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As policy instruments for industrial competitiveness and systems innovation – Extended summary

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1 Executive Summary

This report aims to draw policy lessons from the evaluations undertaken after six years of 17 Strategic Innovation Programmes (SIPs) funded by the Swedish Governmental Agency for Innovation Systems (Vinnova), the Swedish Research Council for Environment, Agricultural Sciences and Spatial Planning (Formas) and the Swedish Energy Agency since 2013. We consider their progress, first, through the lens of innovation and competitiveness and, second, using a framework based on the research literature on socio-technical transitions to consider how the SIP funding instrument could be modified better to tackle societal challenges and systems innovation.

1.1 The SIP initiative

The SIP initiative sought to improve conditions for research and innovation (R&I) collaboration through a bottom-up approach to create conditions for sustainable solutions to global societal challenges and to increase competitiveness in areas of great relevance to Sweden's economy. A SIP was to be open to any actor and its management was outsourced to actor consortia. Funding for up to twelve years was on offer provided evaluations every three years were favourable.

Four consecutive calls for proposals issued by the agencies resulted in four tranches of 17 SIPs. Most of them focused on manufacturing processes, transportation, health & health care, and urban planning, and most of them built on established networks from previous R&I programmes, while three completely lacked antecedent programmes.

A SIP is governed by a board and its day-to-day operations are managed by a programme office. Programme activities are based on an agenda that is implemented through competitive calls for R&I projects, strategic projects and complementary activities. The calls for R&I projects are developed in collaboration with the agencies, which administer calls, engage experts to assess proposals, take funding decisions and monitor projects. Strategic projects are used to address needs that are common to most of the programme's actors but that are inappropriate to realise through competitive calls. Strategic projects require negotiation with the agencies. Complementary activities may be realised either using coordination funding or through strategic projects. The bulk of most SIP portfolios is made up of R&I projects resulting from competitive calls, meaning that there are significant limits to a SIP's ability to tailor its project portfolio to achieve the objectives of its agenda.

The total resources for the entire SIP initiative will amount to SEK16b (if all 17 SIPs are funded for 12 years). Of this, SEK7.2b will be public funding while the remainder is expected to be co-funded by industry and other societal actors.

In 2018 the agencies assigned Technopolis Group, through its Swedish subsidiary Faugert & Co Utvärdering, to evaluate the SIPs after six years. This report summarises the 17 programme evaluations and analyses the SIPs from a transitions perspective to support policy learning.

1.2 Participants

The main beneficiaries of the public funding have been R&D performers (62%), i.e. higher education institutions and research institutes, followed by small and medium-sized enterprises (SMEs; 13%), large companies (10%) and public authorities (6%). Large companies have dominated as co-funders (51%), followed by SMEs (22%), public authorities

(10%) and R&D performers (10%). Funding trends illustrate a shift in focus from near-total orientation towards company needs in the SIPs of the first tranche to needs of the public sector gradually becoming more important in subsequent tranches.

Public funding has been heavily concentrated to the leading technical and medical R&D performers, meaning that most actors have received marginal amounts. Consequently, the regional distribution of public funding reflects where Sweden's main technical and medical R&D performers are located.

Co-funding is also concentrated, but considerably less so than the public funding. The concentration of co-funding by companies in Manufacturing & mining, Company services and ICT correlates very well with the same groups being responsible for most of Sweden's Business Expenditure on Research and Development. Companies in these groups contribute more than half of Sweden's value added. This indicates that most companies that invest heavily in R&D probably have participated in the SIPs. Eventually, all significant industry branches appear to have had their R&I needs satisfied by at least one SIP. The regional pattern of company co-funding also correlates with the distribution of the nation's value added by companies in the same groups. This suggests that the SIPs have engaged companies all over the country in approximate proportion to their contribution to the value added of the main industry sectors.

During their first six years the 17 SIPs engaged 2 700 unique actors, an increase of 70 percent compared to the first three years. While participation obviously has been dominated by industry incumbents and the main R&D performers, the 17 SIPs have been open to all types of actors and they have managed to engage most relevant actors, including ones without previous experience of R&I or of collaborating with others on R&I matters. The dominance of established actors is a feature of the SIP instrument's focus on areas of national strength in combination with competitive calls.

1.3 Impacts

The most common impact for project participants of all types was to establish long-term R&I collaboration with others, which arguably builds a foundation for additional impacts. Among the most common additional impacts for companies and public authorities alike were new projects with Swedish public funding and self-funded follow-on projects, thus indicating that participants have 'real projects' that require a sequence of projects to gradually approach their long-terms goals. Many projects produced prototypes but few resulted in patents or PhD recruitments, which is consistent with incremental development at intermediate technology readiness levels dominating the programmes. Expectations for future impacts were high overall. Several frequently reported impacts refer to using project results to improve products, services or processes. Together such intermediate impacts may prove important in the longer term, particularly since expectations for future achievements in these respects were high. While some companies reported that commercial impacts had already been achieved, most referred to expected future ones. Few implementation-related impacts were reported by public authorities, possibly in part since they are difficult to identify.

The additional impacts reported by R&D performers largely correlated with those of companies and public authorities. Among the most common ones were new publicly funded projects and development of prototypes, but there were few patents or postgraduate degrees, confirming the presence of real projects also among R&D performers, and that projects entailed more development than research. Many R&D performers reported increased international competitiveness with high expectations for further increases in the future.

Companies and public authorities agreed that they had developed more scientific working practices, while most R&D performers believed that they had adapted theirs better to serve industry and some of them better to serve public authorities. This bodes well for future R&I collaboration being mutually beneficial.

