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Transport investment in railways to generate knowledge transfer from interfirm worker mobility

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Abstract
An analysis using extensive Finnish microdata reveals new insights into economic returns on transport investments. Cost-benefit analysis is combined with returns to new intangible and human capital from interfirm worker mobility. Halving travel time to one hour in the Helsinki-Turku railway corridor increases commuting by 40% and yields annual returns of 30 million 2015€ in time savings and travel costs and 40-50 million € from new intangible and human capital. Two-thirds of gains are from new intangible capital, and one-third is from new human capital. These are largely explained by new jobs in the Helsinki metropolitan area.

Keywords
transport, railway, labor market, intangible capital, growth accounting

JEL classification: H40, O47, O33, O32, J30, J21

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1 Introduction

This paper utilizes unique linked employer-employee data to analyze interfirm worker mobility and growth spurred by improved transport connections. The focus of this paper is on the planned construction of a one-hour train connection between Turku and Helsinki, which are 150 km apart, where the coastal railway is 196 km, and the travel time is twice as long. The costs and benefits of a better railway connection can be classified as i) regional and national economic development and labor market integration, ii) net costs of the construction and operation including those accruing to other transport, iii) time savings for fast train users, and iv) improved quality of services and environmental impact. Conventional cost-best analysis (CBA) focuses on savings in travel time without separately accounting for work-related travel and spillovers from better allocation of the workforce. Earlier studies, such as those reported by Vickerman *et al.* [1], assume that most of the benefits from better railway connections are from non-work travel. Vickerman [2] and Bröcker [3] find modest economic growth effects from faster train connections, which typically comprise less than 1% of the GDP. Regional growth contribution can be 3-5%, depending on the degree of development but at the cost of periphery areas (see also Carballo-Cruz [4]).

The IASON[1] project applied computable general equilibrium CGE models (CGEurope) with modest spatial distribution effects. Finally, Thiry *et al.* [5] found that priority Trans European Networks would add only 0.25% to the European Union GDP over 25 years. The reason for this is a vast increase in low-cost air travel that is substituted for the use of railways. With imperfect competition and scale, economies the lower deadweight losses may yield 20-80% higher growth effects (Renes, Schade et al. 2004; Graham, Gibbons et al. 2009).

The population in the Helsinki-Turku railway corridor is 1.9 million, covering 35% of the total population in Finland. The new faster railway planned to be located between Turku and Helsinki, with an approximately 40 km shorter distance and two tracks instead of the one existing track, reduces travel time from 1 hour 57 minutes to one hour. The one-track connection has speed limits and bottlenecks because of which existing fast trains (trains at a speed of 250 km or below) are not in continuous use. Building up two-track rails and therefore fully using the existing fast pendolino trains would also make trains competitive to the 169 km motorway between Helsinki and Turku.

The shortening of the railway distance by 40 km and the halving of travel time is achieved with the current fast trains, but a traditional cost-benefit analysis shows benefits that do

[1] Integrated Appraisal of Spatial economic and Network effects of transport investments and policies

not cover the initial estimates of the required 1.5 billion € investment in infrastructure by the Finnish transport agency. The standard assumptions may partly explain this, as Prud'homme and Lee [6] suggest that the CBA should sufficiently cover periods of 40 years and longer and apply lower discount rates.

Graham *et al.* [7] find instead important work-related travel benefits from achieving a better match between labor demand and supply. Less densely populated areas can satisfy their labor supply shortages, and metropolitan areas have excess demand for (skilled) labor. Graham et al. find that a 10% increase in accessibility improves productivity by 2-2.5% in business services, which are concentrated in the biggest cities. Specifically, the labor mobility of tertiary level-educated people, experts with special qualifications, and research and development (R&D) and information and communication technology (ICT) workers has been shown to improve the growth and innovativeness of firms [8; 9; 10; 11]. Stoyanov and Zubanov [12] find high-productivity firms creating spillovers through outbound labor mobility. BVH [13] argues that the implementation of a new high-speed rail (HSR) is a natural experiment that isolates labor market agglomeration gains separately to produce market benefits. High-speed trains reduce commuting times between regions and thereby effectively increase the size of local labor markets without directly affecting the size of product markets. They find that between one-third and half of overall agglomeration externalities are rooted in increasing returns to scale in local labor markets.

Fröidh [14] shows that better accessibility improves productivity, especially in business services. An important part of positive creative destructions occurs through interfirm labor mobility such that high-productivity firms increase their market share. Negative creation destruction is the opposite, with layout employees being forced into re-employment in low-productivity firms. In Piekkola and Åkerholm [15], the positive creative destruction was more important, and labor productivity growth improved through market restructuring in the 2007-2012 period. This study gives additional insights on how to measure national growth impacts from interfirm worker mobility creating new intangible and human capital and how this is related to creative destruction. Intangible capital is important, as its omission offers a biased view of economic performance [16; 17]. Piekkola [18] shows that in the EU area, intangible investments contributed approximately 1.5% or 1.7% in Northern Europe to annual labor productivity growth in 2008-2011. These figures are substantial, given that overall labor productivity growth was of the same magnitude. Moreover, half of the GDP contribution was explained by market restructuring, where intangible capital-intensive firms increased their market shares. Piekkola [19] finds new forms of intangible capital to be behind productivity improvement in recent years in Finland.

Intangible capital (IC) work relates to management, marketing, R&D and ICT. Human capital (HC) is created by all other workers. Interfirm worker mobility can also create spillovers. This can relate to the clustering of firms that are among the most productive in their industry. Bagger *et al.* [20] find that in Finland, innovators tend to be more clustered than in Denmark such that spillovers tend to also have a spatial dimension. In Finland, 80% of the IC-producing business service jobs are located in the 13 biggest cities, including Helsinki and Turku [21].

Section 2 first applies CBA to evaluate producer and consumer surpluses from the one-hour train and the implied increase in commuting by region. Commuting is then linked to work-related travel. Section 3 shows estimates of the level of new IC and HC, and Section 4 applies a production function estimation to obtain performance-based estimates. Section 5 analyzes in a growth-accounting framework the growth effects of new IC and HC created by interfirm worker mobility due to the one-hour train. Section 6 summarizes the major findings and concludes.

2 Cost-benefit analysis and changes in commuting and worker mobility

The Helsinki region (Helsinki, Espoo, Kauniainen and Vantaa) is the biggest labor market area in Finland, with 526 000 jobs in 2013. One-fifth of workers, 100 000, commute to the Helsinki region, and 70% of these workers are from nearby municipalities.[2] The Turku region, including Naantali and Raisio, is the third largest regional labor market after the Helsinki metropolitan area and Tampere regions with 123 000 jobs. Twenty-seven percent of 77000 workers in Turku city commute to Turku city, and 39% of these workers are from the nearby cities of Naantali and Raisio.

The worker mobility figures are taken from employee data from the Confederation of Finnish Employers (EK) and cover one-third of the private sector workers in Finland. The employee data cover 8.6 million man-years and contain 5,597 companies with 44,455 firm-year observations for the years 1997-2014. The data include a rich set of variables that covers compensation, education, and profession. White-collar employees are compensated on the basis of salaries, whereas blue-color workers, who comprise half of all employed workers, receive an hourly wage. The employee data in the sample cover, on average, half a million employees annually (but 187 000 in 2014 with incomplete data). This mobility has important economic significance, as EK member firms produce 67% of the Finnish private sector GDP and most of the exports. The organizational capital (OC) (management and marketing), R&D and ICT occupations are assumed to create IC.[3]

With regard to commuting, we apply the simple framework of Eliasson and Börjesson [22] based on the CBA of Swedish Transport Administration strategic planning and appraisal BVH [13]. The line segment in the analyzed time period S (e.g., rush hour or weekday but not separate here) between two stations has a length of L, and the total number of trains of train type i (maximum speed up to 250 km/h here) is n_i with travel time t_i in both directions (the number of trains in each direction is hence $n_i / 2$). The trains of type i have

[2] The 11 municipalities are Hyvinkää, Järvenpää, Kerava, Kirkkonummi, Lohja, Nurmijärvi and Tuusula, with a size of 16500-20500 employees, and the smaller municipalities include Vihti, Inkoo, Sipoo and Siuntio. Long-distance commuters who live in the planned Helsinki-Turku railway corridor or coastal railway corridor and commute to the Helsinki region are mainly from Kirkkonummi (10700), Vihti (6200), Lohja (5200) and Turku (2100).

