What is the effect of synergy in international collaboration on regional economies?

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Abstract

We analyze the effects of relative increments of mutual information among the geographical, technological, and organizational distributions of firms on the relative augmentation of regional summary turnover in terms of synergies. How do increases in synergy in international cooperation affect regional turnover? The methodological contribution of this study is that we translate the synergy (abstractly measured in bits of information) into more familiar economic terms, such as turnover for the special case of domestic-foreign collaborations. The analysis is based on Norwegian data, as Norway is a small country with an open and export-oriented economy. Data for Norway is publicly available in great detail.

Keywords Triple Helix, synergy, international cooperation, regional economy, measurement

Introduction

The possible way to enhance the quality and efficiency of a regional economy lies in the development of both regional and cross-border collaboration. The central role of such collaborative interaction is discussed in both the cluster and the global value chain (GVC) literature [Humphrey and Schmitz, 2002]. The former emphasizes interactions between local firms and knowledge institutions, whereas the latter gives prime importance to interaction with global buyers. Collaboration helps to provide added value as a result of the creation of new

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products and market services. The core of a region's economic success is dependent on the quality of its innovation system and the ability for firms located in the region to sustain competitive advantages [Maskell and Malmberg, 1999 a, b] in an economy dominated by global value chains [Gereffi and Lee, 2012; 2016].

The concept of regional innovation systems [Cooke, 1992] was articulated in reaction to the concept of national systems of innovations [Freeman, 1987; Lundvall, 1988; 1992], but is relatively new as a metaphor used at the level of policy making [Cooke & Memedovic, 2003]. Systems of innovations can be analyzed in terms of the Triple Helix (TH) model of innovations [Leydesdorff & Etzkowitz, 1996]. The TH metaphor links economics, sociology, and innovation theory by studying the network of institutional relations among universities, industries, and governmental agencies.

A TH innovation system comprises interactions among three major institutions – science, government, and industry – which are responsible for economic development. In innovative regions, a strong and constant interaction among these actors is assumed. The interactions are especially important for cross-border regions which wish to enhance their innovation performance [Lundquist & Trippl, 2013].

In this study, the TH system of relations is considered an eco-system that can be more or less synergetic relative to the interactions among agents. A measure for synergy is provided by the mutual information in three (or more) dimensions [Yeung, 2008]. Mutual information can be calculated using the TH indicator, which was first developed for interactions among geographical, technological, and organizational distributions [Leydesdorff *et al.*, 2006]. The TH indicator is based on information theory and enables us to measure the synergy of a TH system in terms of bits of information. However, an economist may have difficulties understanding what the bits of information would mean in more familiar economic terms (cf. Theil, 1972), such as the ones used to determine the level of territorial economic development, that is, the aggregate turnover of all the enterprises in a territory. This study is an attempt to answer this question.

The economic potential of regions can be augmented by technological development. Technology transfer can be considered a means for maximizing the potential of technologies. Transferred technologies can be considered complements to the economic structure, socio-economic institutions and innovative capabilities of regions. Newly acquired technologies create

room for new combinations and new markets, and are often seen as the main driver of cross-border collaboration [Van Den Broek & Smulders, 2013].

New technologies can be transferred as a part of foreign participation in domestic firms. Foreign participation is often a result of the emergence of global value chains, established by multinational corporations in order to enhance their profit margin [Gereffi, 1994]. Firms with foreign participation can contribute to regional development. The net value of products and services produced with the transferred technologies can be considered as additional input to cross-border markets. One of the core questions which policy makers responsible for the economic development of regions have to answer can be formulated as follows: should more attention be paid to generating synergy in international collaboration or in the domain of domestic firms? What would enhance efficiency in the development of regional economies? The research question of the present study is an attempt to answer this question on the basis of the TH approach.

Method and data

Data at the aggregated level for foreign ownership of firms at a county level was taken from Statistics Norway. Firm level data on domestic and foreign ownership and their turnover for two Norwegian regions – Møre og Romsdal and Sør-Trøndelag – were constructed based on data from the PureHelp[4] database (on municipality number, NACE code, number of employees, and turnover) and Proff[5] database (for ownership data). The databases were manually matched for the 500 firms with highest turnover in the counties and data for each company was transferred to Excel files. The records include municipality code, NACE code, size code, turnover (in Norwegian Kroner (NOK)), type of ownership, also international and national turnover for the actual company. A level of at least 20% foreign ownership is used as cutoff for indicating foreign ownership.

We use high-level aggregation of the ISIC/NACE categories, listed in Appendix A, [Eurostat, 2008] to differentiate the firms with respect to the technological dimension. The organizational dimension is subdivided into eight groups, according the number of employees:

[4] www.purehelp.no

[5] www.proff.no

zero employees; 1-4 employees; 5–9 employees; 10–19 employees; 20–49 employees; 50–99; 100–249; >250 employees. Firms with different sizes can be expected to have different organizational structures, business models, and economic dynamics [Blau and Schoenherr, 1971].

Mutual information in three dimensions – geographical, organizational, and technological – at national and regional levels has been calculated for a number of countries, such as the Netherlands [Leydesdorff, Dolfsma, & Van der Panne, 2006], Germany [Leydesdorff & Fritsch, 2006], Hungary [Lengyel & Leydesdorff, 2011], Sweden [Leydesdorff, & Strand, 2013], Norway [Strand & Leydesdorff, 2013], Russia [Leydesdorff, Perevodchikov, & Uvarov, 2015]. Mutual information is defined in the following manner [Abramson, 1963; Ashby, 1964]:

$$T_{GOT} = H_G + H_O + H_T - H_{GO} - H_{GT} - H_{OT} + H_{GOT} \quad (1)$$

Here $H_i, H_{i,j}, H_{i,j,k}$ are corresponding Shannon entropy measures (indices *i, j, k* stand for *G, O, T*):

$$H_i = -\sum_i p_i log\, p_i$$

$$H_{ij} = -\sum_i p_{ij} log\, p_{ij} \quad (2)$$

$$H_{ijk} = -\sum_i p_{ijk} log\, p_{ijk}$$

And probabilities: p_i, p_{ij}, p_{ijk} are defined as the ratio of the number of firms in the corresponding subdivision to the total number of firms in a region. For example, $p_G = \frac{n_G}{N}$, where n_G is the number of firms in the municipality with index *G*, and *N* is the total number of firms in the county, to which the municipality with index *G* belongs, etc.