The 17 SIPs' achievements in engaging the relevant actors in formulating and realising common agendas and thereby invigorating their areas have brought substantial systemic impacts. While most impacts hitherto summarised refer to R&I projects, strategic projects have achieved system-level impacts by addressing common challenges and needs through international outlooks and benchmarking exercises, development of common platforms and infrastructure, as well as courses and graduate schools. Strategic projects have successfully addressed system-related weaknesses and have contributed to changed working practices, which has resulted in integration of R&I subsystems that are characterised by wide participation, relevance, quality and efficiency.

The SIP initiative's additionality is considerable, while its objective fulfilment is only partial. The latter is mainly due to the objectives being high-level societal objectives to which the SIP initiative and individual SIPs can at best contribute.

1.4 Systems innovation

The SIP instrument was originally designed as a more open successor to Branch Research Programmes, supporting industrial innovation and competitiveness. The government then decided that it should be used to help address societal challenges, creating an interesting kind of natural experiment that has allowed us to ask what changes would be needed in order to make it fully effective in the context of societal challenges, and systems innovation more generally. The wider policy context has also changed during the lifetime of the SIPs towards increased focus on sustainability, and this appears to have influenced the behaviour of the SIPs. Now, issues such as circular economy, sustainability more generally, but also the life sciences are being tackled at the national level in addition to the level of instruments like the SIPs. This has potential to develop into a system where certain prioritised themes are handled nationally through multi-level governance while others are delegated to agency programmes.

Systems innovations require instruments with more functionality than the SIP funding agencies can provide. However, SIPs could help co-produce them together with other actors that have the competence and ability to tackle needs outside the R&I sphere, such as scaling up, creating new markets, regulating and the 'creative destruction' of old sociotechnical systems (like fossil-fuel based production) that need to be superseded. The specific requirements for coordination will vary from case to case, but agencies will clearly need new coordination skills and processes.

A strength of the SIP instrument is that it can be used to involve implementers and the demand side to a greater extent than has been done in R&I policies so far. Probably, other demand-side instruments will be needed in addition, for example in demand aggregation. Reforms are clearly needed in some government organisations (notably, but not only, in healthcare) to increase their ability to understand and articulate their needs and to standardise and efficiently procure the innovations they need.

The SIP initiative has used actor consortia in public-private partnerships (PPPs) to run the individual SIPs and re-learnt the old lesson that the interests of those who control governance are reflected in what organisations do. Industry is the strong interest group in most of the SIPs. This has encouraged innovation to be incremental and technology-focused. To respond more fully to the need for socio-technical change, the demand side, including public

authorities, needs to be more involved. Adjustments need to be made, also, to find out how to govern individual PPPs in ways that prevent rent-seeking behaviour while allowing them effectively to implement strategy. For cases where multi-level governance is needed, new models will be needed to integrate the work at government and funding instrument levels.

We have in this study relied heavily on the new and fast-developing research literature about socio-technical transitions for ideas. There is very little policy experience to date from which we can learn, but nonetheless a great need to develop policy further. This is therefore a period in which policy experimentation – and sometimes failure – is very much needed. This means more research (specifically focused on policy implementation of socio-technical transitions) is needed, as is building capacity to design and use new policies and instrument.

1.5 Conclusion

Our overall conclusion is that the SIP instrument has proved effective as a technology programme to build national capacity and competitiveness. With some adjustments, it is likely to be effective also to tackle societal challenges by triggering socio-technical transitions. It does, however, need to be used within a wider policy and instrument mix that meets the needs of all three R&I policy generations – fundamental research, technological development and innovation, and transitions or systems innovation.

2 Extended Summary

This is an extended summary of a study that attempts to draw policy lessons from the evaluations undertaken after six years of 17 Strategic Innovation Programmes (SIPs) funded by the Swedish Governmental Agency for Innovation Systems (Vinnova), the Swedish Research Council for Environment, Agricultural Sciences and Spatial Planning (Formas) and the Swedish Energy Agency since 2013. The study considers their progress, first, through the lens of innovation and competitiveness and, second, using a framework based on the research literature on socio-technical transitions to consider how the SIP funding instrument could be modified better to tackle societal challenges and systems innovation.[1]

2.1 The SIP initiative

In the Swedish government's 2012 research and innovation (R&I) Bill, Vinnova, Formas and the Energy Agency were tasked with introducing a new instrument to improve conditions for R&I collaboration among higher education institutions (HEIs), research institutes, industry, public sector, civil society and other actors. The SIP initiative aimed to create conditions for sustainable solutions to global societal challenges and to increase competitiveness in areas of great relevance to Sweden's economy.

Sweden already had a long history of publicly funded programmes to promote R&I collaboration between industry and R&D performers (HEIs and institutes), but the SIP initiative introduced several novelties compared to previous instruments, including the Branch Research Programmes (BFPs):

- A SIP was to focus on demand from users – mostly meaning companies, but eventually also public authorities – which was to form the foundation for a Strategic Innovation Agenda (SIA).
- SIP management was outsourced to actor consortia.
- A SIP was to be open to any legal entity in Sweden regardless of type or sector.
- SIP funding was to be long-term (up to 12 years), subject to an evaluation at the end of each three-year stage.

The SIPs were together expected to contribute to five high-level objectives:

- Increased sustainable growth.
- Improved competitiveness and increased exports for Swedish industry.
- To make Sweden an attractive country to invest and conduct business in.
- Sustainable societal development to secure employment, welfare, environmental and energy policy objectives.
- Create conditions for sustainable solutions to global societal challenges.