[3] The 16% share of personnel in organizational, R&D and ICT work in 2003 is comparable to the average share of 18% in the six European countries with LEED data in the EU's 7th framework program project INNODRIVE 2009-2011. Management (3.4%) and marketing (5.4%) are the main categories for organizational work. The share of R&D workers is similar at 7.1% (or 4.2% if those mainly service-sector workers with tertiary technical education are excluded). The total share of ICT workers is approximately 2.1%. An increasing share of intangible-capital-related workers is also explained by the falling share of production workers; this proportion had fallen from approximately 61% in 1997 to 39% by 2012.

travel time t_i, and the average waiting time is 15 minutes per n_i /2 trains in time period S.[4] The generalized travel cost is $c_i = p_i - \phi_i + \alpha t_i \;\; + \beta(15/S)/(n_i/2)$, where p_i is fare price, ϕ_i is savings in the social cost of CO_2, and α and β are monetary values of travel time and waiting time, respectively. Travel demand between the stations follows a constant elasticity demand $D^1 = (c_i^1 / c_i^0)^{\varepsilon}$ for period 1 so that the consumer surplus (CS) of a change in generalized costs from c_i^0 to c_i^1 is::

$$CS = \sum_i \int_{c_i^0}^{c_i^1} D(c)dc \approx \sum_i 1/2\left[D^0 + D^1\right]\left(c_i^1 - c_i^0\right). \tag{1}$$

The producer surplus (PS) is equal to fare revenues minus operations costs. Operation costs increase linearly with the train operating time $n_i t_i$, passenger total time $D_i t_i$ and passenger distance $D_i L$. The producer surplus of a change of travel times and the number of trains from period 0 to 1 is

$$\begin{aligned} PS = &\sum_i \left[D^1 - D^0\right]p_i + \gamma_1\left(n_i^0 t_i^0 - n_i^1 t_i^1\right) + \gamma_2\left(D^0 t_i^0 - D^1 t_i^1\right) \\ &+ \gamma_3\left(D^0 - D^1\right)L \end{aligned} \tag{2}$$

where $\gamma_1, \gamma_2, \gamma_3$ are parameters. Total social benefits are CS + PS. The travel time t_i is a function of the minimal travel time, infrastructure capacity and the number of trains. It depends on the capacity, which can be modeled in different ways. We use a capacity relationship used by the Swedish Transport Administration for strategic planning and appraisal, which is similar in structure to capacity relationships used in other countries. The capacity used C is the fraction of the time period S that the line segment is occupied by trains. Each line segment divides into homogenous track segments k. C is calculated for each homogenous track segment k on the line segment picking up the representative figure (highest C) as capacity used for the whole line segment. For single tracks, this yields

$$C = \sum_i \left\lfloor \max_k \left(n_i T_{ik} + \rho n_i M_i\right) / S \right\rfloor, \tag{3}$$

Where M_i is additional waiting time for trains of type *i* to meet, T_{ik} is the minimal travel time of track segment *k* for train type *i* (including time in stops) and ρ is the probability

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[4] Swedish guidelines apply to a high-frequency train with a waiting time of $\beta 2S/n_i$, where $2S/n_i$ is headway and β is waiting time.

that two trains meet. The used capacity is thus the fraction of the time period *S,* during which a train occupies the segment, including the waiting time for meetings. The scheduled travel time for trains of type *i* on the line segment, t_i, is then computed from the minimal travel time of the line segment, T_{ik}, track length *L* in kilometers and *C:*

$$t_i = T_i + \max\left[(0.2 * C - 0.06)L, 0\right], \qquad (4)$$

where *L* is given in kilometers (195 km in the old and 155 km in the new infrastructure) and T_i is given in minutes. For two tracks, there is no capacity constraint $t_i = T_i$. The model includes 4 minutes additional waiting time at each stop. The parameter values used in Swedish guidelines and updated for values of vehicle time and waiting time for guidelines in Finnish Transport Agency in-vehicle time are as follows:

Table 1. Parameters of the CBA framework

Parameters	Costs
Value of in-vehicle time a	10 €/hour
Value of waiting time b	10 €/hour
γ_1	9.9 €/hour
γ_2	0.03/min/train
γ_3	0.01/min/train
Demand elasticity	-0.9

Assumed a demand elasticity of -0.9 is more than in Swedish guidelines (-0.7) but less than that estimated for intercity travel by rail in Small and Winston [23], which is -1.2 for fare price and -1.58 for travel time. The effect of the skill level of travelers is ambiguous and not taken into account: those who are highly educated have more long-distance travel, but according to Fröidh [14 p. 359], travelers on leisure trips and low-income earners generally have a stronger preference for lower fares. In the old one-track infrastructure, the minimum travel time of one of the four tracks between stations is T_{k1}=34.7 minutes, and in the new infrastructure with two track line segments and 1 stop, it is T_{k2}=30 minutes. Assume that there is n_1=1, n_2=1.5 train/hour passing between the two stations (0.5 or 0.75 trains/hour in each direction), carrying 1000 passengers/hour. The probability that a train meets another train at any given track segment is ρ_1=0.45 in the old infrastructure, and in the new infrastructure with two tracks ρ_2=0.[5] With 5 minutes of waiting time M, the

5 For the old infrastructure, $\rho_1 = n(T/60)/T_k = 1 \cdot (107/69)/4$.

capacity used is C_1=0.48 from (3), which gives the total timetable travel time t_1=113, t_2=60 minutes.[6]

Carbon dioxide emissions per passenger are close to zero with electric trains and 325 g/km for cars. The savings in social cost of CO_2 per passenger is 1.8 € in using the train instead of a car at a 169-km distance and at a price of $36/€33 per ton of CO_2 in 2015.[7] It is assumed that the new price is subsidized by 1.5€.[8] Consumer and producer surpluses and changes in demand from (1) and (2) are given in table 2.

Table 2. Consumer and producer surpluses and change in demand in Helsinki Pasila - Turku Kupittaa

Infrastructure	Travel time	Price p	$p+\alpha*t$	SC CO_2+ Congestion ϕ	$\beta*$ 15/S(n/2)	Cost c	Demand	Change	CS+PS million€
Old railway	117	25	44.46	0	5.00	49.5	725136	295000 (41%)	13.6+
New railway	60	22	32.00	-1.5	3.33	33.8	1020609		6.0

Applying a similar framework to other main connections in Helsinki-Turku corridor gives the following estimates of consumer and producer surpluses[9]:

[6] For the old infrastructure, $C=\max_k\left[n\cdot T_k+\rho\cdot n\cdot M\right]/T=\left[1\cdot 34.7+0.58\cdot 1\cdot 5\right]/60$.

[7] See EPA United States Environment Protection Agency (at 3% discount rate) http://www3.epa.gov/climatechange/EPAactivities/economics/scc.html and https://en.wikipedia.org/wiki/Environmental_design_in_rail_transportation.

[8] Equivalently, 5 minutes less time spent in the congested Helsinki-Turku motorway by 1 million car users would imply a similar 1.5€ savings.

[9] Figures should be considered tentative. Commuting in Turku-Salo is set to one-half of all commuters in the Turku-Helsinki corridor. Calculations for Lohja-Helsinki assumes 100 000 yearly travel commuters by car transferred to using an additional train type to build a railway connection from Lohja to Helsinki.

Table 3. One-hour train and increase in consumer and producer surpluses

Cost-benefit analysis CBA	Increase in commuting	Consumer surplus	Producer surplus
Helsinki-Turku	295 000 (41%)	13.6	6
Salo-Helsinki	85 000 (45%)	3.1	1.4
Salo-Turku	122 000 (34%)	1.8	0.4
Lohja-Helsinki	27 000 (27%)	0.9	0.2
All	529 000 (38%)	19.4	8.0

Salo is 58 km east of Turku, and Lohja is 61 km west of Helsinki.

