P_j^{\alpha_j - 1} \lambda_j + \sum_i (\beta_{ji} * P_j^{\alpha_j - 1} * \lambda_i)$$

Appendix 3: Explanation of 'scores' assigned in application of impact framework

The table below clarifies the scores presented in the completed impact framework (Table 6). Due to the preliminary nature of this assessment, these findings should be regarded as hypotheses that are to be tested in an actual in-depth analysis.

In the conducted case study, policy impulses and policy necessity were observed to differ significantly for two sub-elements of the function 'Resource mobilization'. We therefore decided to report on policy for financial capital (F6a) and for human capital (F6b) separately.

F	Function	Explanation
F1	Entrepreneurial experimentation	The demand-driven Topsector activities, including MIT support for involving SMEs and international promotion, are effectively increasing the extent firms in this domain are experimenting with new energy technologies. However, the Dutch energy sector already contains innovative parties and is relatively inclined to renew itself anyway. The variety in options that is being explored does not suggest inertia due to myopia.
F2	Knowledge development	The TKIs executing the research projects appear oriented to incremental improvements of existing trajectories. This is regrettable, as public policy can make a difference when incumbents are limiting the scope of R&D. Moreover, more research is much needed to advance insight in the viability and socio-economic potential of various technologies.
F3	Knowledge exchange	The topteams/Topsectors have brought very diverse parties together, including SMEs and NGOs. Nevertheless, many of the firms belong to the core that usually participates in public-private collaborations. Also the design/user-side of new technologies is poorly represented. The government is well-positioned to connect these parties. It is likely that this could help to improve the low acceptance of new technologies, which is now blocking progress.
F4	Guiding direction of search	The topteams are influential in deciding which projects will be executed by the TKIs. They bundle interests by diverse parties. Although some topics are discarded (sometimes due to administrative difficulties in the allocation of resources), concentration of efforts helps to overcome stagnation due to 'analysis paralysis'. This is critical at this point. Also, the structure allows societal goals to be effectively integrated in the development of new paths.
F5	Market formation	As the Topsector approach was mainly governed by the Min. of Economic Affairs (and Education, Culture and Science), it missed out on opportunities to involve other authorities. Especially the Ministry of Infrastructure & Environment could have helped to set directions and give signals to market parties (e.g. by including energy goals more explicit in her own procurement and other policies). Due to technical focus of in particular the TKI research, policy did not meet its potential to involve downstream suppliers (ICT, insurance, certificates) or clients/users. When the technology matures, this can become essential.
F6a	Resources: financial capital	Funding remains a difficult issue in a sector characterized by capital-intensive long-term infrastructures. For most of the technologies, however, knowledge/technological development is now more important than capital for large scale production/implementation.
F6b	Resources: human capital (HC)	The Topsectors have successfully formulated HR agendas and Knowledge and Innovation contracts (see also: Technology Pact) to draw more student to relevant fields. A strong inflow of appropriately skilled human capital is essential to compensate for outflows of personnel.
F7	Legitimation / counteracting resistance	Although it got easier to find the way to policy makers, progress in TIS building in the Topsector Energy is still hampered by outdated legislation and slow administration. This forces firms to spend resources on work-arounds, rather than on development.