Four consecutive calls for proposals resulted in four tranches of 17 SIPs, see Table 1. A majority of the SIPs built on established networks from previous programmes and only three completely lacked predecessor programmes. Most SIPs thus 'hit the ground running', while a

[1] By 'systems innovation' we mean changing socio-technical systems or regimes to tackle 'wicked' problems or 'societal challenges'. These may involve large-scale transitions or transformations, such as eliminating fossils fuels from energy production, medium-scale interventions such as 'missions' or smaller-scale interventions, such as Vision Zero Cancer (Nollvision cancer) in Sweden, currently working to bring together diagnosis, treatment and patient data into a faster, more efficient and effective sub-system in the Swedish healthcare system. Many, but not all, systems innovations relate to sustainability.

minority struggled. In most cases the SIP initiative therefore offered actors an opportunity to continue building on industrial strengths, whereas in some cases they provided 'seed funding' to new and promising areas.

Table 1 The 17 SIPs. Funding refers to public funding in SEK million granted during first six years.

Start Year	Name	Scope	Predecessors	Funding
First tranche				
2013	Metallic Materials	Metals industry	BFP	417
2013	Process Industrial IT and Automation	Process industry	Various	301
2013	Swedish Mining Innovation	Mining industry	BFP	216
2013	LIGHTer	Lightweight design	Various	191
2013	Sustainable Production in Sweden	Manufacturing industry	BFP	393
Second tranche				
2014	BioInnovation	Bio-based industry	BFP	362
2014	Innovair	Aeronautics industry	BFP	540
2014	Swelife	Life science sector	BFP	341
2014	Smarter Electronic Systems	Electronic components & systems	BFP	264
2014	SIO Grafen	Graphene	None	108
2014	IoT Sverige	Internet of things	None	194
Third tranche				
2015	Drive Sweden	Mobility solutions	BFP	215
2015	InfraSweden2030	Transport infrastructure	Various	139
2015	Medtech4Health	Medical technology industry	BFP	238
2015	RE:Source	Circular materials use	Various	242
2015	Smart Built Environment	Sustainable built environment	Various	253
Fourth tranche				
2017	Viable Cities	Climate-neutral cities	None	353

The three agencies required the SIPs to employ the same organisational setup and operations. A SIP is governed by a board elected at an annual members' meeting, while its day-to-day operations are managed by a programme office. Programme activities are based on the SIP's SIA and are implemented through calls for R&I projects, strategic projects and complementary activities. Calls for R&I projects are developed in collaboration with the agencies, which administer calls, engage experts to assess proposals, take funding decisions and monitor projects. Strategic projects are used to address needs that are common to most of the programme's actors, but that are inappropriate to realise through competitive calls. Strategic projects require negotiation with the funding agencies. Complementary activities – such as international outlooks, investigations, workshops, courses, graduate schools, networking events and programme conferences – may be realised either using coordination funding or strategic projects. The bulk of most SIPs' portfolios thus is made up of R&I projects resulting from competitive calls, which means that in practice there are significant limits to the SIPs' ability to tailor their project portfolios to achieve the objectives of their agendas. The available possibilities are to restrict calls for R&I projects to specific areas or actor types, and to use strategic projects and complementary activities. However, several SIPs have discovered that restricted calls produce too few proposals of adequate quality and relevance and have therefore stopped using them.

The government's 2016 R&I Bill introduced a Collaboration Programme for Research and Innovation to strengthen ties to industry and innovation in digitalisation, life science, and environmental and climate technology. In contrast to the SIP initiative's user focus, the new initiative had a policy-driven design where the government's objectives set the agenda. Vinnova was tasked with implementation and mainly did so by providing additional funding to selected SIPs. In practice, the new initiative thus provided some of the SIPs with additional resources, but in the form of R&I projects that the SIPs themselves did not chose.

The agencies estimate that the total resources for the entire SIP initiative will amount to approximately SEK16b (if all 17 programs are funded for 12 years). Of this, SEK5.9b will be public funding through the SIP initiative and SEK1.3b public funding through the Collaboration Programme. The remainder is expected to come from industry and other societal actors.

All SIPs were evaluated after three years and all were granted funding for a second stage. In 2018 the agencies contracted Technopolis Group, through its Swedish subsidiary Faugert & Co Utvärdering, to evaluate the SIPs after six years, i.e. at midterm. The evaluations were conducted in 2019, 2020, 2021 and 2023. The first 16 SIPs were granted funding for the third stage; the decision on further funding for the 17th SIP will be taken by the end of 2023.

2.2 SIPs

During the 17 SIPs' first six years the agencies granted a total of SEK4.8b in public funding (including funding to programme offices) to 2 313 projects. Project participants matched the public funding by an equal amount of co-funding. The average public funding per SIP was SEK280m, but this varied from SEK108m to SEK540m (cf. Table 1).

Success rates in open, competitive calls for proposals for R&I projects have varied widely, among both calls and SIPs. The average success rates at SIP level have ranged from 17 to 76 percent, with an overall average of 45 percent. All SIPs but three have had success rates higher – generally significantly higher – than the average for the agency that has had the main administrative responsibility for their calls.

As mentioned in the previous section, a SIP may influence how its public funding is spent by the way calls for proposals are formulated and by initiating strategic projects. The SIPs have chosen quite different strategies in terms of size of projects, which range from just over SEK1m in average public funding per project to almost four times as much, with an overall average of SEK2m for all SIPs. The share of public funding invested in strategic projects has also varied greatly, from 2 percent to 49 percent, with an overall average of 19 percent.

