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ABSTRACT

Vertical Industry Linkages: Sources of Productivity Gains and Cumulative Causation?*

In this Paper we analyse vertical industry linkages and the extent to which these work as channels for externalities. First, we test for activity-based externalities stemming from output growth and output level in vertically linked industries. Second, we aim at revealing the importance of a large home market for upstream industries. Eventually, by comparing results on localized inter-industry externalities and on the impact of local sales, we try to identify to what extent the geographical agglomeration of an industry is self-reinforcing. A number of Norwegian maritime transport and services sectors are analysed. The results are promising in the sense that the model distinguishes empirically between different sources of externalities and unveils vertical linkages that give rise to endogenous agglomeration

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NON-TECHNICAL SUMMARY

Industrial agglomerations can be established and maintained due to historical events, natural resources or externalities. 'Lumpy' distribution of economic activity across space may thus have different explanations. Still, in order to make predictions regarding the location of economic activity and optimal design of economic policy, we want to be able to distinguish between the agglomerations that rely on the presence of localized externalities and may be self-reinforcing, and those that have other sorts of explanations.

In this Paper we analyse an industrial agglomeration of vertically linked firms. We want to investigate the nature of the vertical linkages that exist among a number of geographically concentrated service industries, in order to detect potential positive externalities as well as endogenous agglomeration forces. Vertical linkages express sales linkages and may, as such, merely tell us that the expansion of a downstream industry may affect certain upstream industries, due to the downstream industry's demand for intermediate goods. Still, vertical linkages may also represent something more than just sales linkages: they may in some cases be an important channel for externalities.

Our approach differs from preceding empirical analyses of externalities. First, we concentrate on a number of very disaggregated service sectors. For most of these, public data were not available and in these cases micro data gathered directly from firms have been used. Second, focusing on vertical linkages, we address two issues: (i) Do the linkages merely represent sales linkages or are they also important channels for the transmission of externalities? (ii) Are observed regional agglomerations self-reinforcing or not? In order to answer these questions we test for the existence of inter-industry externalities and investigate the relationship between downstream sales and local upstream sales.

There is a large empirical literature on knowledge spillovers and external economies of scale (see Griliches (1992) for an overview). But so far, one has mainly concentrated on manufacturing industries. There are several reasons for this. First, data on services are hard to get hold of in general. Variables such as employment and output are available for some very aggregated service sectors, whereas variables such as input use, cost shares, capital formation etc., which are crucial for an empirical analysis of increasing returns and productivity, are usually missing. Second, for less aggregated service sectors, even output and employment figures are difficult to get hold of. Third, R&D expenditure data are scarcely ever available on any aggregation level for these sectors. The main reason is that the occurrence of R&D departments in firms within the service sector is pretty rare. This does not necessarily mean that knowledge is not generated and accumulated, or that knowledge

spillovers are not transmitted. Still, what it does mean, is that when testing for externalities, we want to follow the kind of approach suggested by Caballero and Lyons (1990), who focus on activity-based externalities, rather than R&D spillovers.

Being aware that an increasing share of economic activity takes place within the service sector, it seems an important task to bring such sectors to the empirical analysis. Moreover, if we want to take recent theories on industrial agglomeration and cumulative causation seriously (see e.g. Fujita et al, 1999), it is clear that this also requires the use of highly disaggregated data.

Through an analysis of vertically linked industries, we test for externalities and whether an observed regional agglomeration is self-reinforcing. First, along the line of work on activity based externalities, we model whether output growth in one industry depends on the activity growth and activity level of localized vertically linked industries. Then, we look at how a downstream industry's sales are related to local upstream industries' sales. Finally, we show that by comparing the results on correlation of sales, i.e. significance of demand linkages, with evidence on externalities, we are able to identify vertical linkages giving rise to self-reinforcing geographical agglomeration.

We analyse a number of vertically linked Norwegian maritime transport and service sectors. The choice of sectors is partly motivated by earlier findings of externalities between the aggregated maritime services sector and ocean transport (see Knarvik and Steen, 1999). The results are promising in the sense that we are able to distinguish empirically between (1) different sources of externalities, and (2) to reveal whether vertical linkages give rise to mutual gains from localization and self-reinforcing agglomeration, i.e. to reveal the importance of a local home market.

We find that the maritime transport industry experiences positive externalities, the magnitude of which is related to the activity level of five out of six maritime services industries. The results also suggest that the ties that exist between three of the maritime services industries (Banking, P&I insurance and Maritime consultants) and the maritime transport industry give rise to self-reinforcing geographical concentration.

1. INTRODUCTION

Industrial agglomerations can be established and maintained due to historical events, natural resources or externalities. "Lumpy" distribution of economic activity across space may thus have different explanations. Still, in order to make predictions regarding the location of economic activity and optimal design of economic policy, we want to be able to distinguish between the agglomerations that rely on the presence of localised externalities and may be self-reinforcing, and those that have other sorts of explanations.

In this paper we analyse an industrial agglomeration of vertically linked firms. We want to investigate the nature of the vertical linkages that exist among a number of geographically concentrated service industries, in order to detect potential positive externalities as well as endogenous agglomeration forces. Vertical linkages express sales linkages and may, as such, merely tell us that the expansion of a downstream industry may affect certain upstream industries, due to the downstream industry's demand for intermediate goods. Still, vertical linkages may also represent something more than just sales linkages: they may in some cases be an important channel for externalities.

