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Cross-border investment expenditure spillovers in European gas infrastructure

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ABSTRACT

We investigate the implications of an integrated vis-à-vis a national perspective regarding investment in natural gas infrastructure. In particular, we analyze cross-border spillovers related to the investment expenditure of five Western European countries. We develop a practical approach to estimate such cross-border investment expenditure spillovers using a multi-regional input-output model. We find that international spillovers are generally larger for employment compensation compared to capital compensation and that the spillovers are unevenly distributed among the countries and the types of labor. Both high-skilled and medium-skilled labor is impacted most in the country where the investments take place, whereas low-skilled labor is mostly generated outside the EU. We argue that an integrated European gas infrastructure investment policy is to be recommended.

1. Introduction

European Union (EU) energy market projections show large variations in future gas flows, some even predict a decline in the total flow, but most models expect significant local demand growth (Smith, 2013). To facilitate these flows additional transport and storage facilities are required. One of the bottlenecks in the current infrastructure is the lack of interconnectivity between European countries. The European Commission actively pursues an integrated energy market (European Commission, 2015). Individual countries try to benefit by assigning priority to their national gas sector for which they define domestic infrastructural strategies. Moreover, these investments are generally assessed at the national level only. The economic impact in other countries is usually included in the national investment analysis as negative leakage (Eijgenraam et al., 2000). As a result, the international spillovers tend to be ignored. Especially since the turmoil in the Ukraine, politicians in Europe come to realize that their dependency on gas has a geopolitical dimension and that collaboration within the EU might be helpful (Cobanli, 2014; Richter and Holz, 2015). This warrants attention for the international effects of gas infrastructure investments in the EU. We try to contribute to the assessment of energy infrastructure investments by developing a practical method for estimating cross-border spillovers of these investments.

Gas transmission investment expenditures may entail large cross-border indirect effects. At a European level, these effects do not have an impact in case of a perfect market from the perspective of an overall cost-benefit analysis. However, the European labor and financial markets are subject to several frictions and imperfections. This suggests that the indirect cross-border effects need to be accounted for. In addition, investments do have distributional effects, both in geographical terms and across labor and capital. These effects need to be considered from an economic perspective. So far, such analysis is missing in the cost-benefit analysis that concentrates on the cross-border impacts after the project's implementation. We develop a practical approach to estimate these spillovers and investigate the indirect cross-border impact of investment expenditures related to gas transmission infrastructure. We use a multi-regional input-output (MRIO) model that tracks the impacts along the respective international value chains. This allows for reporting on the size and distribution of the cross-border spillovers by country (and sector) of impact. As such, we trace investment expenditures along the respective value chains of the sectors supplying the investment goods, where we

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distinguish between domestic impacts, impacts in other EU countries, and non-EU impacts. We analyze cross-border spillovers that are estimated based on the investment plans of Austria, Belgium, France, Germany and The Netherlands as published in the Ten Year Network Development Plan (TYNDP) of the European Network of Transmission System Operators of Gas (ENTSOG, 2013).[1] In general, we expect the cross-border spillovers to other EU countries to be a minor part of the total impact of gas infrastructure investments. However, especially for small countries, the cross-border impacts are expected to be larger due to their higher degree of international openness. We are also interested in the distribution of the impact. Any cross-border impacts are most likely to occur in the largest trading partners of the countries. Knowledge on the size and distribution of the cross-border spillovers may aid the discussion of who should contribute to financing the investment, especially when it is a project of EU-wide importance.

Therefore, we investigate the regional impact of gas infrastructure investments, instead of taking a national perspective and develop a practical approach to estimate the cross-border spillovers. We argue that there is a case to adjust the evidence base for investment decision-making to include cross-border stimulus as a perceived benefit, instead of viewing it as a leakage. We find substantial differences between countries regarding the impact of gas infrastructure investment on domestic value added and the cross-border leakages to other countries. The distribution of the intra-EU cross-border spillovers appears to be concentrated in only a few countries. We also find that the impacts on employment by skill levels are not evenly distributed for medium-skilled labor.

In the next section, we first give background information about large-scale EU gas infrastructure investment plans, before we turn to a description of our method, data and results.

2. EU gas market integration

Energy policy is listed high on the political agenda. For example, the Energy Union has been marked as a priority by the European Commission (2015). It focuses on creating an integrated internal energy market and on ensuring the security of energy supply. Working towards either objective requires adjustments of the institutional framework (regulation, policies) and technical alterations (such as investment in additional pipelines and interconnectors and storage to increase both capacity and flexibility). In this respect, the gas sector sees the EU-wide unbundling of utility companies into trading companies and transmission system operators (TSOs). Competition among the trading companies is facilitated by rules that aim to create a well-functioning internal market for gas. In contrast, the gas transmission operators were continued as state-owned enterprises under stringent regulation, next to European wide institutions like the Agency for the Cooperation of Energy Regulators (ACER) and ENTSOG.

Investing in infrastructure is a means to increase the security of supply and to enhance competition. Low security of supply is in most cases due to a large dependence on one source and limited connectivity (see Le Coq and Paltseva, 2009). To address security of energy supply, the EU calls for more diversification in gas sources and transmission pipelines and for an increase in interconnection capacity as borders turn out to be bottlenecks (Gasmi and Oviedo, 2010; European Commission, 2012a).