The agencies' model for SIP funding provides 100 percent funding in years 3–10, 33 percent in year 1 and 12, and 67 percent in years 2 and 11. On average, the SIPs did not manage to ramp up operations that quickly; in practice it took at least 4–5 years to reach what may be some form of steady state. In the long term, the agencies expect 50 percent co-funding at programme level (but not in each project). The degree of co-funding initially was considerably lower, but it has increased with time. As mentioned in the previous section, the total co-funding of all SIPs matched the public funding after six years.

2.3 R&I projects

In their first six years, the 17 SIPs' open, competitive calls for proposals resulted in 1 781 R&I projects, 538 of which were led by women (30%).[2] At SIP level, the share of female project leaders ranged from 14 to 51 percent. For all 17 SIPs, the success rate was 6 percent higher

[2] Out of 2 313 granted projects, 1 781 resulted from open, competitive calls for R&I projects.

for proposals with female project leaders than for male, but at SIP level this difference ranged from 8 percent lower to 20 percent higher.

In terms of public funding to R&I projects by topic area, manufacturing processes heavily dominated in the SIPs of the first tranche, while transportation and health & health care took over in the two subsequent tranches. However, the emergence of health & health care was not a general trend but due to two specific SIPs (Swelife and MT4H). Urban planning emerged in the second tranche and increased in the third. For the 16 SIPs of the first three tranches 32 percent of public funding went to projects on manufacturing processes, 17 percent to transportation and 15 percent to health & health care.[3]

The Sustainable Development Goals (SDGs) Industry, innovation and infrastructure (SDG 9) and Decent work and economic growth (SDG8) dominated among R&I projects of the earlier tranches, while Good health and well-being (SDG3) and Sustainable cities and communities (SDG11) became more prominent in later tranches. Again, the emergence of SDG3 is limited to Swelife and MT4H. In the 15 SIPs of the first three tranches, 36 percent of R&I projects addressed SDG9, 16 percent SDG8, 15 percent SDG3 and 11 percent Responsible consumption and production (SDG12).[4]

In web surveys, R&I project participants were asked to assess their R&I projects' technology readiness level (TRL). Company respondents judged that most projects had started at TRL1–3 and that they had ended at TRL6–8, with an average TRL progression of individual projects of 2.1. R&D performers' assessments agreed quite well with those of company respondents, although their assessment of TRL progression was more conservative at 1.9. Although this seems to indicate that company and R&D performer respondents generally agreed on TRLs, there was considerable disagreement at the level of some individual SIPs.

2.4 Participants

Most of the public funding was granted to R&D performers, i.e. HEIs and institutes, although their share decreased significantly with the SIPs of the second and third tranches, while the share to companies, both large and small and medium-sized enterprises (SMEs), increased considerably. The share going to public authorities also increased notably with each tranche. Overall, 62 percent of public funding benefited R&D providers, 23 percent companies and 6 percent public authorities. The prominence of an 'others' category, 8 percent of the total, is mainly explained by several programme offices being hosted by such organisations.[5] Funding granted to foreign organisations was marginal.

Companies heavily dominated as co-funders, but the dominance of large companies decreased with each tranche, while co-funding from SMEs increased until the third tranche. Co-funding from public authorities increased from close to nil in the first tranche to nearly half in the fourth. Overall, large companies contributed 51 percent of co-funding, SMEs 22 percent, R&D performers and public authorities 10 percent each, others 5 percent and foreign organisations 2 percent.

The funding and co-funding trends illustrate a shift in focus from near-total orientation towards company needs in the SIPs of the first tranche to needs of the public sector gradually becoming more important in subsequent tranches. These trends resemble those for R&I

[3] Information on topic area was not available for the SIP of the fourth tranche.

[4] Information on SDG focus was not available for one SIP of the third tranche and for the SIP of the fourth tranche.

[5] Including organisations such as industry confederations, technology parks, HEI holding companies, technology transfer offices, foundations and non-governmental organisations.

project topic areas, but the trends by topic area are considerably more dramatic than the trends in company co-funding.

The Top-20 beneficiaries together received 58 percent of the public funding (excluding coordination). To a significant extent, this concentration is due to most technical and medical R&D in academia being concentrated to a small number of HEIs. Similarly, almost all technical R&D in the institute sector has been consolidated into one group that received 16 percent. Public funding is thus heavily concentrated to a small number of organisations, meaning that most actors in a very long tail of 2 700 organisations received marginal or no public funding.

The Top-20 co-funders accounted for 30 percent of total co-funding, illustrating that co-funding is notably less concentrated than public funding. The eleven companies on Top-20, some of Sweden's biggest, accounted for 21 percent.

Companies in Manufacturing & mining dominated company co-funding in the SIPs of the earlier tranches but this dominance nevertheless quickly decreased for each tranche, while companies providing various support services and companies in ICT, Trade, Transportation and Real estate took their place. Companies in Manufacturing & mining, Company services and ICT together accounted for 88 percent of total company co-funding, which correlates very well with the same groups being responsible for 90 percent of Sweden's Business Expenditure on Research and Development (BERD). Companies in the same groups contribute more than half of Sweden's value added. This indicates that most companies that invest heavily in R&D probably have participated in the SIPs. The notable decline for Manufacturing & mining with each tranche is explained by all significant industry branches eventually having had their needs satisfied by at least one SIP. Moreover, the regional concentration of company co-funding correlates with the distribution of the nation's value added by companies in Manufacturing & mining, Company services and ICT, thus indicating that the SIPs have engaged companies all over the country in approximate proportion to their contribution to the value added of the dominant industry sectors.