Our approach differs from preceding empirical analyses of externalities. First, we concentrate on a number of very disaggregated service sectors. For most of these, public data were not available, and in these cases micro data gathered directly from firms have been used. Second, focusing on vertical linkages, we address two issues: (i) do the linkages merely represent sales linkages or are they also important channels for the transmission of externalities? (ii) Are observed regional agglomerations self-reinforcing or not? In order to answer these questions we test for the existence of inter-industry externalities, and investigate the relationship between downstream sales and local upstream sales.

There is a large empirical literature on knowledge spillovers and external economies of scale (see Griliches (1992) for an overview). But so far one has mainly concentrated on manufacturing industries. There are several reasons for this. First, data on services are hard to get hold of in general. Variables such as employment and output are available for some very aggregated service sectors, whereas variables such as input use, cost shares, capital formation etc., which are crucial for an empirical analysis of increasing returns and productivity, are usually missing. Second, for less aggregated service sectors, even output and employment figures are difficult to get hold of. Third, R&D expenditure data are scarcely ever available on any aggregation level for these sectors. The main reason is that the occurrence of R&D departments in firms within the service sector is pretty rare. This does not necessarily mean that knowledge is not generated and accumulated, or that knowledge spillovers are not transmitted. Still, what it does mean, is that when testing for externalities, we want to follow the kind of approach suggested by Caballero and Lyons (1990), who focus on activity based externalities, rather than R&D spillovers.

Being aware that an increasing share of economic activity takes place within the service sector, it seems an important task to bring such sectors to the empirical analysis. Moreover, if we want to take recent theories on industrial agglomeration and cumulative causation seriously (see e.g. Fujita et al, 1999), it is clear that this also requires the use of highly disaggregated data.

We analyse a number of vertically linked Norwegian maritime transport and service sectors. The choice of sectors is partly motivated by earlier findings of externalities between the aggregated maritime services sector and ocean transport (see Knarvik and Steen, 1998). The results are promising in the sense that we are able to distinguish empirically between different sources of externalities and, possibly even more important, to reveal whether a geographical industrial concentration is self-reinforcing.

We find that the maritime transport industry experiences positive externalities, the magnitude of which is related to the activity level of five out of six maritime services industries. The results also suggest that the ties that exist between three of the maritime services industries and the maritime transport industry give rise to self-reinforcing geographical concentration.

This paper is organised as follows: section 2 provides the theoretical background for the empirical analysis. In section 3 the empirical specification of the models is presented. Section 4 presents the results, while section 5 offers some concluding remarks.

2. THEORETICAL BACKGROUND

Why do we observe that industries cluster geographically? Regional agglomerations may be due to firms seeking proximity to for instance natural resources; in which case, what they seek is not closeness to other firms as such. Another reason for firms to concentrate is the existence of vertical links: if a number of firms all require the same intermediates, they may end up geographically concentrated, not because they seek proximity to each other, but because they all seek proximity to the same suppliers in order to save transport costs on intermediates. Agglomerations may, however, also rely on the existence of localised technological or pecuniary externalities.[1]

Industrial agglomerations of the latter type may again be split into two groups: self-reinforcing and non-self-reinforcing. An industrial agglomeration will be self-reinforcing when the establishment of a new firm not only increases competition, but also enhances the profitability (productivity) of established firms. When will this typically be the case? If the activity of firms allows for the generation of localised externalities, which impact positively on other firms within the *same* industry, an industrial agglomeration will be self-reinforcing.

[1] While technological externalities often are thought of as more or less invisible, pecuniary externalities are mediated by markets, and are accordingly often referred to as market linkages. For a closer description of technological externalities and the way they work, see Romer (1990), Glaeser et al (1992) and Griliches (1992). As for pecuniary externalities, see Griliches (1992), Krugman (1991), Venables (1996), and Ottaviano and Puga (1998).

But even in the absence of intra-industry externalities, an agglomeration may be self-reinforcing. This will be the case if (1) there is a geographically concentrated group of vertically linked firms, where firms in the downstream industry enjoy externalities arising from the activity of upstream firms (inter-industry externalities); and (2) upstream activity, in turn, depends *significantly* on the demand from *local* downstream activity. Given that (1) and (2) are satisfied, the number of firms in the downstream industry will indirectly affect the productivity of the individual downstream firms. If we were considering a closed economy, condition (2) would, in fact, be superfluous; given the absence of trade, there is, per definition, a 'one to one' relationship between downstream and upstream sales, as all sales are local. However, in an open economy this is not necessarily the case: localised inter-industry externalities transmitted from upstream to downstream firms, may then only give rise to self-reinforcing geographical agglomeration, provided that local the sales of downstream firms have a significant impact on local upstream firms' sales.

Analysing intra-industry externalities requires firm level data, data that are not available to us. Hence, we shall concentrate on inter-industry externalities, as a force for (self-reinforcing) agglomeration. When looking for inter-industry externalities, we distinguish between two types of activity based externalities, depending on source: (i) activity *level* of local upstream firms, and (ii) activity *growth* of local upstream firms. We estimate the impact of upstream activity growth and upstream activity level on downstream productivity growth. The focus on the former source of externalities is motivated by a hypothesis of external economies of scale applying at the level of a group of industries, and represents the type of model used by Caballero and Lyons (1990), Basu and Fernald (1995) and others. Why should also upstream activity *level* matter for downstream productivity growth? The upstream industries considered here are maritime services sectors. They primarily employ skilled workers, and similarly to other business services, their most important knowledge base is typically presumed to be embodied in their labour force. As employment tends to be highly correlated with activity level, one way of thinking about services industries' activity level, is as a kind of proxy for knowledge base. But activity level also informs us about the scope and intensity for networking and labour mobility: the more activity, the more agents to interact with and exchange information with, and the more firms for workers to move between. Hence, it is likely that industrial activity level is important both for the size of a knowledge base, the diversity of the knowledge base, and for the efficient transmission of knowledge spillovers among agents.