Projections of gas demand show increasing gas flows in about half of the scenarios included in a study by Smith (2013). He finds that the difference between declining or rising demand hinges mostly on assumptions related to displacement rates. This can be the rate at which fossil fuels will be displaced by renewables and/or nuclear generation, or the rate at which gas will displace other fossil fuels as a (transitory) fuel for electricity generation. Other arguments that point at a potential increase in the demand for gas are the somewhat lower carbon content of gas compared to other fossil fuels and its higher production flexibility in electric power generation. Regarding the supply side, European domestic production is expected to decrease due to dwindling reserves. Then, higher demand coupled with decreasing domestic production will result in a substantial increase in import flows. Consequently, the transmission of these gas flows from outside the EU to the different nations will require additional investments. Further, even when aggregate EU gas demand growth is projected as moderate, the differences across nations can be significant. Adequate transmission capacity and flexibility to specific nations and regions will need to be ensured (Smith, 2013).

Transmission investment decisions are made by the TSOs. The risk related to gas infrastructure investments mainly lies in uncertainty about demand for future transport services. The European Union has set up a financial facility to support targeted infrastructure investment (European Commission, 2011). Of the total budget of € 50 billion for 2014–2020, € 9.1 billion is reserved for energy infrastructure investment. It is estimated that € 2.9 billion will be required to leverage gas infrastructure investments, of which investments will fall short by an estimated amount of € 16 billion. The amount needed to leverage gas infrastructure investments is estimated to be € 100 million for the West Europe corridor and € 1 billion for the Central Europe corridor (European Commission, 2012b). An objective and transparent assessment of each investment plan is required in order to ensure that social welfare is maximized. We argue it is crucial that this assessment is done from an EU-wide viewpoint, to properly account for cross-border effects and to ensure system-wide optimality, both in the short terms and in the long term.

ENTSOG compiles the TYNDPs and the 2013–2022 TYNDP lists projects for a total value of 72.77 billion euro (ENTSOG, 2013).[2] The largest share (83%) of the costs of investment plans relates to transmission projects, where the remaining 17% consists of storage and LNG projects. In terms of cost shares, for 87% of the projected costs the final investment decision has not yet been taken. Next to the biannual EU TYNDP, TSOs also have to publish Gas Regional Investment Plans, which promote further regional cooperation. We will use the information from these investment plans to arrive at cost estimates, which are then allocated to the sectors serving the investment demand. Investment plans also needs to be assessed regarding the optimal configuration of the network. This especially holds for projects of common interest. Currently, the developments at the EU level are at a stage where a framework is devised to assess investment plans in light of one integrated EU gas infrastructure. ENTSOG has developed the methodology to assess the impact of cross-border gas infrastructure investments (ENTSOG, 2015).[3] This methodology includes an assessment of cross-border impacts by analyzing the change in social welfare induced by a project in each impacted country. This change is captured by the change in the supply curve due to better access to a cheaper source (ENTSOG, 2015, p.29). However, this approach only focuses on the economic impacts of the project after implementation. We argue that a complete cost-benefit analysis should also include the cross-border impacts at the stage of implementation, i.e., the cross-border impacts of the investment expenditure.

3. Methodology and data

Investing in large-scale infrastructure projects creates international spillovers. A nationally focused assessment of the impacts usually

[1] ENTSOG TYNDP 2013–2022; http://www.entsog.eu/publications/tyndp/2013#ENTSOG-TEN-YEAR-NETWORK-DEVELOPMENT-PLAN-2013–2022.

[2] See Table 2.6 of the Main Report. Not all projects have made cost estimates available to ENTSOG, hence the total cost estimate covers only 35% of all projects. It is explicitly noted that this ratio cannot be extrapolated to calculate the total cost estimate for all projects.

[3] See for the documentation of the full process http://www.entsog.eu/publications/cba-methodology#CBA-METHODOLOGIES.

includes an estimation of the total amount of investment expenditure that leaks away from the country. This estimate is recorded as a negative effect, without further assessing where the money flows to (e.g., which country, sector, and production factor). Previous literature focuses on optimal network configuration in direct relation to the functioning of the network and disregards the impact of the investment itself on the wider economy. For example, Bergendahl (1988) investigates whether gas capacity expansion into new regions is profitable from a social point of view. He first determines the optimal size of the investment based on demand at different locations along the pipeline, and then investigates whether the return is acceptable. De Nooij et al. (2010) devise a cost-benefit framework which allows them to establish that the costs of taking care that networks are always able to maintain supply most likely outweigh the benefits if it would need to be upheld during periods of maintenance. Neuhoff et al. (2008) use linear programming to select investment options regarding electricity generation by optimizing system dispatch given assumptions on security requirements, fuel and other costs including environmental costs, and transmission possibilities. Their results highlight the crucial role of transmission constraints. The approach of Spiecker et al. (2013) allows the assessment of interconnector investments given the presence of intermittency and endogenous power plant investments. Baltensperger et al. (2015) simulate the impact of infrastructure expansions on social welfare and security of gas supply. Huppmann and Egerer (2015) investigate the impact of zonal planners deciding on electricity transport network investment and focus on the consequences for international welfare arising from power network upgrading. Üster and Dilaveroğlu (2014) and Midthun et al. (2015) try to optimize the design and operation of national gas transmission networks. Neuhoff et al. (2015) specifically investigate the design of international power transmission capacity in relation to the integration of renewable energy sources. Lehmann et al. (2015) reflect on the role of capacity payment to secure the supply of electricity in this respect. Mulder and Scholtens (2016) provide a plant-level analysis of international spill-over effects from electricity generation. We contribute to this literature by presenting a method that accounts for analyzing the size and distribution of the cross-border impacts associated with investment expenditure for gas infrastructure; we do not account for market structure and uncertainty.