The total increase in commuters of 459 000 exceeds the 340 000 estimated by Laakso *et al.* [24], the primary reason for which is the expected increase in commuters from Salo. The new train connection improves consumer and producer surpluses by 27.4 million€, and 2/3 of this amount results from an increase in consumer surplus. The 41% increase in the number of passengers between Helsinki and Turku is used as an average measure of an increase in commuting. The regional division of commuting applies an exponential decay function, which is a commonly used accessibility measure. The growth in commuting $\Delta H_{i,j}$ from region i to region j based on the attractiveness of the region is given by

$$\Delta H_{i,j} = B\left(A_i e^{-\lambda T_{NEWi,j}} - H_{T_0 i,j}\right), \tag{5}$$

where $H_{T_0 i,j}$ is the original number of commuters to region j=Helsinki or Turku city region from region i, $A_i e^{-\lambda T_{NEWi,j}}$ is the accessibility of region i given attractiveness factor A_i (log of employment in region i in Johansson *et al.* [25]) and B is chosen to scale the overall growth in number of commuters to that given by CBA (approximately 40%). In contrast to Johansson *et al.* [25], we abstract from other explanatory factors, such as wage differences between regions and pecuniary commuting costs. Semi-elastic decay parameter λ in accessibility measure $e^{-\lambda T}$ is from a log estimation of commuting per employment in the region in 2013 with employment as the implicit attractiveness factor A_i and time distance measured in minutes. This yields decay parameter λ =2.2 in approximately 25 larger (Nuts IV) regional areas with commuting to the Helsinki region and λ =1.6 with commuting to the Turku region. [10]

[10] In log form, regressand is $\log(C_{ij}/L_i)$ and regressor is λT_i where L_i is employment and C_{ij} is commuting from region i to j=Helsinki region and Turku city. The decay parameter λ reported in the text is not sensitive to using an employment-weighted estimation (in contrast to using more disaggregated municipal-level data).

However, the model works poorly in the 117-minute distance between Helsinki and Turku, yielding strong effects on commuting from halving the travel time with the one-hour train. Johansson *et al.* [25] find that the large size of the destination region is an important factor for commuting in the region. Symmetrically, this implies that the attractiveness factor is lower when the origin region is larger in size. Hence, the attractiveness factor is not equal to employment but is less. The attractiveness A_i used is not actual employment in the region of origin, whereas predicted employment would apply, given the commuting and estimated decay parameter λ . The predicted employment better shows the potential workers interested in commuting. For example, in Helsinki, potential employment to commute to Turku is 5400 employees, not all of the 296 000 employees in the city. Another adjustment is the scaling, B . Growth in commuting is halved (B =0.5) to give the same overall growth in commuting by approximately 40%, as implied by CBA. Table 4 shows the results.

Table 4. Changes in travel time and commuting with one-hour train in Helsinki-Turku.

Commuting to Helsinki region	Employees in region 2013	Commuting share (%) of employment	Travel time change (%)	Commu-ting	New commu-ters	Commu-ting increase %
Vihti	13 414	45.7	-18	6 124	919	15
Lohja	20 535	25.6	-43	5 261	2 334	44
Other Uusimaa	10 331	9.9	-16	886	133	15
Salo	24 224	4.7	-46	905	1 092	121
Turku	77 215	2.8	-41	2 163	1 288	60
Turku region no railway	18 753	2.7	-3	109	6	6
Turku region railway	41 585	1.9	-23	414	308	74
Coastal railway area	31 997	39.5				
All	238 054	39.5	-28	15 862	6 081	38
Commuting to Turku region						
Helsinki region	525 659	0.2	-38	1 291	1 304	101
Salo	24 224	7.1	-26	1 719	153	9
Turku region no railway	41 585	42.2				
Turku region railway	18 753	72.3	-45	8 543	3 455	40
Coastal	31 997	0.6	-7	183	19	11
All	642 218	5	-33	11 736	4 931	42

The overall increase in commuting 38-42% comprises 25 000 new commuters. Approximately 17 500 new commuters are within a short distance of travel, either from Turku region municipalities to Turku city or from Lohja and Vihti to the Helsinki region. Long-distance commuting increases by 7500, and 4500 of these commuters travel to the Helsinki region. The estimated increase in commuting is in line with the report by Laakso *et al.* [24] that concentrates on long-distance work-related travel effects with 8000 new commuters. Finally, in Salo-Turku commuting, the increase implied by accessibility is a modest 9% rather than the CBA analysis of 15% (not shown). In Lohja-Helsinki commuting, the increase of 44% is more than implied by the CBA estimation of 27%, which can also be explained by the continuing trend of population growth in the area (the population has doubled in the period from 1980-2014).

A later analysis of interfirm worker mobility assumes a limited substitution of the use of cars by use of the train (except for Lohja). Note also that changes in employment are not bound by the same physical restrictions as work-related commuting because employees may also change residence. Givoni and Dobruszkes [26] show that switching from car or aircraft use has been modest given the new high-speed train connections based on research of the past 50 years around the world. The following figure first shows the growth of interfirm worker mobility between regions that create new IC and HC over the period from 1999-2013. The regions are the Helsinki-Turku railway corridor (Turku, Salo and Raasepori regions; Kirkkonummi, Lohja, Siuntio, Vihti, Karkkila, and Karjaa) and the Helsinki region (Helsinki, Espoo, Kauniainen, Vantaa).

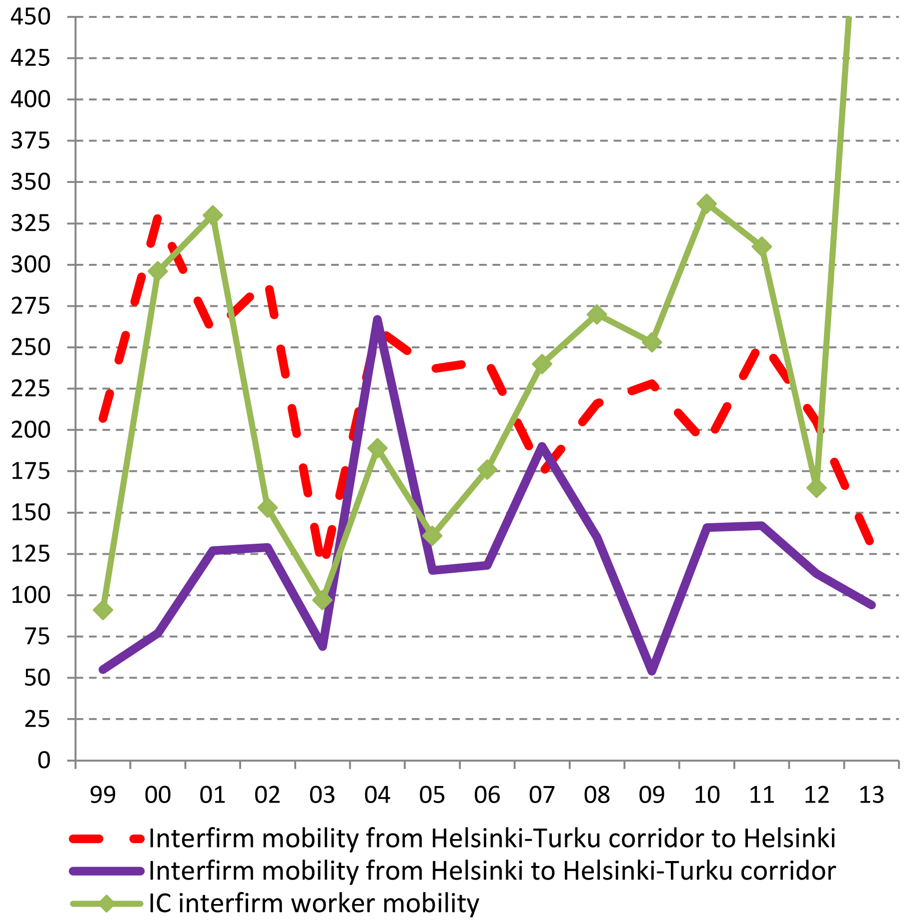

Figure 1. Interfirm worker mobility 1999-2013 around Helsinki-Turku railway corridor

It can be seen that twice as many workers switch to working from firms in the Helsinki-Turku corridor to firms in the Helsinki region than vice versa. Trends in this interfirm mobility have been negative, while interfirm mobility of IC workers in Finland has increased by 2.7% per year.[11] Job transfers in each area to the Helsinki or Turku regions are related to commuting in a cross-regional OLS estimation for the year of 2013 and controlling for accessibility. Log form OLS estimation shows that the elasticity of job transfers to commuting is 1.7 in the direction of the Helsinki region (standard error=0.65, adj. R^2=0.34) and 0.93 in the direction of Turku city (standard error=0.21, adj. R^2=0.87). Commuting increases from table 4 can now be related to interfirm worker mobility given that a 1% increase in commuting to the Helsinki region is related to 1.7% interfirm worker mobility, and the respective elasticity is close to one in commuting and interfirm mobility to Turku city. Interfirm job mobility creating new HC and IC evolves as follows.

[11] The significant factors are the ICT boom in 1999 and downsizing the facilities of Nokia (and Microsoft) in Salo in 2009 and 2012.