We try to merge two approaches focusing on activity growth and activity level, respectively, by specifying a model where both effects are explicitly included.

3. EMPIRICAL ANALYSIS

3.1 The model

First, along the line of work on activity driven externalities (e.g. Caballero and Lyons (1990)) we test for the impact of maritime upstream activity on productivity growth of maritime downstream firms. Second, in order to conclude on whether an observed geographical industrial concentration is self-reinforcing or not, we look at how the downstream industry's sales affect local upstream industries' sales, which allows us to conclude on the importance of cumulative causation as a driving force of location of maritime activities. Testing for the impact of an expansion of downstream activity on the sales of upstream industries is done by regressing the value of output of an upstream industry on the value of output of the downstream industry. This test indicates whether inter-industry externalities may give rise to cumulative causation and self-reinforcing industrial agglomeration. By comparing results on the significance of demand linkages, and findings of externalities, four outcomes are possible:

(a) Significant demand linkages and positive findings of externalities;

(b) Significant demand linkages and no findings of externalities;

(c) Insignificant demand linkages and positive findings of externalities;

(d) Insignificant demand linkages and no findings of externalities.

While (a) implies the existence of self-reinforcing industrial agglomeration; (b) indicates that the observed geographical agglomeration of maritime activity does not rely on the presence of externalities, despite significant vertical sales linkages; (c) underscores the importance of externalities for the existence of the maritime agglomeration, while no signs of cumulative causation are found; and (d) suggests that externalities are not the driving agglomeration force.

Setting up the model to test for externalities, we draw on the work of Caballero and Lyons (1990), Basu and Fernald (1995), Griliches (1992) and Knarvik and Steen (1998). We start with a production function, where output (Q) in a downstream industry is defined as a function of the inputs labour (L), capital (K), materials (M), and the productivity term (V):

$$Q = F(L, K, M, V) \tag{1}$$

We assume F to be homogenous of degree γ in L, K, and M, and use log differences as approximation for logarithmic derivatives. Letting $\Delta l = \ln L_t - \ln L_{t-1}$, we define the input aggregate $\Delta x \equiv s_L \Delta l + s_K \Delta k + s_M \Delta m$, where s_L, s_K, s_M denote cost shares, *e.g.* $s_L = wL / (wL + P_K K + P_M M)$, and reformulate (1) as:

$$\Delta q_i = \gamma \Delta x_i + \beta \Delta v_i \, , \tag{2}$$

with subscript *i* referring to the industry.

γ measures the degree of returns to scale. γ>1 implies increasing internal returns to scale. The productivity term (Δv_i) is a function of upstream output ($\tilde{q}$), upstream output growth ($\Delta \tilde{q}$), an orthogonal aggregate (Δu) representing the productivity development common to downstream as well as upstream industries, and an idiosyncratic component of productivity development (Δu_i), which will have the standard properties; $\Delta \mathrm{u_i} \sim iid(0,\sigma)$;

$$\Delta v_i = \tilde{q} + \Delta\tilde{q} + \Delta u + \Delta u_i \,. \tag{3}$$

Adding up the information in (2) and (3), we have that[2]

$$\Delta q_i = \gamma\Delta x_i + \beta_q \tilde{q} + \beta_{\Delta q}\Delta\tilde{q} + \beta_u \Delta u \;\; + \Delta u_i \,; \tag{4}$$

which we modify in order to let total factor productivity growth replace output growth as the left hand side variable:

$$\Delta TFP_i = (\gamma - 1)\Delta x_i + \beta_q \tilde{q} + \beta_{\Delta q}\Delta\tilde{q} + \beta_u \Delta u \;\; + \Delta u_i \,. \tag{5}$$

In this model there is, however, an endogeneity problem that arises from the probable correlation between (unobservable) productivity growth (Δv, Δu_i) and input use: input use probably rises to take advantage of the higher level of productivity, and there might be correlation between the right hand side variables and the error term. To solve this, we use instrumental variable techniques with instruments, that are exogenous with respect to shocks in the productivity term and the error term.[3]

Furthermore, measured inputs tend to fluctuate less than measured output. Hence, it might be difficult to disentangle whether the impact of the externality variables actually indicates externalities, or whether it is just the result of shocks common to the agglomerated industries, leading to unmeasured fluctuations in the utilisation of various inputs and effort levels (Griliches, 1991, Knarvik and Steen, 1998). Our disaggregated analysis enables us to

[2] If the source of external economies of scale is pecuniary rather than technological externalities, value of output (q), may not need to be affected, but value added will. Depending on whether the increased profitability incurred by pecuniary externalities deposits in increased returns to factors or in increased employment due to an expansion of the industry, value added or output will be affected. Knarvik and Steen (1998) modify the present framework to provide a more complete test for pecuniary externalities, where value of output -- the left hand side variable in (5) -- is replaced with growth in value added. This modified setup with value added as the left hand side variable is unfortunately related with some problems: Basu and Fernald (1995) show that in the presence of increasing returns to scale and/or imperfect competition the use of value added as regressand may lead to spurious findings of large apparent externalities. Knarvik and Steen's empirical results showed that this bias caused problems with the interpretation of their results. Hence, pecuniary externalities are not fully tested for using this approach here.