In this paper, we focus specifically on the international linkages (see also Baltensperger et al., 2015; Huppman and Egerer, 2015; Neuhoff et al., 2015). We argue that from the EU perspective, flows to other EU countries should not be regarded as negative effects. Hence, we expand the scope of the investment analysis and estimate investment expenditure related to the investment projects presented in the TYNDP and systematically assess the impacts of these different investment plans on each European economy via a multi-regional input-output model.

3.1. International input-output modeling

Our main research interest is to establish the cross-border indirect effects of an investment stimulus, in terms of economic impacts in other countries than the country where the initial economic stimulus takes place. We use a multi-regional input-output (MRIO) model (Miller and Blair, 2009) to estimate the cross-border spillovers. This methodology has also been used to estimate trade in value added and represent global value chains (e.g., Johnson and Noguera, 2012; OECD, 2013; Koopman et al., 2014; Timmer et al., 2014). Miller and Blair (2009) argue it is the most appropriate framework to assess cross-border direct and indirect impacts of spending. These impacts can range from value added impacts to environmental impacts. The underlying data, represented in an MRIO table shows all connections between industries in terms of intermediate deliveries. Consumption by households, the government and capital formation (investment) enter the model exogenously. The direct and indirect additional production required to produce the exogenous final demand can be calculated by summing over all additional intermediate products required. The advantage of the model is its inclusive scope and its detail; the complete economy is represented in an integrated network of industries. Analyzing effects of final demand shocks provides a full picture of the economy wide effects.

In our paper, the vectors representing demand packages for infrastructural expenditures are used as demand shocks in MRIO modeling. The impacts in terms of value added generated can be traced to the respective countries that contribute at some stage, possibly only indirectly, to the production process of the investment goods. The input-output identity is mathematically represented as follows, where bold capital letters represent matrices and bold small-cap letters denote column vectors:

$$\mathbf{x} = \mathbf{A}\mathbf{x} + \mathbf{f}. \tag{1}$$

Matrix $\mathbf{A}$ shows all intermediate purchases by buying industry j and selling industry i as share in total inputs of the buying industry. Along the columns and rows, the same set of industries is listed, where along a column, all purchases of an industry over one year are recorded, and in a row, all sales of an industry over one year are recorded. Vector $\mathbf{x}$ contains the values of output per industry and vector $\mathbf{f}$ represents the vector of exogenous final demand. Solving Eq. (1) for $\mathbf{x}$ gives the input-output model:

$$\mathbf{x} = (\mathbf{I} - \mathbf{A})^{-1}\mathbf{f}, \tag{2}$$

where $\mathbf{I}$ is the identity matrix of the same size as $\mathbf{A}$. The solution is also often represented as $\mathbf{x} = \mathbf{L}\mathbf{f}$. An element of the matrix $\mathbf{L}$ denoted with the indices $i = 1 \cdots I$ and $j = 1 \cdots J$ shows the direct and indirect additional output of industry i required to produce one more final product j. More information on the model, its background, mathematical properties and underlying assumptions can be found in Miller and Blair (2009). This fundamental model can be used to represent one country, but it can also incorporate many countries. In case multiple countries are distinguished two more indices are added: $r = 1 \cdots R$ to represent the country of origin and $s = 1 \cdots S$ to represent the country of destination. In this vectors $\mathbf{x}$ and $\mathbf{f}$ have $R*I$ elements and $\mathbf{L}$ is of dimensions $R*I$ by $S*J$. In this paper, we use information on investments to specify a vector $\mathbf{c}$, which represents the expenditure on goods and services following an investment plan for gas infrastructure. The role of this vector is analogous to vector $\mathbf{f}$, but we use $\mathbf{c}$ to distinguish it from total final demand by all categories, which also includes demand by households, government and change in inventories.

To focus on more standard measures of economic activity than gross output, we calculate the impact in terms of value added and employment effects. First, for the value added effects, we use a vector $\mathbf{w}$ that represents the value added in terms of value added by labor per unit of output, and vector $\mathbf{v}$ that represents value added by capital per unit of output. Our results are calculated as follows. Value added by labor is given by:

$$w = \mathbf{w}'\mathbf{L}\mathbf{c}, \tag{3}$$

and value added by capital is calculated by:

$$v = \mathbf{v}'\mathbf{L}\mathbf{c}, \tag{4}$$

where the symbol "′" denotes the transposition of the vector noted before the symbol. In our analysis we use an international input-output model, which allows us to break down the results on value added generated to identify the country where the final demand is generated.