2.5 Impacts for participants

Bibliometric analyses reveal that in total, at least 333 journal papers and 288 conference papers (identified in Scopus) were published by the 17 SIPs during their first six years. Most journal papers were of high quality. As expected, authors from HEIs heavily dominate as authors. Company representatives made some contributions, particularly in SIPs of the first tranche.

The most common impact for project participants of all types was establishment of long-term R&I collaboration with others, which arguably provides a foundation for additional impacts. Several additional impacts are also quite common but seem to take longer to materialise. According to companies and public authorities the most frequently reported additional impacts already achieved were new projects with Swedish public funding, development of prototypes, self-funded follow-on projects and more scientific working practices. Following on these were several aspects related to implementation of project results to improve the organisation's products, services or processes. Together such 'intermediate' impacts may prove quite important in the longer term, particularly since expectations for future achievements were so large. Rather few company respondents assessed that the company already had experienced commercial impacts. With expectations included, a majority of company respondents nevertheless assessed that the company eventually would experience increased turnover, increased international competitiveness, new business areas, increased market shares and increased exports.

The most common impacts already achieved for R&D performers were that their R&I had become more relevant to industry, new projects with Swedish public funding, development of prototypes and increased international competitiveness, followed by development or modification of materials or techniques and their R&I having become more relevant to the public sector. Around one in five respondents reported that the project had resulted in new privately or internationally funded projects. While a majority of R&D performers assessed that their R&I activities had become more relevant to industry, less than half as many responded that these activities had become more relevant to the public sector – or society, if you wish. However, these averages for all 17 SIPs obscure the fact that there was a quite distinct change in focus from the needs of industry in the earlier tranches to the needs of the public sector in the latter.

2.6 Impacts for system and society

2.6.1 Systemic impacts

In total, there were around 8 600 participations in R&I projects during the 17 SIPs' first six years. The average number of participations per SIP was 506, while the average varied between 257 and 1 051. Just over 2 700 unique participants were responsible for the 8 600 participations, representing an increase of 70 percent in unique participants compared to the first three years. Participation of all actor types increased, but mostly among companies, others and foreign organisations. In contrast, there were much smaller increases for HEIs and institutes, mainly since most of them participated already in the first stage.

The SIPs have generally been open to all types of actors, and together they have been particularly successful in reaching out to significant proportions of available large companies, HEIs, institutes and regions. In terms of industry sectors, they have been quite successful in engaging most companies that are large contributors to Sweden's BERD. The fact that participation of SMEs and other public authorities than regions have been far less comprehensive is likely due to lack of interest from actors of these types. The 17 SIPs thus have engaged most relevant Sweden-based actors.

The main participants among R&D providers have been strengthened and have thus become more attractive as partners, particularly to companies and public authorities. That said, SIP participation also has included novices to R&I, mainly among SMEs and public authorities, while the 'usual suspects' probably have participated in (and co-funded) more R&I activities than they would otherwise have done. The obvious concentration to certain actors is a feature of the design of the SIP instrument due to its focus on user needs in areas of national strength in combination with competitive calls for R&I projects. From a national perspective, this concentration is not necessarily bad, but it has implications for systems innovation in that it is up to incumbents to drive change.

A few SIPs have developed collaboration networks more or less from scratch, while most have further developed and extended existing ones. Such network formation and extension has counteracted fragmentation of R&I activities, arguably generating synergies. The synergies have been further augmented by companies and public authorities having developed more scientific internal working practices, while R&D performers have adapted their operations better to serve industry and the public sector.

Most SIPs have allocated significant shares of their resources to strategic projects to address challenges and needs common to the area or at least to many of its actors. The purposes of such projects usually were to support future R&I projects and to facilitate implementation of

innovations. Strategic projects have successfully addressed system-related deficiencies and contributed to changed working practices.

Hence, the SIP initiative has contributed to integration of R&I subsystems – and in some cases creation of new ones – that are characterised by wide participation, relevance, quality and efficiency.

2.6.2 Function in R&I funding system

Survey respondents considered the three funding agencies' other ('non-SIP') programmes, as well as other SIPs, the most important complementary sources of funding. In the Swedish funding landscape, the SIP initiative, Vinnova and the Energy Agency essentially represent the most applied end of the spectrum of R&I funding opportunities, whereas other agencies fund fundamental research, mostly at HEIs and generally without user participation. While Vinnova and the Energy Agency, through their other programmes thus largely fund similarly applied R&I as the SIPs do, there is nevertheless an element of complementarity between their funding offers (including the SIPs) and those of the funders of fundamental research. The SIP participants' appetite for venturing abroad was relatively low. Only R&D performers seemed to consider international opportunities in general and the EU Framework Programmes in specific somewhat important, in part due to the rather generous funding opportunities and high success rates that most SIPs offer.

2.6.3 Industrial and societal impacts

The five high-level objectives of the SIP initiative focus on the competitiveness of industry and the nation on the one hand, and on addressing societal challenges on the other, in both cases with an eye on sustainability. The SIP instrument provided interested stakeholders with platforms for strategic dialogue that resulted in long-term visions based on needs, often stakeholders' own – basically correlating to the competitiveness objectives. Over time, societal objectives became more pronounced, both for the SIPs of earlier tranches that later incorporated elements of societal objectives in their agendas, and the SIPs of later tranches that already from the onset had greater focus on societal needs.