[3]Related to (5), there is also a further potential endogeneity problem that arises from the influence of productivity shocks (Δu_i) on aggregate output. This may be solved by using aggregate input growth rate as a proxy for

specify instrument variables that are important determinants of the maritime business cycle and which will mitigate this problem.

3.2 Empirical specification

To test for externalities arising from output levels and output growth of local upstream industries, we estimate (5) using SURE (Seemingly Unrelated Regression Estimation) and three stage least squares (3SLS). Applying the same methods of estimation, we also analyse how expansion of a downstream industry affects the sales of local upstream industries.

We analyse seven Norwegian maritime transport and services sectors: ocean transport , shipbrokers, P&I insurance, classification companies, ocean hull insurance, maritime consultants, and shipping divisions of financial institutions. Ocean transport represents the downstream industry in the regional maritime agglomeration, while the other sectors all represent upstream industries to ocean transport. Our focus will be on ocean transport, and in particular on how growth in ocean transport TFP is affected by the size and growth of six maritime services industries. Looking at sales linkages we reverse the set-up, and regress the individual upstream service industries' output on the output of ocean transport, and real GNP for Norway. The latter variable is included to capture possible common correlation due to the general business cycle effect.

For details on the individual sectors, on how the data were collected, and the data set was constructed, see the appendix. The data we use are much more disaggregated than any available Norwegian public data on services, and are based on micro data gathered directly from active firms. To operate at a rather disaggregated level is essential, however, if we want to analyse industrial agglomerations of vertically linked firms. Moving to a more aggregated

aggregate output growth rate. Due to data limitations on the service sector, we are, however, not able to make this modication.

level, means that we automatically lose information that is valuable for the analysis of the ties between agglomerated firms.

The γ measures the degree of returns to scale – internal to firms or to the individual industries. In order to reduce the number of left hand side variables and save on degrees of freedom, we shall make the simplifying – but in the TFP literature rather common – assumption that γ=1, i.e. assume that ocean transport is characterised by constant returns to scale.[4] This assumption also found support in analyses of the data set, where we allowed γ to be estimated freely: in all the models the estimated coefficient of (γ–1) was found to take on values very close to zero, and was not significant.

The $\tilde{q}$ and $\Delta\tilde{q}$ refer to inter-industry externalities stemming from output level and output growth in local upstream sectors ($\beta_q, \beta_{\Delta q}$>0 indicate positive externalities, while $\beta_q, \beta_{\Delta q}$<0 indicate negative externalities). What distinguishes the present analysis from that undertaken by e.g. Caballero and Lyons (1990), is the inclusion of $\tilde{q}$ as a source of positive externalities. Hence, not only do we presume productivity growth in the maritime transport industry to be related to activity growth in vertically linked industry, but we also presume the activity *level* in these industries as such, to impact positively on maritime transport productivity growth.

For many of the upstream industries output cannot be measured in the traditional sense. Neither gross production value, nor employment data were available. We solved the problem by using industry specific information on variables that measure the economic activity taking place in the industry. For further details on the exact variables that have been used for the different industries, see the appendix.

[4] We have 10 years of observations for each sector. However, even when we exploit the panel data properties we benefit statistically from using a model with as few variables as possible.

It is quite common to let the error term be defined by the aggregate of the last two right hand side variables in (5). This implies that it may be difficult to disentangle common shocks to the maritime sector from real externalities. To accommodate general technological progress, we disentangle Δu from the error term. Δu is a matrix represented by two figures, the change in real GNP for Norway and a linear time trend, reflecting common Norwegian technological development and possible common trends within the industries. The β_u then consists of two parameters; $\beta_{u\Delta GNP}$ and $\beta_{\text{u trend}}$.

Our choice of instrument variables also enables us better to disentangle whether the externality variables measure externalities or whether it is just the impact of shocks common to the vertically linked industries that is measured. We use three instruments; the oil price, the freight market rate for bulk, and the exchange rate between US $ and NOK. All of these are exogenous to the industries, but represent important determinants in terms of the maritime business cycle. The oil price and the freight market indices primarily capture changes in demand, and the exchange rate between US$ and NOK is important to the Norwegian maritime industries since most contracts are paid in US$.[5]

4. EMPIRICAL EVIDENCE

We start with the test for externalities. Then we proceed with a "correlation of sales" model, where we seek to reveal how the sales of the maritime transport industry affect the sales of the individual services (upstream) industries, i.e. the significance of sales (demand) linkages. Finally we compare the results from the two models, in order to conclude on the importance of cumulative causation for the location of the maritime transport & service sector.

[5] The standard endogeneity problem faced when estimating production functions is that whereas output is a function of input use, input demand depends on both input prices and output level. Primarily our instruments account for the 'common shock problem', but since both the oil price and the exchange rate are important cost components, this standard endogeneity problem is also partly remedied.