Second, we look at employment. We use a vector denoted by $\mathbf{e}$ to represent the employment in hours per unit of production. Analogous to Eqs. (3) and (4) we calculate the result as follows:

$$e = \mathbf{e}'\mathbf{L}\mathbf{c}. \tag{5}$$

3.2. Data

3.2.1. MRIO

The international input-output data used for this study is from EXIOBASE (see Tukker et al., 2009; Tukker et al., 2013).[4] This database was first developed for the EXIOPOL project, which had as full name: 'A new environmental accounting framework using externality data and input-output tools for policy analysis'. For this study, version 2 of the database has been used, which provides input-output relations for the year 2007. These are captured in an MRIO table that represents 43 individual countries and five aggregate regions representing the 'rest of the world' (RoW). The individual countries are the 27 Member States of the European Union[5] and 16 other large economies. For each of these countries and the RoW regions intermediate and final demand transactions inside the national borders as well as across national borders are represented. The use of primary factors by each industry in each country is also registered in value terms (i.e., value added by each industry). A distinction is made between value added by compensation of employees and operating surplus (consumption of fixed capital, rents and remaining net operating surplus).

The value of this database over other MRIO databases is its detailed industry representation. In total 163 industries are represented for each country, making this database more suitable to trace the effects of expenditure on specific goods and services. Currently, data is available for only two reference years: 2000 and 2007. The 2007 data used in the present study reflects the economic situation of a few years prior to the start of the TYNDP plans investigated. However, this study only makes use of input shares and the resulting information on linkages between industries and not the absolute values present in the database. Generally, these input coefficients are taken to be rather stable over longer periods (Miller and Blair, 2009). In addition to the monetary representation of primary inputs, the use of employment in hours by skill category is also available. The skill categories that are distinguished are: high-skilled, medium-skilled and low-skilled. The quantity data on primary factors is not an integral part of the input-output table, which only contains flows in value terms. They are part of extensive satellite accounts that also contain information on a host of environmentally relevant data.

3.2.2. Investment

The investment demand estimates are combined with the MRIO model to trace out the distribution of the impacts over countries. Value added coefficients and employment coefficients are used to translate the impacts into employment compensation, capital compensation and employment hours required. The multi-regional input-output model is calibrated with data from EXIOBASE. To connect the investment expenditure to an input-output model, the expenditure on the final investment goods bought needs to be defined. Our paper showcases the strengths of an impact study performed with a multi-regional input-output modeling. When used to calculate the indirect effects of an investment project, all relevant investment expenses will be known in detail. In case several detailed investment scenarios need to be compared, as in a social cost-benefit analysis, care must be taken to work with detailed expenditure estimates. Our aim is to show what type of information can be derived from undertaking this exercise.

For this purpose, a set of projects across five Western European countries has been translated into expenditure estimates, namely Austria, Belgium, France, Germany, and The Netherlands. Austria, Belgium and Germany have an extensive entry and exit capacity, which indicates an important role as international transit country. The Netherlands is primarily an exporting country with relatively high exit capacity, whereas France predominantly is to be regarded as an importing country given its larger entry capacity. All five countries are to be considered important nodes in Western Europe's gas network.

The investment expenditure estimates based on information in the TYNDP is reported in Table 1. The investment plans of the larger countries, France and Germany, are more extensive in terms of absolute values. However, in relation to the overall size of the economy, France plans to invest most and The Netherlands plans to invest more than Germany. The type of investment varies much over the countries. Austria and Germany focus largely on transport investment. The coastal countries invest more in LNG, with the exception of Germany. The larger countries invest in underground storage. Only The Netherlands is somewhat of an outlier, with a large focus on additional compression power and investment in underground storage.

These estimates are in line with the estimates of the EU of the amount of investments required in the Western European corridor, which are estimated at 20 billion euros (European Commission, 2012c, p.8). Austria is part of the Central European corridor, where the total investment need is estimated to be 26 billion Euros. These approximate figures are from calculations made by the European Commission's DG ENER based on data from the model PRIMES. PRIMES is a partial equilibrium model for the European Union energy markets, used for forecasting, scenario construction and policy impact analysis up to the year 2030 (European Commission, 2012b).

The various sets of investment projects for each country need to be translated into expenditure on final goods and services that can be linked to the MRIO table. For this purpose, allocation percentages have been estimated that can distribute the investment expenditures by project type over the industries that deliver the required goods and services. These shares are derived from information taken from the literature (Rui et al., 2012; Harris et al., 2010; Oil and Gas Journal Data Book, 2008) of which the details can be found in the Supplementary material. The percentages point at the share of investment expenditure spent in the sector indicated. Investing in pipelines mainly implies a need for construction effort and materials. Compression and LNG investment requires more machinery and equipment. The allocation percentages used are provided in Table 2.

The final investment demand packages are shown in Table 3. These are derived by multiplying the estimated investment expenditure (see Table 1) by the percentages indicating in which sector this investment is spent, for each type of investment (see Table 2). The input-output data also contains information about the international distribution of total investment demand. That information is used in terms of shares to distribute the final investment demand packages of Table 3 over different source countries. For example, it is assumed that the investment expenditure in machinery and equipment for gas infrastructure projects by country A is distributed over the supplying countries with the same percentages as the distribution of countries A's general investment, say 50% in country A, 30% in country B and 20% in country C. The distributed investment packages represent the *direct* impact of investment expenditure on output in the listed sectors in all countries that supply these final investment goods and services. By means of input-output modeling, these direct impacts can be traced back to the value added impacts, through the full chain of intermediate supply relations and including the *indirect* impacts. In the Supplementary material to this paper, we explain in more detail how the investment expenditure has been estimated.