Table 5. Interfirm worker mobility in 2000-2013 and change (%) with one-hour train

	Location of firm in previous job			
	Helsinki-Turku corridor		Helsinki region	
Location of firm in current job		Change %		Change %
Helsinki region	318	54		
Turku city	101	8	118	94
Other Turku region no railway	48	5	28	9
Other Turku region railway	9	75	30	38
Salo region	15	30	33	8
Lohja	24	30	25	10
Vihti, Karkkila	4	20	12	5
Coastal railway region	37	5	37	0

Coastal region: Raasepori region, Kirkkonummi, Inkoo, Siuntio.

The 54% increase in worker mobility from the Helsinki-Turku corridor to the Helsinki area is the average increase in commuting to the Helsinki area from Vihti, Lohja, Other Uusimaa and Turku city, or 32% multiplied by the high job switch elasticity of commuting, which is 1.70. Interfirm worker mobility from the Helsinki region to Turku city increases by 94%. Interfirm worker mobility to Turku city from the Helsinki-Turku corridor increases by 8%, and most of this is occurs within Turku city. All inter-city job transfers in the much larger Helsinki region are instead ignored.

3 Production and new IC and HC

The LEED data link the Confederation of Finnish Industries employment data to financial data provided by Suomen Asiakastieto[12]. Only firms with sales exceeding €1.5 million (at 2000 prices) are included in the analysis. Non-consolidated firm data on profits, value added, and capital intensity (fixed assets) are used, including the financial crisis period.[13] The dataset linked with financial data is representative of manufacturing, construction and infrastructure (nace F, E) and market services (G, H, I, J, L, M, N, X) in Finland as a whole. It covers on average 67% of the valued added in the private sector in 2009-2013 (55% in 1999, 70% in 2013 and only 21% in 2014 due to incomplete data).

Intellectual capital consists of intangible capital and human capital (of the rest of workers). Intermediate and capital costs are also incurred in the production of intangible capital goods, and these goods are evaluated based on how labor costs, intermediate input and tangible capital combine into value added in business services following Görzig *et al.* [27] and Piekkola [19]. Appendix A shows the details in the construction of expenditure-based intangible capital showing how to evaluate the use of intermediate input and tangible capital in intangible investments. Intangible capital worker mobility is 10% of all job mobility, so it is also important to account for the skills of the entire workforce. Real expenditure-based investments N^z_{EXPit}, z=IC, HC are

$$P^z_{jt} N^z_{EXPit} \equiv A^z W^z_{it} \text{ for } z = IC, HC \; , \tag{6}$$

where W^z_{it} is type z=HC, IC (OC, R&D, ICT) labor costs in firm i multiplied by factor multiplier A^z, and P^z_{jt} is the deflator in industry j (at a two-digit Nace level) proxied by business services deflator P^N_{jt} for IC and by wage index deflator P^w_{jt} for HC. HC investment is simply proxied by labor costs so that $A^{HC} = 1$. All workers may hence have knowledge or firm-specific skills gained in past jobs that are transferred through worker mobility [28; 29]. Mulligan and Sala-i-Martin [30] and Jeong [31] are among the few to construct a measure of human capital based on labor income.[14] Returns to worker mobility may also relate to geographical proximity. Reliance on knowledge other than local knowledge may create less of a lock-in effect [32], and various skills not available in the local labor market may improve productivity [29]. Essletzbichler and Rigby [33] find

[12] Suomen Asiakastieto is the leading business and credit information company in Finland.
[13] The deep recession with an 8% decrease in GDP in a single year 2009 is, by one half, explained by the collapse of manufacturing of electronic equipment (mobile phones sales by Nokia) and the paper and pulp industry.
[14] In their papers, development of the factor inputs and technology is controlled by applying an index based on wage ratio to workers with no skills (uneducated or blue-collar workers).

evidence that hiring new employees from firms located in other regions might be more beneficial.

The performance-based approach uses an estimation of a production function. The approach assumes a constant return-to-scale production function and provides information on the output elasticities of capital stock R_{it}^{z}, z=IC (sum of OC, R&D and ICT), and HC that were initially obtained in the expenditure-based approach.[15] Output elasticities are estimated from production function to construct a performance multiplier. This gives an adjustment for the factor multiplier of expenditure-based approach γ_{PER}^{z} in (6). The explanatory variable is sales, including expenditure-based IC and HC investment $Y_{jt} = Sales_{jt} + \sum_{z=IC,HC} N_{jt}^{z}$. The production function is given by

$$Y_{it} = b_0 L_{it}^{b_L} \prod_{z=IC,FHC} \left(R_{it}^{z}\right)^{b_z} K_{it}^{\ b_K} M_{it}^{\ b_M}\ exp(e_{it}), \tag{7}$$

where $b_L + \sum_{z=IC,FHC} b_z + b_K + b_M = 1$, L_{it} is the total hours worked, R_{it}^{z} refers to the capital stocks of HC or IC for firm i in year t, K_{it} is fixed tangible capital, M_{it} is intermediate input and e_{it} is an error term. Using this in log yields

$$ln Y_{it} = ln b_0 + b_L\, ln L_{it} + \sum_{z=IC,HC} b_z\, ln R_{it}^{z} + b_K\, ln K_{it} + e_{it}. \tag{8}$$

The output elasticities $\hat{b}_z$ of IC and HC are equal to respective income shares under perfect competition and constant returns to scale, and thus, on average

$$\hat{b}_z \approx \frac{P_t^{z} r^{z} R_{it}^{z}}{P_{it}^{Y} Y_{it}}, \tag{9}$$

where the rental rate r^{z} equals depreciation and the external rate of return of 4% and $P_{it}^{Y} Y_{it}$ is the nominal sales. The perpetual inventory method implies that $N_{it}^{z} = \left(g^{z}(1-\delta_z) + \delta_z\right) R_{it}^{z}$, where $g^{z} = (R_{it}^{z} - R_{it-t}^{z}) / R_{jt}^{z}$ is proxied by the average growth rate of wages 2%. Solving for R_{it}^{z} and substituting in (9) gives

[15] The methodology is analogous for deriving the inverse input demand equations in application to translog production function for transport investment (see D.J. Graham, Agglomeration, productivity and transport investment. Journal of transport economics and policy (JTEP) 41 (2007) 317-343, [34] ibid.).

$$\hat{b}_z \approx \frac{P_t^z N_{it}^z}{P_{it}^Y Y_{it}} \frac{r^z}{g^z(1-\delta_z)+\delta_z} \tag{10}$$

The nominal value of a capital investment of type z=IC, HC in the production-function-based approach is given by

$$P_t^z N_{it}^z \equiv \gamma_{PER}^z P_t^z N_{EXPit}^z, \tag{11}$$

where N_{EXPit}^z is an expenditure-based intangible investment of type z from (6) and γ_{PER}^z is the performance-based multiplier. Solving equation (10) for N_{it}^z (taken as holding with equality) and substituting in (11) yields (12), which gives performance-based estimates in (11)

$$\gamma_{PER}^z = \hat{b}_z \frac{P_{it}^Y Y_{it}}{P_t^z N_{EXPit}^z} \frac{g^z(1-\delta_z)+\delta_z}{r^{IC}}. \tag{12}$$

Because various types of IC are correlated, they are studied as a whole using production function to calculate performance-based IC. In the calculations, new IC and HC are also separated from old IC and HC depending on the length of stay in the firms. Such a distinction is important when high-skilled workers tend to sort into high-productive firms, as found in Bagger and Lentz [34]. Considering new IC as a whole is also relevant because of the multicollinearity between organizational, ICT and R&D capital. Maliranta *et al.* [9] find that hiring employees from other firms' non-R&D activities (e.g., management tasks) rather than R&D activities increased productivity or profitability of R&D in the current job. Workers learn new skills in each job relationship that they maintain, even if they are deprived of the capital in former jobs. IC workers are also assumed to transform knowledge of IC from their previous work engagements. This is assumed to depend on the employee's share of the intangible capital workers in the former job. The real stock of new type z capital $R_{it}^{NEW,IC}$ for a firm *i* and the real stock of old type z capital $R_{it}^{OLD,z}$ and with z= HC, OC, R&D, ICT using expenditure-based measure are

$$\begin{aligned} R_{it}^{NEW,z} &= N_{it}^{NEW,z} + (1-\delta_z)\left(R_{it-1}^{NEW,z} + R_{ik,k\neq i,t-1}^{IC}\right), \\ \text{where } N_{it}^{NEW,z} &= \sum\nolimits_{l} (1-\kappa)^{m_{lt}} N_{ilt}^z \\ R_{ik,k\neq i,t-1}^{IC} &= \sum\nolimits_{ik,z\in IC} \alpha_{ICik} R_{k,k\neq i,t-1}^{IC} \end{aligned}, \tag{13}$$

$$R_{it}^{OLD,z} = N_{it}^{z} + (1-\delta_z)R_{it-1}^{OLD,z},$$
$$\text{where } N_{it}^{z} = \sum\nolimits_l (1-(1-\kappa)^{m_{lt}})N_{ilt}^{z} \qquad ,$$
$$R_i^{OLD,z}(0) = \sum\nolimits_i N_i^{IC}(0)/(\delta_z + g_z)$$