4.1 Inter-industry externalities

We estimate the model described in equation (5) for all six services sectors to see whether we can trace inter-industry externalities. Hence we have a system of six equations where total factor productivity growth in ocean transport (downstream) is used as left hand side variable in all equations (ΔTFP_t). On the right hand side upstream output growth is represented by the activity growth in the services sectors; $\Delta LOAN_t$ (shipping divisions of financial institutions), $\Delta CLASS_t$ (classification), $\Delta INSUR_t$ (ocean hull insurance), $\Delta P\&I_t$ (P&I insurance), $\Delta CONSULT_t$ (maritime consultants), $\Delta BROKER_t$ (shipbrokers); while $LOAN_{t-1}, CLASS_{t-1}, INSUR_{t-1}, P\&I_{t-1}$, $CONSULT_{t-1}$ and $BROKER_{t-1}$, denote upstream activity levels in period *t-1*. The trend component is represented by the two variables ΔGNP_t (growth in gross national product) and T (linear time trend). All values are deflated, see the appendix for variable definitions.

Carrying out the test for externalities, we apply SURE as well as 3SLS. As instruments we used the oil price, the bulk market freight rate, and the exchange rate between NOK and US$. The results are shown in Table 1. When we compare the results from the SURE and the 3SLS estimation, these indicate that common demand shocks are responsible for a correlation between the regressors and the error terms, since several of the parameters measuring the external economies of scale[6] are reduced in significance in the 3SLS model. This suggests that these sectors to some extent experience the same business cycle, and that the use of instrument variables allows us to disentangle from externalities shocks that are common to the maritime industries. The validity of the 3SLS results is, however, dependent on how good our instruments are. It is reasonably simple to argue that the instruments used are important to the whole industry, but to ensure that they matter to all the individual services sectors (equations), we test the validity of our instruments using *Sargan validity of instrument test* for each equation. The test statistics have an approximately Chi-square distribution with (*p*-*h*) degrees of freedom (*p* is the number of instruments and *h* is the number of regressors on the right hand side of the equation). The test results are presented in Table 2. In no cases can we reject the null of validity at a 95% significance level. To ensure robustness of our models also against possible existence of autocorrelation, we carried out Ljung-Box tests for autocorrelation (Ljung and Box, 1979). The Ljung-Box Q-statistics for autocorrelation of first and second order are also presented in Table 2. Hence, we consider 3SLS superior to SURE, and we shall in the following focus on the results obtained using the former estimation technique.

[Table 1 and 2 about here]

We find very little support for externalities stemming from upstream output *growth*. This becomes even clearer when undertaking a Wald test where we restrict all the $\beta_{\Delta q}$ parameters across all the six services sectors jointly to be zero. We cannot reject the null hypothesis of no externalities due to output growth, in any of the two models.

Next, we turn to possible externalities arising from upstream activity *level*. Here, evidence on positive inter-industry externalities was found in four out of six cases. But there is no sign of spillovers from ocean hull (traditional) insurance to the transport sector. A joint Wald test where we restrict all upstream activity level parameters to zero, allows us to reject the null at a 97.5% significance level. A joint test for equality across sectors can also be rejected, but now at a 95% level.

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[6] Note that the "externality parameters", $\beta_{\Delta q}$ and β_q, are represented by their variables' names in Table 3, e.g. $\Delta LOAN_t$ represents the parameter $\beta_{\Delta q}$ in the banking services sector, whereas $LOAN_{t-1}$ represent β_q in the banking services sector.

The results are rather striking, as they suggest that to the extent that there are inter-industry externalities within the Norwegian maritime transport & service sector that impact positively on transport TFP growth, they seem to stem from vertically linked sectors' activity levels, not from these sectors' activity growth. The relative importance of the output growth parameters is almost negligible, whereas the output level parameters are generally significant. We have also estimated a model where we only include upstream output level variables. The results are presented in Table 1, columns 5 and 6. The model behaves well in terms of statistical robustness, validity of the instruments is accepted and no autocorrelation is traced (see Table 2). We now find a significant positive relationship between productivity growth in ocean transport and upstream activity level in five out of six services sectors. It is still not significant for ocean hull (traditional) insurance services, but the sign has changed from negative to positive. Imposing the joint tests here shows the same pattern as for the previous models, and strengthens the results.

The two trend parameters behave as anticipated. The GNP growth has in general a positive influence on productivity growth (positive in 16 out of 18 cases, and always positive when significant; 10 out of 18 cases). The time trend is significant in 14 out of 18 cases, indicating that it captures important trend information that otherwise would have been forced into the error term.

It might be objected, however, that if activity level can be thought of as a proxy for industrial knowledge base, total factor productivity growth in an industry may indeed rely not only on the knowledge base of other industries, but also on own knowledge base. Hence, to check the robustness of our results, own activity level was included as an independent variable. We found that own activity level had a significant, positive impact on total factor productivity growth, but its inclusion hardly affected the estimated impact of the other independent variables.

So far we have established the existence of inter-industry externalities arising from upstream industries activity levels. In order to identify the importance of cumulative causation, i.e. the extent to which there is self-reinforcing maritime agglomeration, we need to investigate the significance of vertical demand linkages. This is what we turn to next.

4.2 Self-reinforcing agglomeration

To identify the extent to which agglomeration is self-reinforcing, we first want to test for the impact of downstream activity on upstream activity. The results from correlation of sales models are shown in Table 3. Q denotes gross value of production in ocean transport, GNP the gross national product of Norway. As before, the left hand side variable is the proxy used to represent activity level in each service sector. To reduce the endogeneity problem embedded in this model, we use 3SLS to estimate the model, the instruments being the same as in the externality model in 4.1. We find that ocean transport has a significant, positive impact on the activity levels of three local upstream industries: Banking services, P&I insurance, and Maritime consultants. A joint test where all Q parameters are jointly restricted to zero, confirms the results: the null is clearly rejected. We now impose a joint *Wald* test of equality across industries with respect to the Q parameters. Also now the null is rejected. Hence, how the downstream industry's sales affect the upstream industry's activity level differs across the service sectors.