4. Results and discussion

Our aim is to provide insight in the economic impact of gas infrastructure investment expenditures. The less alike two industries in their intermediate input pattern, in terms of industries delivering or countries exporting the inputs, the larger will be the difference in the outcomes. The five countries studied represent important nodes in Western Europe's gas infrastructures. The cross-border impacts of

[4] The data is publicly available via http://exiobase.eu

[5] Croatia is not included in EXIOBASE 2 (year 2007).

Table 1
Investment in million euros by country and project type.

M€	Pipelines		Compression		LNG		Underground storage		**Total**	*Total as % of GDP*[a]
Austria	578	(81%)	131	(19%)	0	(0%)	0	(0%)	**710**	*0.4%*
Belgium	159	(29%)	44	(8%)	352	(63%)	0	(0%)	**555**	*0.3%*
France	4751	(47%)	1200	(12%)	2615	(26%)	1550	(15%)	**10,118**	*0.8%*
Germany	6726	(76%)	1580	(18%)	0	(0%)	600	(7%)	**8,906**	*0.5%*
Netherlands	312	(13%)	854	(37%)	352	(15%)	800	(35%)	**2,318**	*0.6%*

The percentage between brackets is the share of the project type investment in total investment.
[a] GDP at basic prices (=total gross value added), source: EXIOBASE. Note that the GDP reference value pertains to one year, whereas these investment plans cover a 10-year period.

Table 2
Allocation percentages.

	%	Pipelines	Compression	LNG[a]	Underground storage†
i28	Fabricated metal	21%	35%	35%	25%
i29	Machinery & equipment	8%	14%	14%	10%
i45	Construction	51%	31%	31%	30%
i60.2	Transport	6%	6%	6%	10%
i65	Financial services	3%	3%	3%	5%
i66	Insurance and pension funding	3%	3%	3%	5%
i70	Real estate activities	5%	1%	1%	1%
i74	Business services	4%	8%	8%	14%

Note: the first column refers to EXIOBASE industry codes.
[a] Due to lack of data on LNG investment, the percentages for compression power are also used for LNG. † With minor adjustment adopted from Harris et al. (2010).

where value added is created. This also holds for our investment expenditure demand impulse. The total impact on value added (including taxes less subsidies) is exactly equal to the investment expenditure sum.

The MRIO model allows investigating how the investment expenditure is distributed over the countries and the sectors affected, and the type of value added generated. In our discussion, we focus on the countries affected and the type of value added generated. We first discuss the distribution of the economic impact over domestic impacts, impacts in other EU countries, and impacts in non-EU countries. Next, we look into more detail regarding the impacts in other EU countries to specify which other countries benefit most next to the country where the investment takes place.

In Table 4 the distribution of the impact of gas infrastructure investment over type of value added and geographic location is shown. The total percentages of impact on employment compensation from investment expenditure in the five countries are quite close, the range being from 50% to 55%. The range for total impact on gross operating surplus diverges somewhat more, with values from 36% to 44%. The difference is due to small variations in the impact on taxes. For Austria, Belgium, and Germany a smaller percentage (50–51%) flows to employment compensation, than for The Netherlands and France (54–55%). The mirror images holds for gross operating surplus, by definition. The combined effect of the higher impact on employment compensation from French investment expenditure and the higher impact on taxes, implies that investment in France generates relatively low gross operating surplus.

Table 3
Allocation of investments to sectors in million euros.

	M€	AT	BE	FR	DE	NL	**Total**	*Total %*
i28	Fabricated metal	165	171	2,702	2,089	686	**5,813**	*25.7%*
i29	Machinery & equipment	66	68	1,081	836	274	**2,325**	*10.3%*
i45	Construction	333	202	4,041	4,067	768	**9,412**	*41.6%*
i60.2	Transport	42	32	655	547	168	**1,444**	*6.4%*
i65	Financial services	21	16	328	273	84	**722**	*3.2%*
i66	Insurance and pension funding	21	16	328	273	84	**722**	*3.2%*
i70	Real estate activities	28	10	262	335	28	**664**	*2.9%*
i74	Business services	34	38	721	486	224	**1,503**	*6.6%*
	Total	**710**	**555**	**10,118**	**8,906**	**2,318**	**22,606**	*100%*

their investment expenditure portfolios should be considered when deciding on EU support for infrastructural projects.

To compare their magnitude and to contrast the geographical distribution of the impacts, we will specifically focus on percentages in our analysis and not on absolute numbers. The impact on value added and employment is calculated for the investment stimulus by each country separately. For example, the cross-border spillovers of Germany are the cross-border spillovers from the implementation of the investment package that has been identified for Germany. The results for each country are independent from the impacts generated by investment elsewhere.

4.1. Value added

We first focus on the direct and indirect value added impacts generated due to gas infrastructure expenditure. The specific economic impacts we discuss are employment compensation and gross operating surplus. Both constitute the main income categories of gross domestic product (GDP). In national accounting, total final demand (GDP from the expenditure perspective) should exactly equal total value added (GDP from the income perspective). The exogenous demand impulse is fully propagated through the interindustry linkages to the sectors

Comparing the size of the impact on domestic employment compensation, the larger impacts are associated with the larger countries, while the impacts generated abroad are relatively small for these countries. This is as expected; it is common to find that the larger an economy is, the smaller its international linkages are. However, this does not hold for the impacts on domestic gross operating surplus, as the impact in France is just slightly higher than the lowest percentage for The Netherlands. Germany and Austria capture most themselves in terms of domestic gross operating surplus as result of investment expenditure in these countries.