T_{GOT} is a signed information measure [Yeung, 2008] and consequently cannot be considered Shannon-type information [Krippendorff, 2009]. The case when this information measure is negative can be interpreted as reduction of uncertainty that prevails at a systems level.

Leydesdorff and Ivanova, [2014] conceptualized T_{GOT} as mutual redundancy originating in positionally differentiated inter-human communication systems. Positional differentiation of

communication systems in relation to one another means that systems possess different sets of communication codes which are used to supply meaning to the information. Mutual redundancy measures the surplus of options that are generated when meaning processing systems communicate in terms of informational exchange. This surplus of options itself increases the overall uncertainty. However, if the resulting redundancy is negative uncertainty is decreased. The larger this decrease of uncertainty, the more "synergetic" or "coherent" is the interaction among the communicating systems. In other words, negative valued T_{GOT} can also be called the synergy in interactions.

Ternary synergy among geographical, technological, and organizational distributions T_{GOT} can be calculated for all the regional firms, including nationally owned and those with foreign participation, and separately for the national firms only (T_{GOT}^{nat}). Here synergy for the firms with foreign participation only is defined as a difference between summary synergy and a synergy generated by domestically owned firms:

$$T_{GOT}^{int} = T_{GOT} - T_{GOT}^{nat} \tag{3}$$

The term T_{GOT} accounts for synergy formed purely by international firms and national-foreign interactions, and the term T_{GOT}^{int} comprises synergy formed exclusively by firms with foreign participation. Inputs from national, international, and interaction synergy can thus be explicitly distinguished. For example, H_G, which is defined as:

$$H_G = -\sum_G \frac{n_G^{nat}+n_G^{int}}{N} log \frac{n_G^{nat}+n_G^{int}}{N} \tag{4}$$

can be re-written in the form:

$$H_G = -\sum_G \frac{n_G^{nat}}{N} log \frac{n_G^{nat}}{N} - \sum_G \frac{n_G^{nat}}{N} log(1+\frac{n_G^{int}}{n_G^{nat}}) - \sum_G \frac{n_G^{int}}{N} log \frac{n_G^{int}}{N} -$$

$$\sum_G \frac{n_G^{int}}{N} log\,(1+\frac{n_G^{nat}}{n_G^{int}}) = H_G^{nat} + H_G^{int} + \widetilde{H}_G \tag{5}$$

here H_G^{nat}:

$$H_G^{nat} = -\sum_G \frac{n_G^{nat}}{N} log \frac{n_G^{nat}}{N} \quad (6)$$

is the input of domestic owned firms, H_G^{int}:

$$H_G^{int} = -\sum_G \frac{n_G^{int}}{N} log \frac{n_G^{int}}{N} \quad (7)$$

refers to contribution of firms with foreign participation, and $\widetilde{H}_G$:

$$\widetilde{H}_G = -\sum_G \frac{n_G^{nat}}{N} log(1 + \frac{n_G^{int}}{n_G^{nat}}) - \sum_G \frac{n_G^{int}}{N} log\,(1 + \frac{n_G^{nat}}{n_G^{int}}) \quad (8)$$

accounts for the interaction between national and international dimensions. Analogously, one can distinguish among national, foreign, and interaction inputs for all entropy terms described in Eq. 2. Correspondingly, the summary synergy can be written as net inputs of national (T_{GOT}^{nat}) and international (T_{GOT}^{int}) dimensions plus interaction term ($\tilde{T}_{GOT}$):

$$T_{GOT} = T_{GOT}^{int} + T_{GOT}^{nat} + \tilde{T}_{GOT} \quad (9)$$

We define the contribution of the firms with foreign participation as net input of international dimension plus an interaction term, since the presence of firms with foreign participation is responsible for interactions:

$$T_{GOT}^{int} = T_{GOT}^{int} + \tilde{T}_{GOT} \quad (10)$$

Firms with foreign participation can be attributed to international collaboration. Accordingly, the turnover of firms with foreign participation, (international turnover R_{int}), is a fraction of summary turnover (R). The ratio of international to summary turnover can be interpreted as the share of international collaboration activities in the total regional turnover.

The ratio T_{GOT}^{int}/T_{GOT} as a function of R_{int}/R can vary between 0 and 1. If there are no firms with foreign participation then all the turnover is generated by domestically owned firms only and R_{int}/R = 0. In this case all the synergy is also generated by domestic firms and T_{GOT}^{int}/T_{GOT} = 0. If foreign participation is the case for all the firms then both R_{int}/R and T_{GOT}^{int}/T_{GOT} are equal to unity. Sequential increase in the percentage of foreign-owned firms entails a sequential increase in R_{int}/R and increase in T_{GOT}^{int}/T_{GOT}, so that R_{int}/R and T_{GOT}^{int}/T_{GOT} vary in the interval (0,1). This is true for the case when all the synergies are of the same (negative) sign. Since the synergy is the measure of (regional) innovation system effectiveness, the assumption of all negative synergies means that those accounted for are the only effective innovation systems. In summary, one can assume that the function $T_{GOT}^{int}/T_{GOT} = f(R_{int}/R)$ is a single value function and can be inverted. So that one can measure relative turnover as a function of relative synergy $R_{int}/R = F(T_{GOT}^{int}/T_{GOT})$.