As anticipated, there is a positive and significant business cycle effect on sales: The GNP variable is significant and positive in all service sector equations.

Still, the validity of the 3SLS model depends on how good our instruments are. The test statistics of the *Sargan validity of instrument test* are presented in Table 4 for each equation. Not for any of the six equations in the 3SLS model, can we reject the null hypothesis of validity of the instruments at a 95% significance level. The model is also robust in terms of autocorrelation. The Ljung-Box statistics presented in Table 4 indicate no autocorrelation of first and second order. In all sectors (equations) we can reject autocorrelation at a 95% level.

[Tables 3 and 4 about here]

Table 5 provides a summary of the evidence on externalities and local sales linkages. The positive findings of both inter-industry externalities as well as significant local demand linkages in Banking, P&I insurance and Maritime consultants, suggest the existence of a self-reinforcing maritime agglomeration. This implies that the profitability of the individual firms in the maritime transport sector depends on the size of their industry. The results also indicate that for three maritime services sectors there are mutual gains from the interaction with the local maritime transport sector. Thus, we find that the productivity of Norwegian maritime transport depends on the size of local upstream sectors, the size of which, in turn, is found to be determined by the size of the local maritime transport sector.

Table 5 Self-reinforcing agglomeration

Service Sectors	Demand linkages (Correlation of sales)	Output growth Externalities	Output level Externalities	Self-reinforcing Agglomeration
Banking	+	0	+	Yes
Certification	0	0	+	No
Trad. Insurance	0	0	0	No
P&I Insurance	+	0	+	Yes
Maritime Cons.	+	0	+	Yes
Broker	0	0	+	No

5. FINAL REMARKS

Through an analysis of vertically linked industries, we test for externalities and whether an observed regional agglomeration is self-reinforcing. First, along the line of work on activity based externalities, we model whether output growth in one industry depends on the activity growth and activity level of localised vertically linked industries.

Then, we look at how a downstream industry's sales are related to local upstream industries' sales. Finally, we show that by comparing the results on correlation of sales, i.e. significance of demand linkages, with evidence on externalities, we are able to identify vertical linkages giving rise to self-reinforcing geographical agglomeration.

The results are promising in the sense that we are able to distinguish empirically between different sources of localised externalities. Analysing sectors that produce highly traded goods, we have also sought to reveal the importance of a local home market for upstream industries, as means of determining whether vertical linkages give rise to mutual gains from localisation and self-reinforcing agglomeration.

We analyse a number of Norwegian maritime transport and services sectors. We find that productivity growth in the Norwegian maritime transport sector is positively affected by the size, i.e. activity level, of five out of six important maritime upstream sectors. With respect to three of these five service sectors (Banking, P&I insurance and Maritime consultants), we find that the size of the home market has a significant impact on sales, and that the vertical links between these sectors and maritime transport encourage self-reinforcing agglomeration.

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APPENDIX A: THE DATA

The data set for ocean transport is from Statistics Norway, annually, covering the period 1978 to 1992. The data set is partly constructed from the National Accounts Statistics.[7] To calculate growth in output, labour, materials and capital, we used gross value of output, manhours, value of firms' consumption of goods and services (intermediates), and replacement value of durables. Measuring growth, we used real values, calculated with industry and factor specific deflators throughout. The oil price represents average spot price on brent blend, while the freight rates are based on indices from Norwegian Shipping News and Lloyds Ship Manager. We use the nominal exchange rate between USD and NOK from the IMF.

Cost shares necessary to construct the input aggregate were calculated applying the Tornquist approximation to the continuous time Divisia index. To compute the cost shares, we used nominal values of compensation of employees, intermediates, and capital services. Compensation of employees comprises salaries and wages in cash and kind, other benefits for the employees, and social expenses levied by law.

Necessary for the cost share of capital to be calculated, is an estimation of capital services. To estimate capital services, we adopt a method similar to the one suggested by Griliches and Ringstad (1971) and Klette (1999), but where rental cost of capital is not included. In our data set costs related to the renting of physical capital are included in the intermediate aggregate. Capital services are given by $P_{Ki} K_i = (\rho + \delta_i) K_i$. ρ is the real rate of return (0.07), and is chosen as the average real rate of return to physical capital in manufacturing. It approximately coincides with the real interest rate on loans for the period

[7] For the industry 'ocean transport' there are problems related to how to define the Norwegian ocean transport industry because of a complex ownership structure. Statistics Norway considers income and expenses related to the operating of a ship as income and expenses for Norway if the operator is Norwegian. Furthermore, Norwegian companies' income stemming from time chartering and bareboat chartering is also considered as Norwegian production. But subsidiaries of Norwegian companies located abroad are not considered to be adding to Norwegian production. As for real capital, a ship is defined as Norwegian if the Norwegian ownership interests are at least 50%, regardless of the flag of the vessel.

1978-1992. δ_i is the industry and year specific depreciation rate. K denotes units of capital, capital being measured by fire insurance or replacement value.