When looking at the cross-border impacts, The Netherlands and Belgium are clearly more internationally oriented. This can be con-

Table 4
Distribution of value added generated due to gas infrastructure investment.

%	Employment compensation				Gross operating surplus				Taxes
	Domestic	Other EU	non-EU	Σ	Domestic	Other EU	Non-EU	Σ	Σ
Austria	33%	12%	4%	50%	30%	10%	5%	44%	6%
Belgium	29%	16%	6%	51%	24%	11%	7%	42%	7%
France	40%	11%	4%	55%	23%	8%	5%	36%	8%
Germany	39%	6%	5%	51%	32%	5%	6%	43%	6%
Netherlands	34%	13%	7%	54%	22%	10%	7%	39%	7%

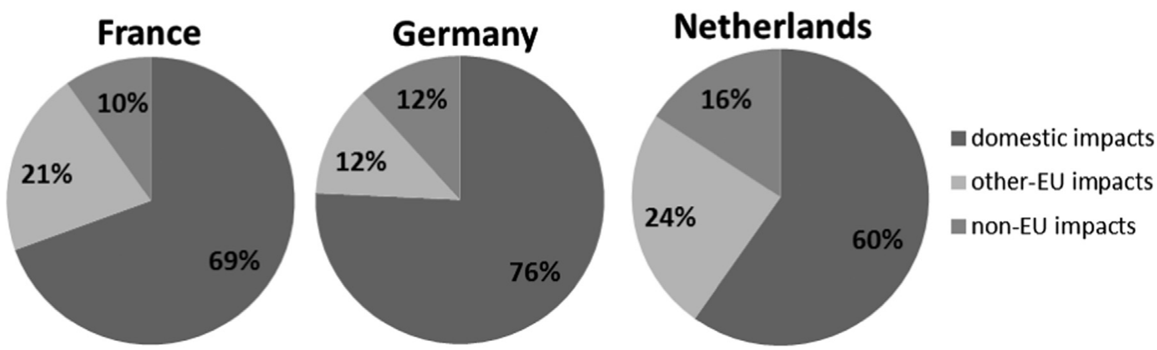

Fig. 1. Domestic and cross-border shares of value added generated by gas infrastructure investment.[6]

cluded from the higher impacts in both other EU countries and in non-EU countries, both for employment compensation and gross operating surplus. Austria comes in third close behind these countries, where in terms of other EU impact it is closer to the Netherlands and Belgium, whereas for non-EU impacts it is closer to the larger countries Germany and France. Although Austria is geographically nearer to non-EU countries than Belgium and The Netherlands, the fact that it is landlocked may explain this limited linkage to non-EU countries. Fig. 1 shows the same finding in an alternative representation; The Netherlands is more open, both towards other EU countries and non-EU countries than Germany or France. The share of non-EU spillovers from gas infrastructure investments is not far apart for these larger countries, but the share of domestic versus other EU linkages shows that France is more integrated within the rest of the EU in this respect than Germany is.

In Table 5 the impact in 'other EU' is presented in more detail. In the columns, the countries are represented that invest in gas infrastructure. In the rows the countries are listed where the largest value added impacts occur. These countries represent at least 86% of the impact in other EU countries. Germany turns out to be an important supplier of products and services used as intermediate inputs by the sectors to which investment expenditure is allocated for all five investors. Of the employment compensation impacts generated in other EU countries because of gas infrastructure investment in Austria, 47% goes to Germany. The impacts generated in Germany are smallest from the investments made in France, both for employment compensation (24%) and gross operating surplus (22%). Outside the investor countries, Italy and the UK both benefit relatively much from investments elsewhere. German investment has the lowest total percentages, so relatively much of their investment flows to other EU countries that are not represented in the table.

4.2. Employment

We now analyze the effects in terms of hours of employment generated, differentiated with respect to skill level. We discern the

Table 5
The impacts in other EU in more detail.

investor	Austria		Belgium		France		Germany		Netherlands	
Impact in:	ec	gos	ec	gos	ec	gos	ec	gos	ec	gos
Austria	–	–	2%	3%	2%	2%	8%	9%	2%	2%
Belgium	3%	3%	–	–	**10%**	**11%**	7%	7%	10%	**10%**
Czech Republic	3%	5%	2%	2%	1%	2%	6%	8%	2%	2%
France	6%	4%	**17%**	**13%**	–	–	**14%**	9%	10%	7%
Germany	**47%**	**44%**	**29%**	**30%**	**24%**	**22%**	–	–	**35%**	**35%**
Italy	**14%**	**10%**	**12%**	9%	**17%**	**13%**	**18%**	**13%**	9%	7%
Netherlands	3%	3%	**12%**	**12%**	**11%**	**10%**	6%	6%	–	–
Poland	2%	4%	2%	3%	1%	2%	5%	9%	2%	4%
Slovak Republic	2%	4%	0%	1%	0%	1%	2%	3%	0%	1%
Spain	2%	3%	4%	5%	8%	10%	5%	6%	4%	5%
Sweden	2%	2%	3%	3%	2%	2%	4%	4%	4%	4%
United Kingdom	6%	6%	**12%**	10%	**17%**	**16%**	**13%**	**10%**	**14%**	**12%**
Total	90%	88%	95%	92%	93%	91%	88%	86%	92%	89%

* ec=employment compensation, gos=gross operating surplus.
Values larger than 10% are in bold face. Values lower than 3.85% are in italic font. The value 3.85% is 100%/26, the percentage each country would be associated with in a completely equal distribution over all 26 EU partner countries. Only countries with at least one value over 3.85% are represented here.