The approximate form of this function is presented as a graph in Figure1. Our assumption is that R_{int}/R is a smooth and monotone function of T_{GOT}^{int}/T_{GOT}.

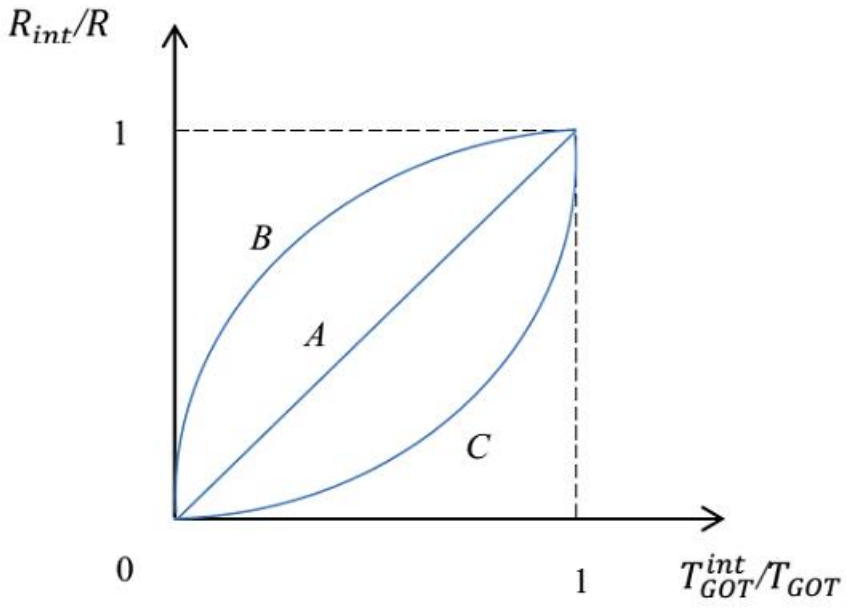

Figure 1 R_{int}/R as a line *A*, convex *B*, or concave *C* function of T_{GOT}^{int}/T_{GOT}

The shape of the function indicates the anticipated returns of international collaboration for the development of regional economies relative to aggregate turnover. One can distinguish three possible cases: a linear functional dependence (line *A*), a convex curve (line *B*), and a concave curve (line *C*). The first case would mean that the increment in synergy, conditioned by international collaboration, linearly depends on the turnover generated by internationally owned firms. The convex curve function would indicate that the internationally generated synergy increment is more efficient, in terms of aggregate turnover increase, at the early stages of international collaboration. So one can expect maximum unit return from the intensification of international collaboration at about half of the firms with foreign participation. The concave curve function would signify that the returns of international collaboration grow as this collaboration intensifies, and one can expect maximum unit return when the number of firms with foreign participation is maximized.

In this study, we have used the TH metaphor as a ladder to estimate the returns of international collaboration on regional economic development. We test the model with Norwegian data for two regions. The investigation into the relation between foreign ownership, international networks, and export for Norwegian firms provides support to the hypothesis that foreign ownership gives the firm a stronger international network, which in turn increases the probability for exports [Menon 2012]. However the situation may differ among regions. In a study of the link between TH synergy and foreign ownership in Hungarian firms Lengyel and Leydesdorff [2011], for example, found a weak correlation between foreign-owned firms and regional synergy.

Norwegian geography and economy, some characteristics

Norway is a sparsely populated country on the west coast of the Scandinavian peninsula. It shares border with Russia and Finland in the north, and Sweden in the east. Norway is amongst the few European countries that are not members of the EU. The economy features a combination of free-market activities and governmental interventions. The country is richly endowed with natural resources - petroleum, hydropower, fish, forest and minerals. The economy is highly dependent on the petroleum sector, which in 2012 accounted for 23% of the value creation in the country [Ministry of Petroleum and Energy, 2012].

Norway is administratively organized at three levels: the central government (NUTS[6] 1), 19 counties (at the NUTS 3 level) and 430 municipalities at the NUTS 5 level. The population is 5 million inhabitants. There are only five urban settlements with a population of more than 100,000 inhabitants: the capital Oslo, Bergen in Hordaland, the Stavanger/Sandnes area in Rogaland, Trondheim in Sør-Trøndelag, and the Fredrikstad/Sarpsborg area in Østfold.

A map of Norwegian counties is given in Figure 2. The capital region surrounding Oslo (county nr. 2) is the most densely populated area of the country. The central government, as well as the major knowledge institutions, are located in Oslo in the southeast. However, the major technical university is located in Trondheim, in the county of Sør-Trøndelag (county nr 16). Finmark in the north has a common border with Russia, Finland, and Sweden. The three most northern and sparsely populated counties have traditionally been dominated by marine related industries, but oil exploration in the Barents Sea have started moving petroleum-related activities from its center in Stavanger in Rogaland further north. Isaksen [2009] investigated the innovation dynamics of six regional clusters in Norway, which are the main industrial centers. He identified a micro system cluster in Vestfold, a systems engineering cluster in Buskerud (Kongsberg), a non-ferrous metal cluster in Oppland (Raufoss), a subsea cluster in Hordaland (Bergen), a maritime cluster in Møre og Romsdal, and an instrumentation cluster in Sør-Trøndelag (Trondheim).