The SIPs were required to be open to all, which resulted in network extension that in turn led to additional actors engaging in R&I, while incumbents likely invested more in R&I. The results of the R&I projects laid the foundation for positive impacts on the competitiveness of both industry and nation, by way of impacts for project participants. While few commercial impacts had been realised after six years, this is to be expected since lead times to commercial impacts in most sectors are longer, often considerably longer, than that. However, many company respondents answered that they expect commercial impacts for the company in the future – eventually meaning job creation and revenue for the tax authorities.

Some commercial impacts for companies also amount to societal impacts. Half of company respondents had noticed that their R&I project already had had positive impacts on the company's R&I activities in Sweden. A quarter of respondents similarly had seen positive impacts on employment and almost one in five on production. Including expectations for the future, clear majorities sooner or later expected positive impacts in all three respects. Moreover, every third survey respondent believed that technology transfer to other sectors had taken place and almost as many that it would happen in the future. Such impacts are societal impacts by contributing to a vital R&I and production base as well as a healthy labour market.

There is consequently compelling evidence to suggest that the SIPs have been beneficial to participating companies' competitiveness, but that the time scales in most cases are longer

than the SIPs' existence at the time of the evaluations. There is also evidence that part of the technology transfer has involved actors, and in some cases sectors, that have not participated in SIPs. From a national perspective, the SIPs have mobilised actors, have successfully addressed system-related weaknesses, have increased the competitiveness of all types of actors, and have offered relatively generous and long-term public funding. This has contributed to making Sweden an attractive country in which to conduct R&I, making it more attractive for conducting business in general.

Impacts relating to national and global societal challenges are considerably more difficult to identify, in part since lead times likely are even longer than for impacts on competitiveness of industry and nation. While the SIPs of earlier tranches gradually incorporated objectives relating to greater resource efficiency and recycling, the ones of later tranches tended to pay more attention to systemic change from the outset.

2.7 Additionality

We address the additionality – added value – of the 17 SIPs, and thus of the SIP initiative as such, through three perspectives: input, output and behavioural additionality.

2.7.1 Input additionality

Survey responses clearly suggest that many, perhaps most, R&I projects would not have been conducted had they not been funded by the SIP. Although many respondents from companies and public authorities judged that they would have carried out the project anyway, most believed that it would have been done with lower ambition level, with fewer partners and/or over a longer time period. While some projects thus would have been carried out also without the SIPs, SIP actors have likely participated in more projects, meaning that their overall co-funding and corresponding activities were greater than they otherwise would have been. For many actors, participation in SIP projects has led to follow-on projects through both Swedish 'non-SIP' and international R&I programmes, thus resulting in additional input in terms of both public funding and co-funding.

2.7.2 Output additionality

Since there are projects that would not otherwise have been undertaken – both R&I projects and strategic projects – they are likely to have contributed to outputs that would not otherwise have emerged. The programmes have mobilised actors likely resulting in synergies, while strategic projects have addressed system-related deficiencies through development of common platforms and infrastructures. The programmes' substantial budgets have strengthened key R&D performers and thus made them more competitive and therefore attractive as partners to companies and public authorities. Participants in other Swedish and international R&I programmes have produced R&I results and gained access to others' results, while SIP actors of all types – though mainly R&D performers – have contributed to results dissemination to other organisations, including ones that have not participated in SIPs. Overall, this indicates that the programmes have increased productivity within their respective parts of the Swedish innovation system, which arguably means that the programmes have contributed to considerable output additionality.

2.7.3 Behavioural additionality

The main stakeholders of the 17 areas have mobilised actors in implementing joint, actor-driven agendas and thus have worked towards common objectives. With time, the SIPs have reached out to ever more actors – including ones without previous experience of R&I and/or collaboration in R&I – to enlarge their networks. A few SIPs have developed networks from

scratch or humble beginnings, while the majority have continued developing existing ones. The SIPs have collaborated with other SIPs, and some actors have learned what it takes to be successful in international R&I programmes. Companies and public authorities have developed more scientific internal working practices, while R&D performers have adapted their operations better to serve industry and the public sector. The strategic projects that have addressed system-related weaknesses have contributed to changed working practices. The mobilisation and the synergies realised are indications of significant behavioural additionality at the levels of both subsystem and organisation, which likely contributes to more efficient use of resources in the Swedish innovation system. The sustainability of many of these changes is highly dependent on future availability of public funding, but even if funding were not available the widely spread positive experiences of collaboration would likely linger for quite some time.

2.8 The SIPs seen through transitions-theory lenses

The SIP instrument was originally designed as a more open successor to BFPs, supporting industrial innovation and competitiveness. The government then decided that it should be used to help address societal challenges, creating an interesting kind of natural experiment that has allowed us to ask what changes would be needed in order to make it fully effective in the context of societal challenges, and systems innovation more generally. The wider policy context has also changed during the lifetime of the SIPs towards increased focus on sustainability, and this appears to have influenced the behaviour of the SIPs. Now, issues such as circular economy, sustainability more generally, but also the life sciences are being tackled at the national level in addition to the level of instruments like the SIPs. This has potential to develop into a system where certain prioritised themes are handled nationally through multi-level governance while others are delegated to agency programmes.

We tend to think of R&I policy in terms of three 'generations' overlaid on each other since the great explosion in spending on science that began during the Second World War. The first involved delegating much authority for the funding and quality control of 'basic' research to the scientific community in the post-War period, building or growing research councils and national science foundations to fund it. The second from the 1960s tried deliberately to connect research to industrial innovation, economic development and growth, using new specialised innovation agencies. Currently we are trying to figure out what organisations we need and how they should work in order to do a third generation of policy to tackle societal challenges by doing 'systems innovation', in the sense not only of changing technology but also the societal rules and infrastructures within which they operate.