The maritime industries and industry abbreviations are tabulated below:

Abbreviation	**Industry and variable measuring economic activity**
LOAN	Shipping financing; all loans to shipping firms
CLASS	Classification companies' turnover
INSUR	Ocean hull insurance premium pay
P&I	Protection & Indemnity insurance measured in number of tonnes insured (inter period transfers of P&I insurance premiums depending on actual insurance payments due to damage, make premium not a valid measure in this sector)
CONSULT	Maritime consultants' turnover
BROKER	Shipbrokers' turnover
TFP	Growth in total factor productivity in Ocean transport
Q	Output in Ocean transport
GNP	Norwegian gross national product
T	Linear time trend

Table 1 TFP models (TFP in ocean transport as right hand side variables)

	Output Growth & Knowledge Capital				*Knowledge Capital Only*	
	SURE		**3SLS**		**3SLS**	
Variable	Coefficient	St. Error	Coefficient	St. Error	Coefficient	St. Error
Δ *LOAN*	0.030^{*}	(0.012)	-0.026	(0.022)		
LOAN	0.003^{*}	(0.001)	0.006^{*}	(0.002)	0.004^{**}	(0.002)
Δ *GNP*	0.348^{***}	(0.210)	-0.649	(0.570)	-0.022	(0.448)
T	$-2.9E-05^{*}$	(7.1E-06)	$-3.5E-05^{**}$	(-1.4E-05)	$-2.8E-05^{**}$	(1.1E-05)
Δ *CLASS*	0.025	(0.027)	0.009	(0.063)		
CLASS	0.098^{**}	(0.048)	0.093	(0.069)	0.081^{**}	(0.036)
Δ *GNP*	0.375	(0.278)	0.393	(0.340)	0.435^{***}	(0.253)
T	-2.5E-05	(1.0E-05)	$-2.3E-05^{***}$	(1.5E-05)	$-2.1E-05^{**}$	(7.6E-06)
Δ *INSUR*	-0.018	(0.025)	-0.032	(0.035)		
INSUR	-0.009	(0.019)	0.018	(0.038)	0.013	(0.024)
Δ *GNP*	0.753^{**}	(0.312)	0.576^{***}	(0.367)	0.683^{**}	(0.340)
T	-5.6E-07	(1.2E-05)	-1.5E-05	(2.1E-05)	-1.3E-05	(1.5E-05)
Δ *P&I*	0.029	(0.023)	-0.242	(0.304)		
P&I	0.402^{*}	(0.127)	-0.226	(0.390)	0.341^{*}	(0.132)
Δ *GNP*	0.427^{**}	(0.210)	1.007^{***}	(0.580)	0.485^{**}	(0.227)
T	-2.4E-05	(6.5E-06)	1.0E-05	(1.8E-05)	$-2.1E-05^{*}$	(6.7E-06)
Δ *CONSULT*	-0.003	(0.005)	-0.016^{***}	(0.008)		
CONSULT	0.074^{*}	(0.026)	0.073^{**}	(0.033)	0.075^{*}	(0.025)
Δ *GNP*	0.504^{*}	(0.194)	0.478^{**}	(0.208)	0.505^{*}	(0.195)
T	$-9.3E-06^{*}$	(3.4E-06)	$-7.7E-06^{***}$	(4.0E-06)	$-9.76E-06^{*}$	(3.4E-06)
Δ *BROKER*	0.006	(0.004)	-0.002	(0.008)		
BROKER	0.018^{**}	(0.008)	0.015	(0.013)	0.016^{***}	(0.010)
Δ *GNP*	0.401^{***}	(0.256)	0.437	(0.380)	0.405	(0.327)
T	$-9.4E-06^{**}$	(4.1E-06)	-7.7E-06	(5.5E-06)	$-8.3E-06^{***}$	(4.8E-06)
***Wald* tests**						
$H_0^{\text{"no output growth externalities"}}$	9.096	*(d.f.=6)*	11.886^{***}	*(d.f.=6)*		
$H_0^{\text{"equality across service sectors: output growth"}}$	8.929	*(d.f.=5)*	4.757	*(d.f.=5)*		
$H_0^{\text{"no knowledge stock externalities"}}$	17.434^{*}	*(d.f.=6)*	$112,88^{*}$	*(d.f.=6)*	9.871	*(d.f.=6)*
$H_0^{\text{"equality across service sectors: Knowledge stock"}}$	15.861^{*}	*(d.f.=5)*	56.033^{*}	*(d.f.=5)*	9.870^{***}	*(d.f.=5)*

*Significance level 97.5%, ** significance level 95%, ***significance level 90%

$H_0^{\text{"no output growth externalities"}}$: *Δ LOAN= Δ CLASS= Δ INSUR= Δ P&I= Δ CONSULT= Δ BROKER=0*

$H_0^{\text{"equality across service sectors: output growth"}}$: *Δ LOAN= Δ CLASS= Δ INSUR= Δ P&I= Δ CONSULT= Δ BROKER*

$H_0^{\text{"no knowledge stock externalities"}}$:*LOAN=CLASS=INSUR=P&I=CONSULT=BROKER=0*

$H_0^{\text{"equality across service sectors: knowledge externalities"}}$: *LOAN=CLASS=INSUR=P&I=CONSULT=BROKER*