[6] Nomenclature *des* unités territoriales statistiques

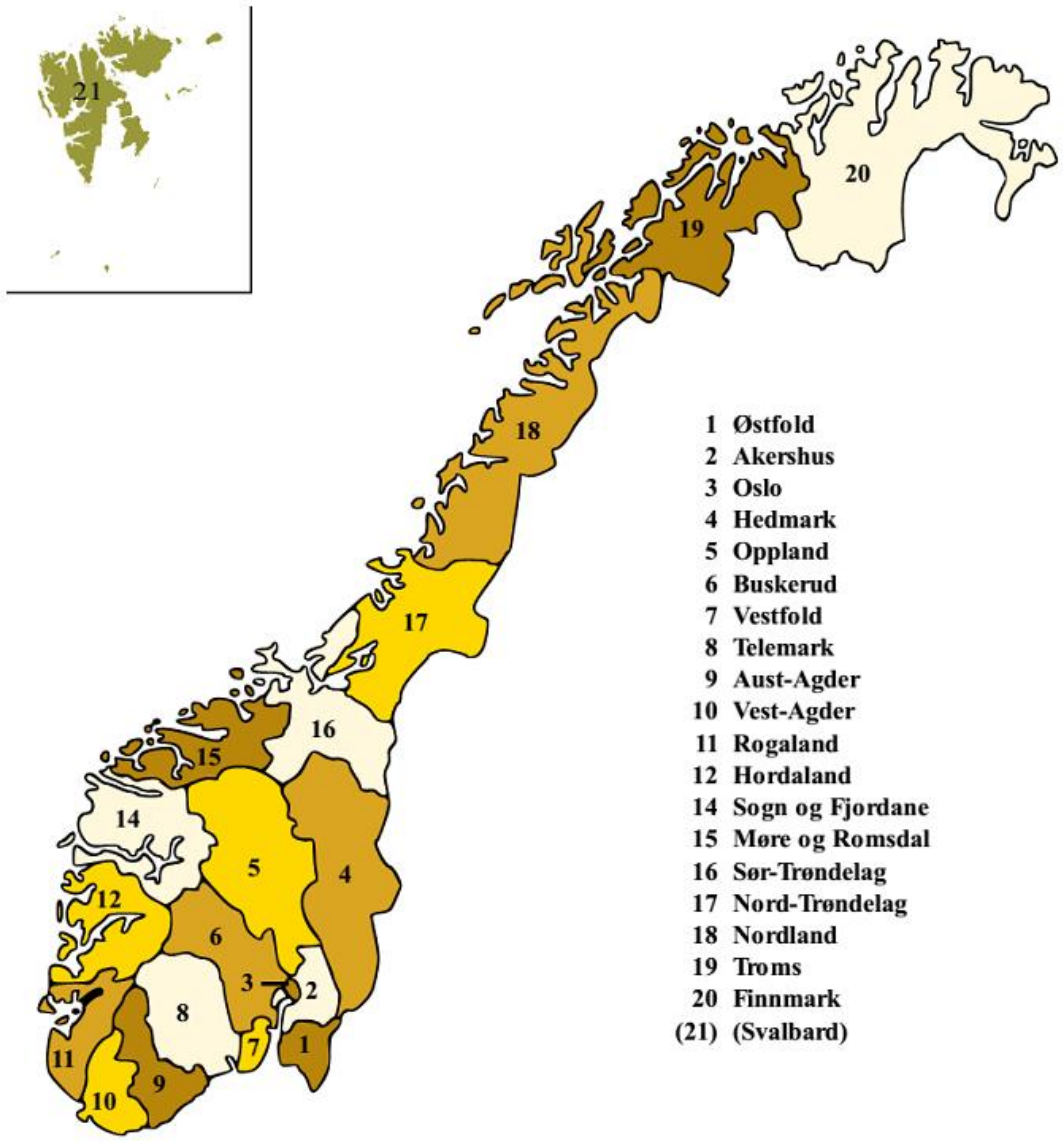

Figure 2 Norwegian counties.

Studies of the characteristics of various regional innovation systems in Norway can be found in Asheim and Isaksen [2002], Isaksen and Onsager [2010], Isaksen and Karlsen [2012], and Strand and Leydesdorff [2013]. The analysis of Triple Helix synergy in Norway shows a

high level of synergy in Rogaland, Hordaland, Møre og Romsdal and Nordland. The results for Nordland are not stable over geographical scales.

In this paper we compare two neighbor counties: Møre og Romsdal, with a strong and export-oriented industry and weak knowledge institutions, and Sør-Trøndelag, with strong academic institutions and smaller and more fragmented industry. Møre og Romsdal up until 2016 had three university colleges and less than 700 researchers. Sør-Trøndelag has the main technical university in Norway (NTNU) with close to 6,000 researchers. SINTEF, one of the largest independent research institutes in Scandinavia, with more than 2,000 researchers is also located in Sør-Trøndelag. In 2016, the college in Ålesund merged with NTNU in Trondheim. This university has its main focus on maritime engineering and business.

The industry in Møre og Romsdal is dominated by the maritime and marine sector. Asheim and Grillitsch [2015] have characterized the county as a peripheral manufacturing region, which performs remarkably well economically, despite the lack of strong academic institutions. Frøystad and Nesset [2015] find in their study of maritime suppliers in Møre og Romsdal, that the firms collaborating with global suppliers and customers have higher probability for product innovations, compared to firms collaborating locally. Isaksen [2009] compare the maritime cluster in Møre og Romsdal with the instrumentation cluster in Sør-Trøndelag. The instrumentation cluster is characterized by employees having a high degree of formal education (30% of staff have up to four years of university education and 40% have more than four years). This in contrast to the maritime cluster (20% of staff have up to four years of university education and less than 10% have more than four years). Both clusters are globally competitive and regionally based.