We classified the SIPs into three types:

- **Reinforcers,** centrally concerned with traditional innovation and competitiveness goals. They generally said little about sustainability or systems innovation at the outset but have in most cases increased the attention paid to sustainability goals. The reinforcers cluster in the two first tranches, and most of them stay close to the former BFP model.
- **Transformers**, which to varying degrees aim at systems innovation or changes in existing socio-technical systems and regimes. They dominate the third (and fourth) tranches.
- **Technological Innovation System (TIS)-builder**, aiming to create a new technological innovation system (and by implication a new socio-technical regime). There is only one pure case among the SIPs, though parts of others attempt a similar development.

Based on the transitions research literature, we developed lists of two kinds of functions apparently needed in policy to trigger systems innovation:

- Functions from the 'transition management' literature, mainly relating to things the SIPs might do at the programme level:
  - Creating arenas for priority setting.
  - 'Creative destruction' and handling incumbents.
  - Use of 'guiding visions'.
  - Building actor networks or coalitions.
  - Action at the political and policy levels.
  - Coordination.
- Functions from the 'technological innovation systems' literature, mainly relating to things the SIPs might do at the project level:
  - Entrepreneurial experimentation with new technologies, markets and business opportunities.
  - Knowledge development, via R&D and learning-by-doing.
  - Knowledge diffusion through networks.
  - Directionality, via activities that encourage new innovators to enter and focus the directions of technical change they pursue.
  - Market formation by opening up market space or articulating demand.
  - Market formation by creating protected space for niche innovations.
  - Legitimation.
  - Resource mobilisation.
  - Reflexivity.

These lists suggest that systems innovations require instruments with more functionality than the SIP funding agencies can provide, and this is confirmed by our analysis of the extent to which the SIPs as a whole were able to undertake the individual functions, which varied considerably. However, the SIPs and the funding agencies could help co-produce them by coordinating with other actors that have the competence and ability to tackle needs outside the R&I sphere, such as scaling up, creating new markets, regulating and the 'creative destruction' of old regimes and infrastructures (like fossil-fuel based production) that need to be superseded. The specific requirements for coordination will vary from case to case, but agencies will clearly need new coordination skills and processes.

A potential strength of the SIP instrument is that it could be used to involve implementers and the demand side to a greater extent than it has done so far. Probably, other demand-side instruments will be needed in addition, for example in demand aggregation. Reforms are clearly needed in some government organisations (notably, but not only, in healthcare) to increase their ability to understand and articulate their needs and to standardise and procure efficiently the innovations they need.

The SIP initiative has used public-private partnerships (PPPs) to run the individual SIPs and re-learnt the old lesson that the interests of those who control governance tend to be reflected in what organisations do. Industry is the strong interest group in most of the SIPs. This has encouraged innovation to be incremental and technology-focused. To respond more fully to the need for socio-technical change, the demand side, including public authorities, needs to be more involved. Adjustments need to be made, also, to find out how to govern individual PPPs in ways that prevent rent-seeking behaviour while allowing them effectively

to implement strategy. For the cases where multi-level governance is needed, new models will be needed to integrate the work at government and funding instrument levels.

We have in this study relied heavily on the new and fast-developing research literature about socio-technical transitions for ideas. There is very little policy experience to date from which we can learn, but nonetheless a great need to develop policy further. This is therefore a period in which policy experimentation – and sometimes failure – is very much needed. This means more research (specifically focused on policy implementation of systems innovation) is needed, as is building capacity to design and use new policies and instrument.

2.9 Recommendations

Our analysis suggests that the SIP funding instrument is rather flexible, making it useful for addressing a wide range of R&I policy needs. Tackling systems innovation implies acting outside as well as inside the R&I policy sphere.

2.9.1 Interventions in the policy system

The need to deal with systems innovation means that policy interventions must become increasingly systemic, extending the second-generation concern with well-functioning innovation systems. While in the past it has been possible to run R&I policy in ministry 'silos', the level of coordination and consistency across the growing number of ministries and other actors now needs to increase. Policy needs to balance interventions across fundamental research, technological innovation and tackling systems innovation, as well as between national and international focus, and between traditional supply-side and demand-side policies.

2.9.1.1 Holistic R&I policy should cover all three policy generations

The policy generations described in the previous section are an example of policy 'layering'. Rather than later generations of policy replacing earlier ones they co-exist, in this case because each generation has a different purpose. Government policy needs not only to use all three for their respective purposes but also aim for complementarity among them. Thus, while SIP-like mechanisms could be adapted to tackle systems innovation, the need for technology development support to which the BFPs responded does not go away.

2.9.1.2 Maintain a strong international dimension in R&I policy and programmes

R&I policies need a strong international dimension, which we feel has been somewhat under-emphasised in the SIPs. Very clear incentives are needed to induce additional actors to participate in EU Framework Programmes; national programmes are necessary to create conditions for actors to be able to participate, but they are by no means sufficient to persuade actors to do so. Reducing the dominance of industry in the governance of most individual SIPs and careful consideration of when tactically to relax the residency requirement could improve the degree to which SIPs participate internationally, reducing the chances of reinventing the wheel or missing out on key developments elsewhere.