(14)

New capital stock $R_{it}^{NEW,z}$ is the sum of new investment $N_{it}^{NEW,z}$ from new workers l in year t and from the past year $R_{jt-1}^{NEW,z}$ and knowledge transfer $R_{ik,k\neq i,t-1}^{IC}$ from total intangible in previous firms k in which new workers were engaged (the latter two after depreciation δ_z). Investment of each worker transforms from new to old at a rate $(1-\kappa)^{m_{lt}}$, where m_{lt} is the length of stay of the worker l in the current firm l (years 0,1,2,3); the remaining part $(1-(1-\kappa)^{m_{lt}})$ builds old intangible capital stock. Accelerating the share of investment thus transfers to old capital stock over the years during which the new worker has been in his or her current job. The intangible capital knowledge transfer $R_{ik,k\neq i,t-1}^{IC}$ by new IC workers from previous firm engagements k (if any) depends on the total intangible capital $R_{k,k\neq i,t-1}^{IC}$ in previous firm k and on α_{ICik}, which is the ratio of workers in current firm i and previously in firm k to the total IC workforce in previous firm k. If all IC workers have left firm k to go to firm i, α_{ICik} equals 1, and hence, firm i has inherited all intangible capital from firm k. In capital accumulation, performance-based estimates are used for IC as a whole (IC as the sum of OC, R&D, and ICT).

When a firm is established, it is not only the sum of previous knowledge but also an entirely new entity so that the new and old IC and HC are not separated. Hence, the initial capital stock is all assumed to be old $R^{OLD,z}(0)$ because many firm births are unreal. The initial old IC investment $N_j^{OLD,z}(0)$ is defined as the average growth-adjusted investment over a three-year period following the first year the firm is observed in the data. $R^{OLD,z}(0)$ is calculated from $N_j^{OLD,z}(0)$ using the geometric sum formula with the depreciation rate of δ_z and the growth rate of the intellectual capital stock g_{IC}. The growth rate g_z is set at 2% for all IC and HC, which follows the sample average growth rate of real wage costs for intangible-capital-related activities.

The ageing is set at one third κ =0.33. Thus in third year of stay in the firm 30% of intellectual investment of new worker is new and 70% is old. In data new IC and HC increases relative to old one with firm age. One reason is that all capital was considered old to begin with.

The ageing is set at one third κ =0.33. Thus, in the third year of stay in the firm, 30% of the intellectual investment of a new worker is new, and 70% is old. In the data, new IC and HC increases relative to old IC and HC with firm age. One reason for this is that all capital was initially considered to be old. The average job tenure for people who transfer between jobs is 11 years for IC workers and 10 years for HC workers so that in previous jobs, the average worker contributed only 2% of his/her work to the creation of new IC or HC. The estimation for each industry i, country j and year t from (7) and separating new and old IC and HC is provided by

$$\begin{aligned} ln\, Y_{it} &= b_0 + b_L \, ln\, L_{it} + \sum_{z=IC,HC} b_{zNEW} \, ln\, R_{it}^{NEW,z} + \sum_{z=IC,HC} b_{zOLD} \, ln\, R_{it}^{OLD,z} \\ &+ b_K \, ln\, K_{it} + b_M \, ln\, M_{it} + b_x^{'} X_{it} + e_{it} \end{aligned} , \qquad (15)$$

where X_{it} is the vector of control dummy variables (years and interaction term of countries and clusters). Expenditure-based values $R_{EXPit}^{NEW,z}, R_{EXPit}^{OLD,z}$ from (6), (13), (14) are used as first-stage proxies for IC and HC capital.

4 Performance-based intangible and human capital

Next, we attempt to disentangle how the different inputs have contributed to productivity growth. The random effects, gmm method with the Wooldridge [35] modification and fixed effects models are used in the estimation of production function. Ilmakunnas and Piekkola (2014) in an Olley-Pakes instrument estimation used the hiring rate at the firm level as the proxy for productivity shocks.[16] This instrument hiring rate would be too closely related to new HC and IC. Therefore, the instrument to proxy productivity shocks is variations in hours per worker[17]. In instrument estimation, exogenous variables include various interactions of other variables with lagged hours per worker (see the footnote for table 6). Table 6 shows the estimations for Finnish firms in 1999-2014.

[16] Hiring is defined as the number of workers who were employed by firms in the final quarter of year t but were not in the same firms in the corresponding quarter in the previous year, divided by the average number of workers over the period.
[17] Basu et al. (2006) use this with scaled variation in detrended hours per worker as an additional explanatory variable.

Table 6. Random effects, instrument gmm and fixed effects estimation of production function in 1999-2014

All years	Random effects	Instrument estimation	Fixed effects
Unskilled	0.269***	0.249***	0.232***
	(31.24)	(15.8)	(23.69)
Skilled	0.0256***	0.0345***	0.0204***
	(23.19)	(12.48)	(17.85)
Old IC	-0.00112	0.0208	-0.00719***
	(0.85)	(1.14)	(5.23)
New IC Helsinki, other	0.0238***	0.164***	0.0172***
	(11.47)	(4.09)	(8.03)
New IC Tampere, Lahti corridors	0.0197***	0.0554	0.0172***
	(7.23)	(1.15)	(6.09)
New IC Turku corridor	0.0164***	0.144*	0.0121***
	(5.02)	(2.23)	(3.62)
Old HC	-0.00327*	-0.323***	-0.0107***
	(2.47)	(4.26)	(7.58)
New HC Helsinki, other	0.0124***	0.0764**	0.00879***
	(7.41)	(2.85)	(5.08)
New HC Tampere, Lahti corridors	0.0101***	0.0223	0.0101***
	(5.28)	(0.71)	(5.1)
New HC Turku corridor	0.0101***	0.0213	0.00781**
	(4.11)	(0.49)	(3.1)
Tangible capital	0.176***	0.0644***	0.109***
	(6.51)	(5.25)	(15.91)
Tangible capital lagged		0.583*	
		(2.02)	
Intermediates	0.109***	-0.00837	0.0973***
	(7.4)	(0.6)	(18.96)
Intermediates lagged		-0.34	
		(1.75)	
Observations	43610	29998	43610
R Squared (within)	0.753	0.825	0.728
Returns to scale	0.746	0.772	0.601
Kleibergen-Paap Wald P value		0.000	
Hansen J statistic P value		0.020	

All in logs. Exogenous variables are fixed capital including one-period lag, lagged intermediates, second and third power of lagged fixed capital, hours per worker and intermediates, lagged interactions of fixed capital and intermediates with lagged hours per worker including second power of each of the interacting variables. Exogenous variables also include lagged intangibles, their second and third power and their respective interactions with hours per worker. Endogenous variables are unskilled labor, skilled labor, intangible capital and intermediate input. Instruments include hours per worker up to third power, lagged unskilled and skilled worker expenditures, intangibles with one to two-period lags and two-period lagged intermediates. P values: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

On average, the returns to scale are 75-77% in instrument and random effect estimations, which we believe to be explained by the imprecise measurement of tangible capital and intermediate input in particular.[18] In instrument estimation, the Hansen J statistics P value shows that the model is overidentified at the 2% level, and the Kleibergen-Paap Wald P value shows that the model is not underidentified. The large set of explanatory variables is likely to be behind the overidentification. Random effect estimation is chosen as the preferred method. Table 6 shows that old IC has insignificant or significant negative output elasticity. The output elasticity of old HC is also negative. The output elasticity of unskilled and skilled labor (labor with a higher tertiary education) is 25-29%.

In random effect models, the largest gains accrue from new IC and HC in the Helsinki region and the rest of Finland (estimated together). In instrument estimation, output elasticities of intangible capital are even exceedingly high for Helsinki and the rest of Finland at 16% and for regions around Turku at 14%. Another important finding is that gains from IC and HC are enhanced after controlling for productivity shocks in instrument estimation. Random effects model estimates should hence not be biased upwards. These are the preferred estimates and close to fixed effects model estimates.