Table 6
Employment generated by skill-level, in million hours.

	Low-skilled				Medium-skilled				High-skilled				Total
	Domestic	other EU	non-EU	Σ	Domestic	other EU	non-EU	Σ	Domestic	other EU	non-EU	Σ	(million hours)
Austria	5%	2%	13%	*20%*	26%	13%	15%	*54%*	14%	7%	4%	*26%*	26
Belgium	3%	2%	17%	*22%*	18%	13%	21%	*52%*	12%	8%	6%	*26%*	20
France	3%	1%	15%	*20%*	30%	9%	15%	*54%*	17%	6%	4%	*26%*	366
Germany	4%	1%	18%	*23%*	31%	7%	17%	*55%*	14%	4%	5%	*22%*	379
Netherlands	3%	2%	23%	*27%*	17%	9%	22%	*49%*	13%	6%	6%	*24%*	103

impact on hours of employment of high-skilled labor, medium-skilled labor, and low-skilled labor. The EXIOBASE data on different types of labor are in line with EU-KLEMS (http://www.euklems.net); high-skilled equals a university degree, medium-skilled: higher professional and vocational education (secondary level), lower-skilled: all up to lower secondary education.

Table 6 shows that the investment generates mainly medium-skilled job hours. Although the total impact on medium-skilled labor is quite similar for the different investors, there is clearly a difference in where the impact occurs. France and Germany are very much domestically focused. Belgium and the Netherlands have the highest percentages of impact in non-EU countries. Centrally located Austria has a relatively high other EU impact. Most strikingly is the opposite patterns shown for low-skilled and high-skilled employment generated. All investors generate relative much low-skilled labor in non-EU countries compared to the domestic and other EU impacts, whereas for high-skilled labor is primarily generated within the investing country. Of Belgian investment, only 33% of the labor hours generated is within the country itself. Of the cross-border impacts, 22% is in other European countries, and 44% is in non-EU countries. The employment impacts of The Netherlands are for 51% in non-EU countries, while Austria and France generate 32% and 34% of the job hours in countries outside the EU. As with the value added results, France and Germany keep most of the employment impact within their own borders, 50% and 49% respectively.

In Fig. 2, we depict the employment impacts by skill-level in relation to the geographical destination for France, Germany and The Netherlands. For all three countries, the distribution across skill-levels is rather similar, especially for the non-EU impacts. Only a few differences can be noted for the domestic and other EU impacts. In Germany, the share of medium-skilled employment hours generated in other EU countries is slightly higher than other countries at the expense of high-skilled labor. The largest difference in terms of labor composition is found for the domestic impacts. The Netherlands has the highest share of high-skilled labor impact of the three countries, whereas Dutch medium-skilled labor benefits least from investment in The Netherlands compared to the domestic impacts in the other two countries.

In Table 7, the impact in other EU countries is shown in more detail. The impacts in terms of employment hours are more diverse than the value added results. Still, Germany benefits relatively much from gas infrastructure investment in each of the four other investor countries as was the case for the value added impacts. Italy and the UK are again relatively much impacted, but in terms of employment hours, Czech Republic and Poland show sizeable impacts also. Austria creates relatively much impact, around a third of its other EU impacts, in Germany across all skill-levels. The reverse is not true; Germany has not much impact on Austrian employment. Austria is clearly more linked to various countries in Eastern Europe, whereas Germany's impacts are mostly concentrated in the Czech Republic and Poland.

As we focused on the distribution of the impacts, a larger or smaller value of investment expenditure will not change this distribution. However, changes in the allocation percentages of the types of expenditures to the sectors that supply the goods and services will have an impact. Different sectors have different links to other industries and to other countries. If the contribution of a certain sector increases or decreases compared to another sector, this will have an impact on the distribution. As already pointed out at the beginning, the less similar two industries are regarding their intermediate input pattern, in terms of industries delivering or countries exporting the inputs, the larger will be the differences regarding the impact.

5. Conclusions and policy recommendations

We estimate the cost-side impact of investments in gas transmission by quantifying the direct and indirect, national and international impacts on the basis of a multi-regional input-output (MRIO) model. First, we estimate the value of investment projects included in the Ten Year Network Development Plans (TYNDP). The overall budgets for the different plans are translated into gross fixed capital formation by the industries that manufacture the pipelines, compressor station elements, storage facilities, and interconnectors. The demand stimulus from investment is traced back through (inter)national value chains to the impact on value added and employment in each of the countries affected. The relative importance of the flows for the countries varies a lot. In terms of additional employment, compensation and gross value added the impacts show in general the same pattern, however, it is quite clear that for smaller countries, the intra-EU impacts are relatively large.