The number of employees in the maritime cluster is an order of magnitude larger than the number of employees in the instrumentation cluster, but these numbers are highly dependent on the inclusion criteria. The numbers of firms as reported by the cluster organizations is 55 firms in Sør-Trøndelag and 200 in Møre og Romsdal [NCE Instrumentation, 2016; GCE Blue Maritime, 2016]. Both clusters are characterized by firms with global value chains. The leading firms in these global value chains are important for external input to the regional cluster firms. Isaksen [2009] reports that both regions have at least two leading firms with a majority of foreign ownership. In Møre og Romsdal the two largest firms, by turnover in 2015, are Vard Group AS,

owned by the Italian Fincantiere group, and Rolls-Royce Marine AS, dominated by UK owners. Both are leading firms in the maritime industry.

The largest firms in Sør-Trøndelag are Reitangruppen AS, mainly in groceries, and the publically funded St Olav Hospital. Møre og Romsdal is also the center for fish export from Norway. Fløysand *et al*. [2012] reports that the maritime cluster in Møre og Romsdal is organized bottom-up, whereas most other clusters in Norway are top-down organized. Medium-tech manufacturing firms dominate in this county, whereas in Sør-Trøndelag, small firms in high-tech manufacturing and high-tech services dominate [Strand and Leydesdorff, 2013]. The example of two neighboring counties, which are so different, makes this a very interesting case to study. A comparison between relevant indicators for the two counties is given in Table 1 below. The TH synergy is compared to R&D expenditure and export income from the region. The table also gives information about the turnover and ownership of the 500 largest firms in each county.

Indicators	Møre og Romsdal	Sør-Trøndelag
TH Synergy (T_{GOT})	-0.421 bits[7]	-0.204 bits
TH *int.* Synergy (T_{GOT}^{int})	-0.24 bits	-0.027 bits
R&D expenditure per capita (NIFU-STEP, 2011)	3.503 NOK[8]	24.094 NOK
Export pr. Employees (Menon, 2012)	711.000 NOK	178.000 NOK
Population (Menon, 2012)	249.000	287.000
Turnover in the 500 largest firms[9] in 2013	170 billion NOK	185 billion NOK
Foreign-owned firms[10] amongst the 500 largest firms in 2013	44	39
Turnover in foreign firms	24%	9%

[7] Bits of Information
[8] Norwegian kroner, 1 NOK= 0.118 Euro or 0.134 $
[9] Turnover based on data from Purehelp.no
[10] Ownership data from Proff.no

compared to domestic		
$(R_{int}/R)/(T_{GOT}^{int}/T_{GOT})$	0.25	0.68

Table 1. Characteristics of the two counties studied in this paper.

Results, discussion

We performed the calculations for the Sør-Trøndelag and Møre og Romsdal counties by focusing on the 500 firms with highest turnover. There are 39 foreign-owned firms in Sør-Trøndelag and 44 foreign-owned firms in Møre og Romsdal among these 500. As indicated in Table 1 the summary turnover is approximately 185 billion NOK and 170 billion NOK, respectively.

The total Sør-Trøndelag county ternary synergy T_{GOT} estimated for all 500 county firms is –0.204 (in bits of information). The part of the synergy generated by foreign-owned firms (T_{GOT}^{int} = –0.027 bits of information). The ratio of internationally generated synergy surplus $T_{GOT}^{int}$to total synergy T_{GOT} vs. internationally generated turnover $R_{int}$to summary turnover R is presented in Figure 3. The end points 0 and 1 are analytical values. The conclusion is that this data can be approximated by a concave polynomial function.

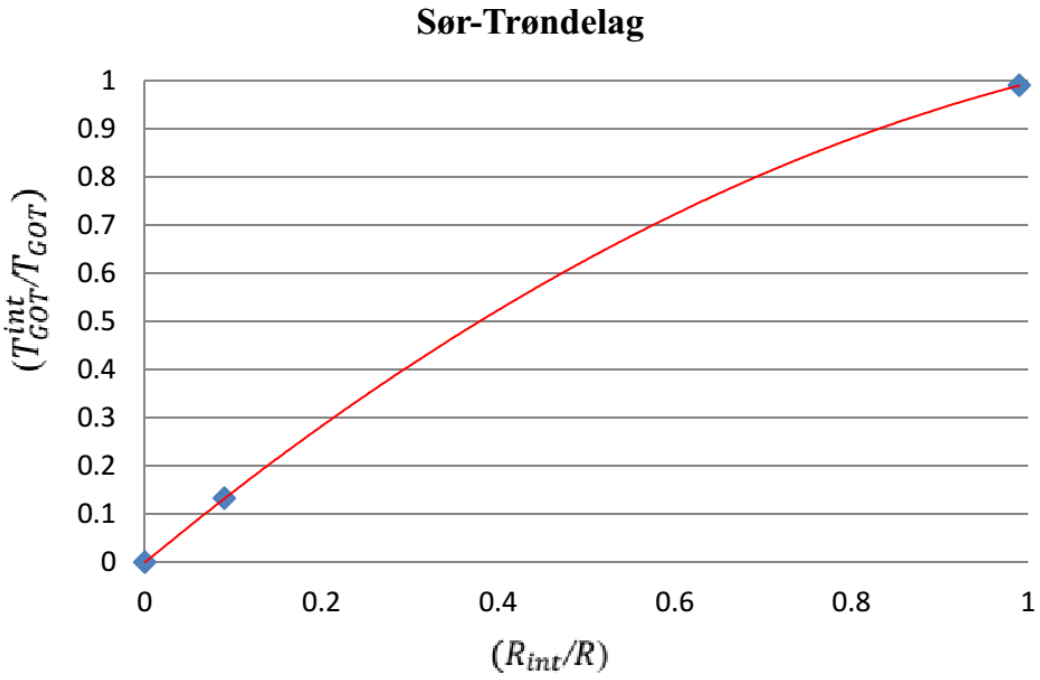

Figure 3. The ratio of internationally generated synergy T^{int}_{GOT} to summary region synergy T_{GOT} vs. the ratio of international turnover R_{int} to summary region turnover R for Sør-Trøndelag. The end points 0 and 1 are the analytical values and solid line is the polynomial approximations.