Summary table A.2 in appendix A shows expenditure- and performance-based values for new and old IC and HC per value added. The much higher figures for old rather than new IC or HC in the expenditure-based approach can be explained by how the division is constructed. For each year in a job, the only share $(1-\kappa)^{m_{ijt}}$ is new work where m_{it} is the length of stay of the worker i in the current job measured in years as 0,1,2,3. For a median worker with 9.2 years of seniority, only 5.4% of his/her IC or HC is new (with m=8.2 in (13) and (14)). Therefore, it is not surprising that in the expenditure-based approach, the share of the new HC investment is 1.6% of the GDP, which is a much lower figure than the share of the old HC investment, which is 16% of the GDP. Similarly, the share of the new IC investment of GDP is 0.7% and is less than the share of the old investment, which is 13% of the GDP.

Performance-based estimates are from (6) and (11) through (14) given the estimation results for $\hat{b}_{zj}$. Table A.2 shows that the performance-based value of new capital stocks is at least double. First, HC stock per GDP 2.9% is almost twice as high than when using expenditure-based estimates at 1.6%. Second, the performance-based value of new IC stock per GDP 2.3% is three times higher than when using expenditure-based estimates at 0.7%. The opposite holds for old IC and HC, which have little economic value. The performance-based value of old IC or HC can be set as zero as implied by zero or the negative output elasticities in table 6.

[18] Exogenous variables also include many interactions not taken into account in returns to scale figures.

5 Growth accounting

In growth accounting, performance-based values relying on a random effects estimation are used. These are not likely to be biased upwards either, as instrument estimation would yield much higher figures. Performance-based new IC and HC created from interfirm worker mobility shows that the net gains and changes in the old IC and HC with insignificant value are ignored in the calculations. The summary table shows that one-third of new HC is located in the Helsinki region and nearly one-fifth in the Helsinki-Turku corridor.

This section utilizes the GDP growth-accounting framework to evaluate the effects of the increase in interfirm job mobility with the introduction of high-speed connections in the Helsinki-Turku corridor. In growth accounting, GDP growth is decomposed into growth contribution of tangible capital and performance-based IC and HC, all per hours worked, H_t, and multifactor productivity growth MP_t (residual) (see Corrado et al., 2014 for details of this method). Average labor productivity growth is explained by all factor inputs but pays attention to those generated by the growth of new IC and HC. The decomposition by Diewert and Fox [36] and Hyytinen and Maliranta [37] separates growth of any inputs determined by internal growth within firms and that driven by changing market structures called creative destruction. Contribution to the change in labor productivity (value added per hours worked) can be decomposed into

$$\Delta ln\left(\frac{VA_t}{H_t}\right) = \sum_i \bar{s}_{Ki} \Delta ln\left(\frac{K_{it}}{H_t}\right) + \sum_{i,z=IC,HC} \bar{s}_{zi} \Delta ln\left(\frac{R_{zit}^{NEW}}{H_t}\right) + \Delta ln MP_t \ , \qquad (16)$$

where VA_t is the value added in year t including all capital investments, H_t is the hours worked, K_{it} is the fixed tangible capital, R_{zit}^{NEW} is the new capital of type z=IC, HC; MP_t is the multifactor productivity (Solow residual with labor augmenting technical change) and Δ is the difference operator. $\bar{s}_{xit} = 0.5(s_{xit} + s_{xit-1})$ is the average two-period value, where s_{xit} describes the variable X_{it} = K_{it} and R_{zit}^{NEW} income shares of total value added (with fixed tangible income as the residual at firm-level incomes). Aggregate figures at the country level can be decomposed into firm-level growth, showing internal growth in continuous firms and figures driven by regional shifts in the relative size of the firms, which is referred to as creative destruction (CD). In accordance with Diewert and Fox (2010) and Hyytinen and Maliranta (2013)[19]:

[19] A program for decomposing micro-level sources of labor productivity was provided by Mika Maliranta from ETLA, The Research Institute of the Finnish Economy.

$$\bar{s}_X \Delta \ln X_t = \sum_{i \in C} \bar{s}_{xit} \Delta \ln x_{it} + \Delta \ln X_t^{CD}, \text{ where} \\ \Delta \ln X_t^{CD} \equiv \sum_i (\ln \bar{x}_{it} - \ln \overline{X}_{it}^C)(s_{xit} - s_{xit-1}) \quad , \tag{17}$$

and where $\ln \bar{x}_{it} = 0.5(\ln x_{it} + \ln x_{it-1})$ is the average two-period industrial value of x_{it} = K_{it} / H_{it}, R_{zit}^{NEW} / H_{it}; and $\ln \overline{X}_t^C = 0.5(\ln X_t^C + \ln X_{t-1}^C)$ is the aggregate average two-period figure $X_t^C = \sum_{i \in C} x_{it}^C$ for continuing firms (C). The term $\Delta \ln X_t^{CD}$ in (17) denotes the effects arising from regional share changes, where $s_{xit} - s_{xit-1}$ is the change of variable X shares with respect to aggregate value added in continuing industries. This includes the regional entry and exit effects so that:

$$\Delta \ln X_t^{CD} = \sum_{i \in C} (\ln \bar{x}_{it} - \ln \overline{X}_t^C)(s_{xit} - s_{xit-1}) + S_{xit}^E \left(\ln X_t^E - \ln \overline{X}_t^C \right) \\ - S_{xit-1}^D \left(\ln X_{t-1}^D - \ln \overline{X}_{t-1}^C \right) \tag{18}$$

The first term (18) denotes the internal change in continuous firms, i.e., the productivity growth within each firm weighted by its value-added share. $\ln \overline{X}_t^C$ denotes the aggregate value in continuing firms. The third and fourth terms denote the part of creative destruction explained by exiting firms denoted by *E* and entering firms denoted by *D*, where S_{xt}^D is the share of variables K, R_z^{NEW} and L in entering firms of the total value added in period t, and S_{xt-1}^E is the equivalent for exiting firms. In the following, entry and exit effects are excluded because a large part of them is inaccurate, e.g., firms are new members of the Confederation of Finnish Employers rather than new firms. The second explanation is that performance-based estimation is conducted in panel estimation and thus is for continuous firms. This gives no performance-based estimation for the value of IC and HC for entering and exiting firms.

Table 7 shows GDP growth as a total of labor productivity and labor supply growth and growth-accounting decomposition of labor productivity growth. The growth contributions of old IC and HC are omitted (zero), as well as those from the rest of Finland, and Helsinki-Tampere and the Lahti corridor are not reported. The table covers 1999-2014 and, for total growth, is also divided into the economic boom from 1999-2007 and the financial and sovereign debt crises from 2008-2014. All components are divided into internal growth and creative destruction. Regional growth from row 4 and downwards is measured in promilles. New HC and IC are from workers with previous and possibly current jobs in the named region.

Table 7. The growth accounting in 1999-2014 (%) and national growth contribution by regions (‰)

Finland by periods and regions	GDP	Hours	Labor productivity	Tangible capital		Unskilled costs		Skilled costs		New HC Helsinki		New HC Hki-Turku corridor		New IC Helsinki		New IC Hki-Turku corridor	
					CD		CD		CD		CD		CD		CD		CD
All %	2.7	-2.5	5.2	-0.2	-2.9	-0.1	2.0	0.5	-1.2	0.05	0.00	0.04	0.01	0.09	0.01	0.02	0.03
Period 1999-2007 %	10.5	0.4	10.1	-0.2	-2.0	0.0	3.9	0.5	-0.4	0.07	0.00	0.05	0.01	0.13	0.02	0.02	0.03
Period 2008-2014 %	-7.3	-6.3	-1.1	-0.3	-4.1	-0.2	-0.3	0.6	-2.2	0.02	-0.01	0.02	0.01	0.03	0.00	0.01	0.02
Finland rest ‰	6.5	-7.5	14.0	-1.2	-14.6	-1.0	10.0	1.7	-4.6	0.15	-0.09	0.13	-0.09	0.31	-0.05	0.06	0.00
Helsinki region ‰	12.1	-5.1	17.2	0.7	-11.5	0.3	5.4	2.8	-5.3	0.25	-0.15	0.11	-0.06	0.35	-0.08	0.06	0.04
Turku city ‰	0.53	0.01	0.52	-0.29	-1.29	-0.01	0.82	0.13	-0.34	0.01	0.00	0.03	0.00	0.02	-0.01	0.01	0.00
Turku region ‰	0.03	0.07	-0.03	0.14	-0.07	-0.06	0.22	-0.02	-0.09	0.00	0.00	0.02	-0.01	0.01	0.00	0.01	0.00
Turku railroad track ‰	0.00	0.02	-0.02	-0.04	0.00	0.02	0.01	0.01	-0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Salo region ‰	0.05	-0.28	0.33	0.06	-0.21	-0.02	0.19	0.09	-0.08	0.02	0.00	0.00	0.00	0.07	0.00	0.00	0.00
Lohja ‰	0.08	-0.13	0.20	-0.01	-0.15	0.00	0.21	0.02	-0.07	0.00	0.00	0.00	-0.01	-0.01	0.00	0.00	0.00
Vihti, Karkkila ‰	-0.09	-0.11	0.02	0.09	0.03	-0.03	0.16	0.02	-0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Coastal area ‰	-0.02	-0.20	0.17	-0.71	-0.43	0.00	0.48	0.08	-0.15	0.00	0.00	0.02	0.00	0.00	0.00	0.01	0.01

CD=Creative destruction. The negligible old intangible and worker capital effects and those for rest of Finland and Helsinki-Tampere-Lahti corridor are not shown.