2.9.1.3 Find the right level to intervene

Systems innovation interventions aim to cause systems change or innovation, but there is a wide range of system sizes that can be tackled. Especially in relation to very large systems innovation, the national R&I system can be too small and too narrow to be effective. Intervention within a country requires a choice between ministry and agency level or an all-of-government approach reaching across individual ministries. The transitions literature

points out that interventions often have a three-level structure, namely intervention strategy and design, management and coordination, and the operational or project level. These are not necessarily housed in the same organisation.

2.9.1.4 Actions separate from systems innovation interventions are needed to organise and reduce fragmentation on the demand side

Systems innovation interventions rely on connecting problems and their solutions to the knowledge and other means to address them. The SIP experience shows that fragmentation and lack of organisation on the demand side makes it hard to achieve this connection. There is scope for government to defragment public demand for innovations – which is anyway needed to increase the rate of innovation in the public sector irrespective of whether governments tackle systems innovation. Equally, it is possible to do demand aggregation within the private sector. Both approaches would reduce barriers to systems innovation.

2.9.2 Interventions at the level of innovation agencies

Effective transition intervention by innovation agencies requires a change in focus from technology generation to solving societal problems and the use of transition functions identified in the transitions literature. This will involve capacity-building, cooperation with actors outside the traditional R&I community and shifting the balance of power in intervention governance towards the demand side. Monitoring and evaluation need to follow the changing needs of interventions through their life cycles.

2.9.2.1 Systems innovation interventions should pursue systems innovation objectives

Systems innovation projects start by identifying a problem in the delivery of societal services such as health, environment or energy supply, and creates a programme of work to identify a solution and work towards implementing it. Theories of change should be much more explicit and realistic than most are today about their programme objectives and the mechanisms through which they will be reached. They should have strong directionality and be informed by explicit 'guiding visions' that generate a focus on implementation, and may well be supported by foresight exercises or road maps. They also need a process (reflexivity) through which they periodically revisit and potentially revise aspects of their objectives and plans.

2.9.2.2 Interventions should be generated in competition and involve not only the R&I community but also the other actors needed to implement system innovations

Systems innovation interventions need to identify 'coalitions of the willing' – strong actor groups with a common purpose and the power to effect change if they are successful. Systems innovation programmes need to generate coalitions with these qualities that extend well beyond the R&I system and industrial competitiveness to solve problems identified in the provision of societal services.

2.9.2.3 Transition interventions should use functions from transitions research to strengthen their ability to affect implementation

The list of functions we discussed in the previous section is not authoritative (in part because the evidence base underlying it needs strengthening, and there is no 'general theory' of systems innovation on which to rely), but to a first approximation it appears to be useful and should serve at the minimum as a way to prompt theory-of-change design so that these functions are included when appropriate.

2.9.2.4 Build capacity for transitional interventions, both in the agencies and in the beneficiary communities

The SIP experience clearly shows the value of experience among the well-practised and -organised communities that are used to benefitting from state technology programmes. It has been correspondingly harder for the SIPs with less such experience to design their interventions and hit the ground running. Correspondingly, like their equivalents in other countries, the agencies are still learning about systems innovation intervention design and management. Agencies should therefore organise learning and training exercises for the benefit of both communities and potentially support external organisations such as branch associations to do so.

2.9.2.5 Systems innovation projects funded by innovation agencies should coordinate with other actors, to access transition functions not available within the R&I sphere

As indicated in the previous section, functions such as 'creative destruction', entrepreneurial experimentation, market formation and mobilising resources for scaling-up and implementation is beyond the reach of innovation agencies and the projects they fund. Coordination or joint action with other actors such as business support agencies, investors, regulators and standardisation bodies may be necessary in order to access the missing functions.

2.9.2.6 Adjust the balance of power in governance

As in other public-private partnerships (PPPs), the SIPs' activities have been influenced by the composition of the partnerships, which in this case tend to be industry dominated, focusing therefore on incremental innovation and neglect of many implementation issues. The balance of power in the PPPs and their boards needs to be adjusted to give a role to downstream and demand-side actors in order to compensate for this deficit.

The balance of power between the SIPs and the funding agencies also needs to be improved to find a way to increase the PPPs' influence over project selection while at the same time protecting themselves from adverse selection by the SIP communities. The agencies should also provide larger coordination budgets and encourage more extensive use of strategic projects to improve chances of achieving directionality.

2.9.2.7 Monitoring and evaluation should reflect the life cycle and intended long duration of transition interventions

Vinnova has developed evaluation practices for long programmes that reflect their life cycle, supporting the start-up phase with formative evaluation and then adding greater summative elements during the life of the programme. This has worked well, and there is evidence from the SIPs, as well as other programmes, that the use of some external support, such as real-time evaluation, help with elaborating theories of change or using a moderator to support reflexivity exercises, can improve performance. Such support helps participants learn and understand some of the new routines needed to work with systems innovation, rather than in more traditional R&I programmes.

A second dimension is the need to devise monitoring systems based on robust theories of change that collect information about short-term activities and outcomes relevant to achieving long-term impacts and which can be used in reflecting upon and adjusting the innovation agenda. This requires clear, specific and realistic intermediate objectives. Monitoring and evaluation cannot capture long-term impacts that are only expected to be realised in the future.

2.10 Endnote

Our overall conclusion is that the SIP instrument has proved effective as a second-generation instrument to build national capacity and competitiveness. With some adjustments to the instrument itself and to aspects of governance, it is likely to be effective also in stimulating transitions and addressing third-generation policy needs. It does, however, need to be used within a wider policy and instrument mix that meets the needs of all three policy generations – fundamental research, technological development and innovation, and transitions or systems innovation.

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