Table 2 Validity and robustness tests TFP models

	Output growth &		*Knowledge Capital*		*Knowledge Capital* Only	
	SURE		**3SLS**		**3SLS**	
Ljung-Box autocorrelation tests (†)						
	1. order	*2. order*	*1. order*	*2. order*	*1. order*	*2. order*
Bank services (LOAN)	0.49*	0.62*	0.02*	0.03*	0.001*	0.15*
Certification services (CLASS)	0.79*	0.81*	0.82*	0.84*	0.88*	0.95*
Insurance services - Traditional (INSUR)	1.23*	1.68*	0.98*	0.99*	0.75*	1.25*
Insurance services - P&I (P&I)	1.64*	1.64*	0.07*	0.07*	1.15*	1.15*
Maritime consultant services (CONSULT)	0.52*	0.52*	0.001*	0.22*	0.74*	0.74*
Brooker services (BROKER)	1.27*	1.27*	1.00*	1.02*	1.04*	1.09*
SARGAN validity of instruments test (§)						
			Test Statistics	*d.f.*	*Test Statistics*	*d.f.*
Bank services (LOAN)			0.771*	6	3.679*	6
Certification services (CLASS)			5.527*	6	5.758*	6
Insurance services - Traditional (INSUR)			6.790*	6	7.260*	6
Insurance services - P&I (P&I)			4.262*	6	5.600*	6
Maritime consultant services (CONSULT)			3.901*	6	5.232*	6
Brooker services (BROKER)			4.983*	6	4.879*	6

(†) The null hypothesis is no autocorrelation of first and second order; */Significant (H_0 can not be rejected) at a 95% level

(§) The null hypothesis is that the instruments used are valid; */Significant (H_0 can not be rejected) at a 95% level

Table 3 Correlation models (sales/activity level in services industries as right hand side variables)

	SURE		***3SLS***	
Variable	*Coefficient*	*St. Error*	*Coefficient*	*St. Error*
Banking services equation (LOAN)				
Q	952.91*	(317.8)	1013.7*	(395.35)
GNP	17.915***	(9.438)	16.535***	(10.851)
CONSTANT	-2.19E+07*	(5.67E+06)	-22478000*	(6055000)
Certification services equation (CLASS)				
Q	9.410***	(5.746)	-0.162	(8.066)
GNP	0.654*	(0.171)	0.871*	(0.221)
CONSTANT	-2.72E+05*	(1.02E+05)	-186000***	(123000)
Insurance services equ. - traditional (INSUR)				
Q	-1.621	(31.890)	-61.017	(45.969)
GNP	-0.272	(0.947)	1.077	(1.262)
CONSTANT	1.50E+06*	(5.69E+05)	2037000*	(704000)
Insurance services equation (P&I)				
Q	1.980*	(0.441)	2.674*	(0.613)
GNP	0.228*	(0.010)	0.213*	(0.014)
CONSTANT	-95096*	(7875)	-0.1E+06*	(9380)
Maritime consultant services equ. (CONSULT)				
Q	10.761*	(3.969)	11.744**	(4.945)
GNP	0.876*	(0.118)	0.853*	(0.136)
CONSTANT	-7.65E+05*	(70770)	-773560*	(75720)
Broker services equation (BROKER)				
Q	57.526**	(24.210)	20.853	(33.342)
GNP	3.347*	(0.719)	4.180*	(0.915)
CONSTANT	-3.21E+06*	(4.32E+05)	-2884100	(510600)
***Wald* tests**				
"*Equality across industries test*"	79.603*	(*d.f.*=5)	51.430*	(*d.f.*=5)
"Q_i *jointly=0*"	321.93*	(*d.f.=6*)	207.56*	(*d.f.=6*)

*Significance level 97.5%, ** significance level 95%, ***significance level 90%

H_0: *(Equality across industries test):* $Q_{LOAN\text{-}EQUATION} = Q_{CLASS\text{-}EQUATION} = \Delta\, Q_{INSUR\text{-}EQUATION} = \Delta\, Q_{P\&I\text{-}EQUATION} = \Delta\, Q_{CONSULT\text{-}EQUATION} = Q_{BROKER\text{-}EQUATION}$

H_0: *(Q_i jointly=0):* $Q_{LOAN\text{-}EQUATION} = Q_{CLASS\text{-}EQUATION} = \Delta\, Q_{INSUR\text{-}EQUATION} = \Delta\, Q_{P\&I\text{-}EQUATION} = \Delta\, Q_{CONSULT\text{-}EQUATION} = Q_{BROKER\text{-}EQUATION} = 0$

Table 4 Validity and robustness tests "correlation models"

	SURE		**3SLS**	
Ljung-Box autocorrelation tests (†)				
	1. order	*2. order*	*1. order*	*2. order*
Bank services (LOAN)	0.16*	4.37*	0.16*	4.63*
Certification services (CLASS)	1.03*	1.24*	2.00*	2.05*
Insurance services – Traditional (INSUR)	3.92*	4.10*	2.41*	2.44*
Insurance services - P&I (P&I)	0.05*	0.22*	0.19*	0.76*
Maritime consultant services (CONSULT)	0.03*	1.31*	0.01*	1.44*
Broker services (BROKER)	2.53*	2.59*	1.43*	1.46*

SARGAN validity of instruments test (§)

	Test Statistics	*d.f.*
Bank services (LOAN)	8.580*	5
Certification services (CLASS)	0.815*	5
Insurance services – Traditional (INSUR)	0.351*	5
Insurance services - P&I (P&I)	0.488*	5
Maritime consultant services (CONSULT)	5.717*	5
Broker services (BROKER)	1.898*	5

(†) The null hypothesis is no autocorrelation of first and second order; */Significant (H_0 can not be rejected) at a 95% level
(§) The null hypothesis is that the instruments used are valid; */Significant (H_0 can not be rejected) at a 95% level