The best fit to the data is a slightly concave function. This may indicate that the efficiency of the relative internationally generated synergy surplus in terms of the relative aggregate turnover would grow as the share of internationally generated synergy increases. The distribution of foreign-owned firms by technology groups in general follows the distribution of the domestically owned firms (Figure 4). The main spheres of activity of domestically owned firms correspond to the second (manufacturing, mining and quarrying, and other industry), third (construction), fourth (wholesale and retail trade, transportation and storage, accommodation, and food service activities), and eighth (professional, scientific, technical, administration, and support service activities) technology groups with a focus on trade, transportation and food

service activities, while foreign-owned firms are mostly engaged in the activities corresponding to second, fourth and eighth technology groups with an emphasis on manufacturing, mining, and other industrial applications.

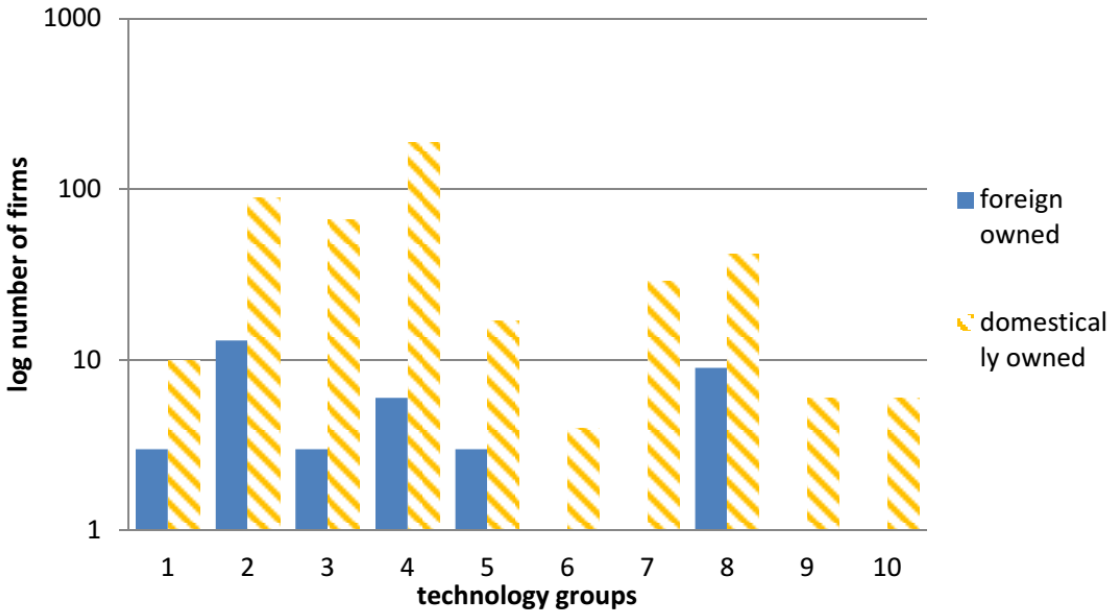

Figure 4. Log of the total number of firms and number of foreign-owned firms with respect to technology groups for Sør-Trøndelag county

Due to largely coinciding spheres of domestically and foreign-owned firms' activities international collaboration does not bring additional substantial diversification to the regional economy and regional exports, and there is a statistically and economically important relationship between export growth and income growth [Lewer and Berg 2003; Hidalgo and Hausmann 2009]. At the same time, boosting synergy in the international dimension demands additional efforts and expenses so that at initial stages with a comparatively low level of internationally owned firms the return is not so substantial. The specific role of foreign-owned companies is that they can be considered a form of foreign investment, which has an effect on

the knowledge transfer, information sharing, technology spillover, and the development of human capital.

Furthermore, one should consider the effect of foreign-owned companies on the development of regional innovation systems, as international collaboration brings an additional dimension to university-industry-government relations. From the literature related to the cluster theories, the concept of "local buzz-global pipelines" is well known [Bathelt et al., 2004]. The local knowledge flows are characterized by informal exchanges of applied knowledge related to ongoing projects, this "local buzz" is highly efficient given that the actors are co-located. The global knowledge flow relates to contact with customers in global markets, this "global pipeline" brings state of the art knowledge from global markets back to the local cluster. This means that local, or national, knowledge institutions may be by-passed by this global pipelines if they don't interact with local industries.

GVC literature is mainly concerned with governance and upgrading of the global value chains [Gereffi and Lee, 2012]. Governance is the coordination of economic activities through non-market activities [Humphrey and Schmitz, 2002] and upgrading refers to shift of activities due to increasing competitive pressure. These authors also stress that "governance is particularly important for the generation, transfer and diffusion of knowledge leading to innovation." In the governance of GVCs, the lead firms play an important role as described in detail by Gereffi and Lee [2012].

In Møre og Romsdal, the total county ternary synergy T_{GOT} estimated for all 500 county firms equals –0.421 bits of information. This value twice exceeds the value of Sør-Trøndelag. A large part of total synergy is generated by foreign-owned firms (T_{GOT}^{int}) –0.396 bits. The ratio of internationally generated synergy surplus T_{GOT}^{int} to total synergy T_{GOT} vs. internationally generated turnover R_{int} to total turnover *R* is presented in Figure5. The end points 0 and 1 are again analytical values. The form of the curve corresponds to the curve B of Figure 1.