The average GDP growth of 2.7% in EK firms is close to the growth in value added for non-financial corporations in Finland at 3.3%. The Helsinki region covers almost half of the growth in the national GDP (12.1‰ of 27‰ in promilles). New IC and HC from the Helsinki region and the Helsinki-Turku corridor improve labor productivity, increasing the GDP by 2.5‰. The growth contribution to the national GDP is largest in the Helsinki region, which is explained by a 40% share of IC and a 30% share of HC located there.[20] The labor productivity growth in Turku city of 0.53% is less than one-third of that of the Helsinki region, at 1.72%, explaining why interfirm mobility towards Helsinki is shown later to have a larger impact on GDP growth than that towards Turku. Note, however, that hours worked have decreased by -5.1% in firms located in the Helsinki region, while hours worked have stayed the same in Turku city. This is explained by firms established in Helsinki having a large share of operations outside the Helsinki metropolitan area, where hours worked have decreased similarly, as in the rest of Finland, by -7.5%.

Creative destruction has in general slowed the building of new intangible capital throughout the period: firms with heavy recruitment of intangible capital workers and hence with a large share of new IC have increased in relative size in the regions. The effects of creative destruction are, however, negative for new IC in the Helsinki region and for all new HC. Firms with new HC have lost their (regional) market share, which largely explains why new HC from the one-hour train is later shown to generate less growth than the implied new IC.

Fixed tangible capital has an average negative effect on labor productivity growth by -1.9%. This is explained by negative creative destruction due to the downsizing of the paper and pulp and electronic industries (Nokia) in some regions.

Table 8 shows the national GDP effects of the one-hour train through new IC and HC given the GDP of 205 billion € in 2014. This is conducted by multiplying the figures in table 7 of the growth contribution of new HC and IC in the Helsinki region and in the Helsinki-Turku railway corridor by the respective increase in regional worker mobility due to the one-hour train from table 5. Part of the gains accrues from more IC workers in the market, while the size of the workforce has decreased, especially in manufacturing, since 2008. Table A.3 in Appendix A reports the results separately for the growth period from 1999-2007 and the financial and sovereign debt crisis period from 2008-2014.

[20] Many large companies have headquarters and therefore are categorized as belonging to the Helsinki region. The entire operations in all of Finland should indeed be included in the analysis.

Table 8. Changes in annual GDP according to region in previous job, random effects and instrument estimation million 2015€

Destination region	Southwest Finland, West Uusimaa					Helsinki region				
	New HC	CD	New IC	CD	Total	New HC	CD	New IC	CD	Total
Random effects estimation										
Helsinki region	22.8	-13.8	14.0	8.4	31.4	.	.	.	.	.
Turku city	0.5	0.1	0.2	0.1	0.9	1.5	-0.5	3.4	-1.2	3.1
Turku region	0.3	-0.1	0.1	0.0	0.2	0.0	0.0	0.2	0.0	0.1
Turku railroad track	0.4	0.3	0.0	0.4	1.1	0.1	-0.2	0.2	-0.1	0.0
Salo region	0.6	0.7	0.4	0.1	1.9	0.4	0.0	1.1	0.0	1.5
Lohja	0.2	-0.5	-0.1	0.0	-0.4	0.0	0.0	-0.1	0.0	-0.1
Vihti, Karkkila	-0.1	0.1	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0
Coastal area	0.2	0.0	0.1	0.1	0.4	0.0	0.0	0.0	0.0	0.0
All	24.9	-13.2	14.9	9.1	35.7	2.0	-0.7	4.7	-1.3	4.7
Instrument estimation										
Helsinki region	29.9	-17.0	72.5	44.0	129.4	.	.	.	.	.
Turku city	0.6	0.1	1.2	0.5	2.4	5.8	-1.5	14.6	-4.1	14.8
Turku region	0.3	-0.1	0.3	0.0	0.5	-0.1	-0.1	0.6	0.0	0.4
Turku railroad track	0.5	0.3	0.2	2.6	3.6	0.5	-0.6	0.8	-0.6	0.0
Salo region	0.9	0.8	2.2	0.3	4.3	1.7	0.0	5.3	-0.1	6.9
Lohja	0.3	-0.6	-0.4	0.0	-0.7	0.2	0.0	-0.5	-0.1	-0.4
Vihti, Karkkila	-0.2	0.2	0.4	0.2	0.7	0.0	0.0	0.1	0.0	0.1
Coastal area	0.3	0.0	0.5	0.3	1.1	0.0	0.0	0.0	0.0	0.0
All	32.7	-16.2	77.0	47.8	141.3	8.0	-2.2	20.9	-5.0	21.7

HC=human capital, IC=intangible capital, CD= creative destruction

New HC and IC created by the one-hour train increases GDP annually 40.4 million € (35.7+4.7), and the gains are largely 90% from the Helsinki region. Table 7 showed that 171 new jobs are created in the Helsinki region so that the value added is increased by 208 thousand € from each job. This is explained by the long-lasting effect of new IC in particular. Two-thirds, 27.4 million € (14.9+9.1-1.3+4.7), is from new IC, and one-third, 13 million € (24.9-13.2+2-0.7), is from new HC. An increase in GDP is mainly from internal growth, while creative destruction caused a decrease of -6.2 million €. Firms intensive in new HC have thus decreased in size. Creative destruction is highly negative at -13.9 million € in new HC. Thus, firms with a large share of new HC have lost markets. One reason for this is the extensive structural changes in Finnish manufacturing as discussed above. The negative creative destruction in new HC concentrates on the second period since 2008 with a loss of GDP of -23.1 million € (see table A.3 in the Appendix). Without negative creative destruction, new HC would have produced larger gains of 26.9 million € (24.9+2.0) rather than new IC at 19.6 million € (14.9+4.7).

Overall, new HC and IC in the Helsinki region dominate the effects of increasing annual GDP at 31.4 million €. Additionally, new HC and IC from interfirm worker mobility from

West Uusimaa and the Southeast region towards Turku and the surrounding regions increases GDP by 2.2 million €, while mobility from the Helsinki region to these areas increases GDP by 3.3 million €. The total, 5.5 million €, is one-sixth of the GDP increase from the Helsinki region. This is despite the fact that new jobs increase only 1.4 times more in the Helsinki region than in Turku (see table 5). As explained before, the difference is due to larger labor productivity improvements in the Helsinki region and to new IC and HC.

6 Conclusion

The Turku-Helsinki railway belongs to core TEN-T networks in the EU that connect Stockholm and St. Petersburg and may receive a 20-33% share of finance from the EU. A traditional cost-benefit analysis yielded net returns of 30 million €, while gains from new IC and HC are significantly higher at 40 million € when performance-based evaluation of new HC and intangible capital is used in the valuation. Because gains are much higher at 163 million € when using instrument estimation, the cautious approximation of total gains from new IC and HC is 40-50 million €. Total gains are hence approximately 70-80 million €. This figure is also in the upper range of benefits evaluated in Laakso (2016), in which the evaluation is based on higher GDP growth in metropolitan areas than in other areas. The gains estimated here are rooted in increasing returns to scale in local labor markets as in BVH [13] but are all explained by the reallocation of intellectual capital. Gains are 1% of the GDP in the Helsinki-Turku corridor area (which was defined to exclude the Helsinki area). However, gains also relate to the positive creative destruction of new IC work in IC-intensive firms.