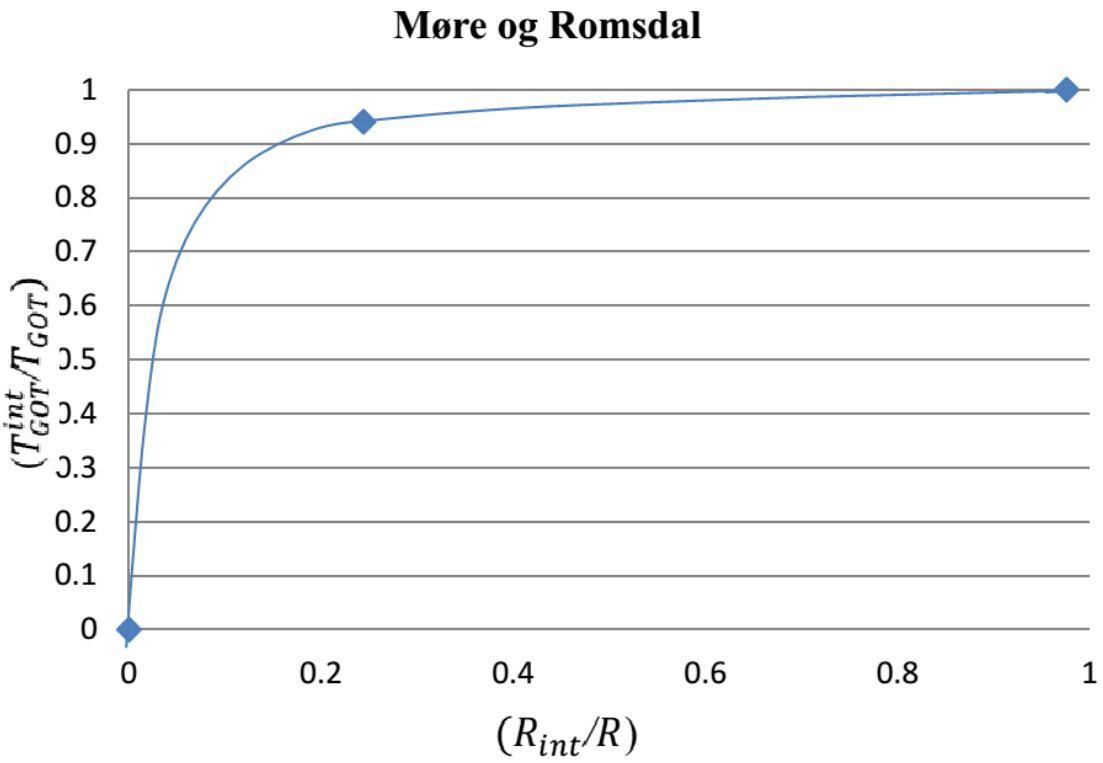

Figure 5. The ratio of internationally generated synergy T_{GOT}^{int} to total regional synergy T_{GOT} vs. the ratio of international turnover R_{int} to total regional turnover R for Møre og Romsdal. The end points 0 and 1 are analytical values and the solid line is the polynomial approximations.

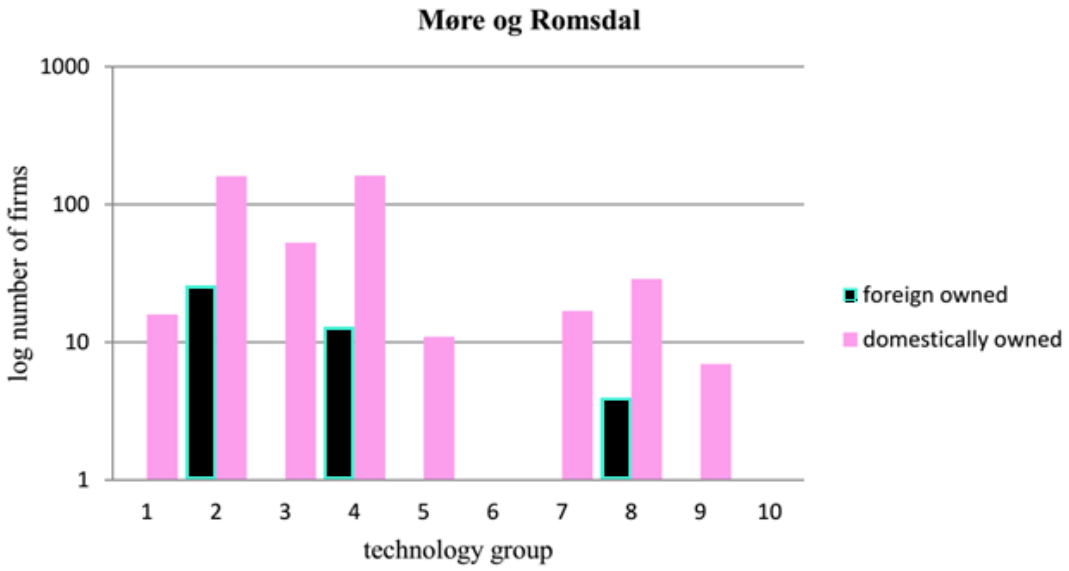

Figure 6. Log of the total number of firms and number of foreign-owned firms with respect to technology groups for Møre og Romsdal county

When comparing results for the two counties the difference is striking. Most of the synergy in Møre og Romsdal is attributed to the firms with foreign ownership, whereas foreign-owned firms account for only a small part of the synergy in Sør-Trøndelag. Based on previous calculations using data for all Norwegian firms, one would expect the production- and export-oriented county of Møre og Romsdal to demonstrate other characteristics than the more science- and knowledge-oriented county of Sør-Tøndelag [Strand and Leydesdorff, 2013]. However these results in Figure 6 are rather extreme.

Based on the knowledge of the two counties we would expect foreign ownership in low- and medium-tech industries, such as shipbuilding and ship equipment production. Generally, global integrated value chains characterize the maritime offshore industry. The firms are mature, well-established, and large. In Sør-Trøndelag, we would expect a higher number of new, small high-tech companies in their growing phase. These small firms will have relatively small turnover compared to the more mature firms in Møre og Romsdal. We would expect that an analysis of a larger share of firms for both counties would dampen the effect for Møre og Romsdal and increase the effect of foreign ownership on synergy in Sør-Trøndelag. (However,

inclusion of ownership data requires two separate databases to be matched manually for each firm)

This said, how can it be that a county like Sør-Trøndelag with ten times the number of academics and researchers compared with Møre og Romsdal, does not demonstrate the same level of Triple Helix synergy? Can this be a sign of fragmentation, as reported by Onsager et al. [2010], or ”parallel worlds”, as reported by OECD [2006], in the situation for the academic institutions in Sør-Trøndelag? Is it so that researchers at these institutions prefer career-relevant academic research in favor of working together with the industry on more applied (and perhaps less easily publishable) problems? Alternatively, is it so that the knowledge resources in Sør-Trøndelag act like a knowledge bank for national industry and that the results of the knowledge transfer from these institutions can only be detected in the industrial regions where it is implemented?

The industrial structure as such may also affect the results. For example, a large offshore construction vessel with a price tag of several billons NOK (Norwegian kroner) needs a huge number of regional suppliers compared with a high-tech firm producing a small series of advanced instrumentation. But an alternative would be provided by the previously mentioned local buzz-global pipeline hypotheses, where industry-relevant knowledge flows directly from global customers to the local cluster firms. It has previously been suggested [Strand and Leydesdorff, 2013] that the national knowledge institutions may be bypassed if not relevant.

For small firms located in a regional cluster where the central role is played by internationally owned firms, like in Møre og Romsdal, this may provide opportunities for “piggybacking” where the small firms follow the internationally leading firms. By this mechanism, small cluster firms with little recourse can still be able to obtain international contracts and generate export income on global markets.

The role of the knowledge institutions (academia) is very interesting because of the merger between a strong academic partner (NTNU) and a more applied and industry-focused regional university college in Ålesund. According to GVC and cluster literature, the knowledge institutions play a central role in the various improvement processes caused by competitive pressure and new knowledge. Upgrading takes place both vertically along the value chains and horizontally among the cluster firms. Interaction between the strong academic institutions in Sør-Trøndelag and the strong industry may enhance the cluster and value chain improvement.

Likewise, there is a danger that the industry-focused knowledge institution embedded in the maritime cluster will be directed towards more academic and less applied research.

National and regional governments have also an important role in developing conditions that are attractive to the leading firms. Internationally owned leading firms are more likely to locate their R&D facilities in regions and countries with favorable research funding and strong knowledge institutions. Governmental research policies should encourage the interaction between firms and knowledge institutions in order to enhance the understanding of challenges faced by industry that can perhaps be solved with new knowledge from academia.

Conclusion

By using ownership data for the 500 largest firms in terms of turnover in two neighboring counties, we showed that foreign ownership has a strong effect on synergy. From previous studies we know that the level of triple helix synergy is higher in Møre og Romsdal, compared to Sør-Trøndelag. However, the ratio $(R^{int}/R)/(T_{GOT}^{int}/T_{GOT})$ in Sør-Trøndelag (0.68) is approximately two and half times larger than that in Møre og Romsdal (0.25). In other words, the relative international synergy increment efficiency, in terms of relative turnover, is higher in Sør-Trøndelag than in Møre og Romsdal. This result can be explained by the larger R&D expenditure per capita in Sør-Trøndelag. The result suggests that it is easier to improve the TH synergy in Sør-Trøndelag than in Møre og Romsdal, since the available potential has not yet been fully used.

From a methodological perspective, our results show that one can link the abstract concept of Triple Helix synergy, measured in bits of information, to more familiar economic terms like turnover. Variations in industry structure as well as maturity of the industry between the two counties may explain the strong effects that were detected. We expect that the inclusion of more firms will dampen these effects; however, this remains to be shown.

What can one do to enhance synergy in a region? Answers from Triple Helix theory, cluster theory and research on GVC all point to the role of increased interactions. From the perspective of Triple Helix theory, the interactions are between the actors in industry, academia and government. Cluster theory points to interactions and localized learning among the firms in a

cluster, whereas GVC emphasizes the role of interaction between the firms and the global customer. The findings from the three streams of research and the results from the perfomed calculations point to the central role of the internationally owned firms in the clusters. Internationally owned firms seem to be a key element for enhancing synergy in a region; but further research is needed for clarifying the various aspects of the roles of lead firms. The observed effect may be due to the relations between the knowledge institutions, the government and other firms in the region.

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Conflict of interests

The authors declare that they have no conflicts of interest.

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Appendix

ISIC Rev. 4/NACE Rev. 2 high-level aggregation	ISIC Rev. 4/NACE Rev. 2 sections	NACE Rev.2 two digit codes	Description
1	A	01-03	Agriculture, forestry and fishing
2	B,C, D, E	05-39	Manufacturing, mining and quarrying, and other industry
3	F	41-43	Construction
4	G, H, I	45-56	Wholesale and retail trade, transportation and storage, accommodation and food service activities
5	J	58-63	Information and communications
6	K	64-66	Financial and insurance activities
7	L	68	Real estate activities
8	M, N	69-82	Professional, scientific, technical, administration and support service activities
9	O, P, Q	84-88	Public administration, defense, education, human health and social work activities
10	R, S, T, U	90-99	Other services

Table 2. Correspondence between high level aggregation of ISIC/NACE categories and two digit NACE Rev. 2 codes