According to Fröidh [14 p. 359], the average valuation of a supply of journeys tends to increase when it is radically improved, as in the introduction of the Svealand line in Sweden (see also Kottenhoff and Lindh [21]).[21] Here, it takes 26 years to pay back the initial infrastructural investment with a 3% interest rate or 19 years with 20% subsidies from the EU. It is clear that a positive investment climate and growth require more of the active use of EU finances and more productive investment than what has been planned. In comparison, infrastructural investments in transport are approximately 2700 million € per year in Sweden in the period from 2013-2018, while infrastructural investments are expected to be six times lower at 500 million € in Finland during the same period [38]. Sweden is also planning to invest in the building of high-speed trains in the future. Transport policy planning requires more analysis of the regional economic effects, which accrue here largely from better allocation of the labor force. Improved employment is to be expected as additional support for the one-hour train.

[21] The planned one-hour train resembles to some extent the Svealand line in Sweden that opened in 1997, replacing an older railway line between Eskilstuna and Stockholm (a distance of 115 km). The new line reduced travel time from 1 hour 40 minutes in 1993 and approximately 2 hours in 1993-1997 to one hour since 1997.

Annex A. Intangible capital

Intermediate and capital costs are also incurred in the production of intangible capital goods, and these goods are evaluated from the input-output tables of business services in category 7 of the Classification of Economic Activities in the European Community (Nace Rev. 2):

- Other business activities (Nace 71) as a proxy for organizational goods,
- Research and development (Nace 72) as a proxy for R&D goods, and
- Computer and related activities (Nace 62) as a proxy for ICT goods.

Piekkola [19] provides the value of a combined multiplier M_{jt}^{IC} in (1), which is time invariant in the expenditure-based approach. The share of workers producing intangible goods is set at 40% for organizational occupations (twice the share used in [27]), 70% for R&D occupations and 50% for ICT occupations. The factor multiplier from the intermediate and capital costs is set to be representative of the entire EU27 area and is a weighted average of the factor multipliers for Germany (40% weight), the UK (30% weight), Finland (15% weight), the Czech Republic and Slovenia (both countries have weights of 7.5%).[22] The factor multipliers employed account for the use of capital, and intermediate inputs are 1.76 for organizational wage expenses, 1.55 for R&D wage expenses and 1.48 for ICT wage expenses. Labor costs are annual earnings instead of hourly wages because the earnings include performance-related pay and because workers in managerial positions are not paid for overtime hours. As a result, managers' recorded hours are consistently lower than their actual number of hours.

Table A.1 summarizes the combined multiplier A^{IC} (the product of the share of effort devoted to IC production and the factor multiplier) and the depreciation rates we employed.

[22] The input-output tables are from the EU KLEMS database and the countries were with LEED data in INNODRIVE, which is the product of the 6th framework research project financed by the European Commission to analyze productivity in the European Union at the industry level.

Table A.1 OC, R&D and ICT combined multipliers in the expenditure-based approach and their depreciation

	OC	R&D	ICT
Employment shares	40%	70%	50%
Combined multiplier M^{IC}	70%	110%	70%
Depreciation rate δ_{IC}	20% production 25% services	15%	33%

Organizational and ICT investments represent 70% of the labor costs in the occupations we considered (In ICT, the figure is an approximation of the combined multiplier of 0.74.). In R&D activities, the total wage costs are close approximations of the total investment and have a combined multiplier of 110%.

Table A.2 Summary

Variable	Mean	Std	Median	Obs
Value added factor prices (million)	22.594	130139	3175	41011
Value added growth	4.8 %	41.4 %	2.9 %	36290
Employment	176	801	37.5	41011
IC worker share	0.163	0.227	0.0667	41011
Old HC investment/GDP random effects	0.0 %	0.0 %	0.0 %	41011
New HC investment all /GDP random effects	2.9 %	0.1 %	2.9 %	41011
Other Finland share	31.3 %	0.7 %	31.2 %	41011
Helsinki region share	29.6 %	0.8 %	30.0 %	41011
Hki-Tre, Lahti corridor share	21.0 %	0.5 %	21.0 %	41011
Hki-Turku corridor share	18.1 %	0.5 %	18.0 %	41011
Old HC investment/GDP	13.0 %	3.6 %	12.5 %	41011
New HC investment all /GDP	1.6 %	0.4 %	1.7 %	41011
Other Finland share	49.2 %	4.0 %	49.1 %	41011
Helsinki region share	32.6 %	2.1 %	33.3 %	41011
Hki-Tre, Lahti corridor share	11.4 %	2.5 %	10.9 %	41011
Hki-Turku corridor share	7.2 %	1.1 %	6.7 %	41011
Old IC investment/GDP random effects	0.0 %	0.0 %	0.0 %	41011
New IC investment/GDP random effects	2.3 %	0.5 %	2.1 %	41011
Other Finland share	33.6 %	4.7 %	32.3 %	41011
Helsinki region share	36.9 %	4.9 %	36.9 %	41011
Hki-Tre, Lahti corridor share	17.7 %	5.4 %	17.2 %	41011
Hki-Turku corridor share	11.7 %	4.3 %	10.5 %	41011
Old IC investment/GDP	13.0 %	3.6 %	12.5 %	41011
New IC investment/GDP	0.7 %	0.2 %	0.6 %	41011
Other Finland share	36.8 %	3.4 %	37.1 %	41011
Helsinki region share	43.6 %	1.9 %	43.5 %	41011
Hki-Tre, Lahti corridor share	11.7 %	2.6 %	11.0 %	41011
Hki-Turku corridor share	8.2 %	1.3 %	8.2 %	41011
Fixed asset per value added	30.2 %	1.4 %	29.6 %	41011
Material per value added	8.5 %	2.0 %	9.1 %	41011

New value added (with double deflation), fixed capital, and materials are deflated at 2010 producer prices. New value added includes IC and HC investments.

Table A.3 One hour train in Helsinki-Turku corridor and changes in annual GDP, random effects and instrument estimation in 1999-2007 and 2008-2014

	Southwest Finland, West Uusimaa					Helsinki region			
	New HC	CD	New IC	CD	Total	New HC	CD	New IC	CD
Regions 1999-2007									
Finland rest	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Helsinki region	34.3	-8.9	14.4	13.3	53.1	1.5	-0.4	4.0	-0.6
Turku city	0.6	0.3	0.2	0.1	1.3	0.0	0.0	0.3	0.0
Turku region	0.3	-0.1	0.1	0.0	0.3	0.1	0.0	0.2	-0.1
Turku railroad track	0.5	1.0	-0.5	1.0	1.9	0.6	0.0	1.9	0.0
Salo region	0.8	0.9	0.4	0.0	2.2	0.1	0.0	0.1	0.0
Lohja	0.4	0.3	0.2	0.1	0.9	0.0	0.0	0.0	0.0
Vihti, Karkkila	0.0	0.2	0.0	0.0	0.3	0.0	0.0	0.0	0.0
Coastal area	0.4	0.0	0.2	0.1	0.7	0.0	0.0	0.0	0.0
Main railway	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tampere region	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lahti region	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hämeenlinna region	0.0	0.0	0.0	0.0	0.0	2.3	-0.4	6.6	-0.7
All regions, million €	37.3	-6.4	15.1	14.7	60.7	2.3	-0.4	6.6	-0.7
Regions 2008-2014									
Finland rest	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Helsinki region	8.1	-20.2	13.6	2.1	3.5	1.4	-0.7	2.6	-1.9
Turku city	0.4	-0.2	0.3	0.0	0.4	0.0	0.0	0.0	-0.1
Turku region	0.2	-0.1	0.0	-0.1	0.1	0.1	-0.4	0.0	0.0
Turku railroad track	0.2	-0.6	0.6	-0.2	0.0	0.1	0.0	0.1	0.0
Salo region	0.4	0.5	0.4	0.1	1.5	-0.1	0.0	-0.4	0.0
Lohja	0.0	-1.5	-0.4	-0.2	-2.0	0.0	0.0	0.0	0.0
Vihti, Karkkila	-0.3	0.1	0.1	0.1	-0.1	0.0	0.0	0.0	0.0
Coastal area	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Main railway	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tampere region	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lahti region	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hämeenlinna region	0.0	0.0	0.0	0.0	0.0	1.5	-1.2	2.3	-2.1
All regions, million €	9.0	-21.9	14.7	1.8	3.5	1.5	-1.2	2.3	-2.1

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