Our analysis strengthens the case for an EU-wide perspective of gas infrastructure investments. Policy makers at the EU-level already focus on developing an integrated international gas transmission network (European Union, 2015). Within this network, main connection routes may emerge. Given the large extension projects and the increased density of the EU gas network, forces are at play that may result in a shift in the supply and demand conditions that can be derived from these gas flows. Countries with large transit flows may be better able to ensure the security of supply. The same holds for countries with diversified sources and multiple interconnectors. Several countries have indicated they want to pursue a nodal function in this network. However, investing in the creation of a gas hub in each country is sub-optimal. Nevertheless, several national transmission operators focus on a role as regional hub. It usually is strongly supported by national governments in order to secure first mover advantages, develop comparative advantages, stimulate key sectors, and generate employment.

However, it is evident that several of the proposed large-scale infrastructural projects are mutually exclusive. For example, if a strong North-South connection is created in Germany connecting flows from Denmark to France, and alternative connection through The Netherlands and Belgium will be redundant. The main policy recommendation from our study is that an international, in our case European Union wide, focus regarding gas infrastructure investments is to be recommended: these investments need to be coordinated at such international level. The current national focus might lead to

[6] These percentages are derived from the same data underlying Table 4. Note that the percentages in Fig. 1 also include taxes distributed over domestic, other EU and non-EU.

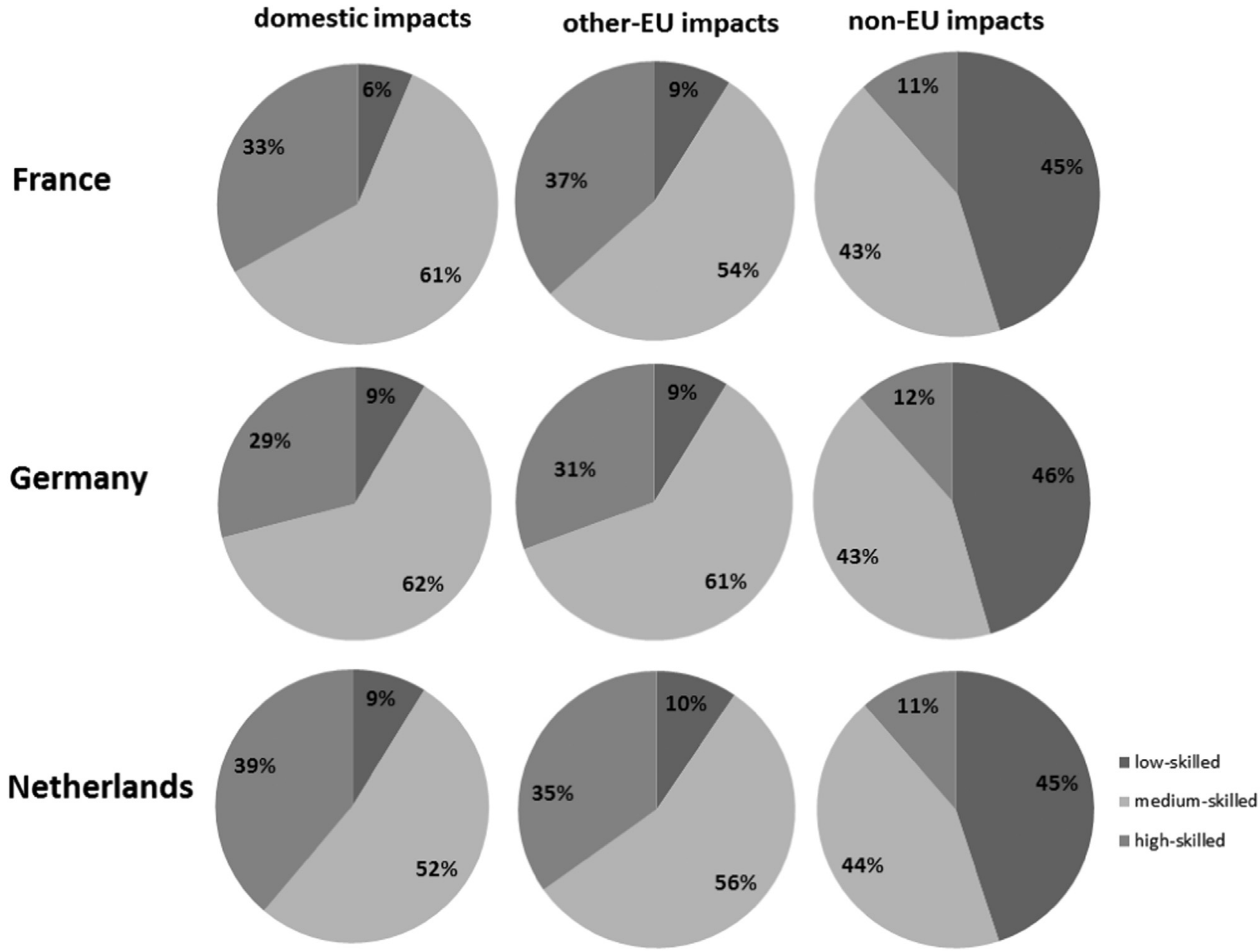

Fig. 2. Shares of employment hours by skill-level.

wasteful overinvestment in case gas infrastructure developments in other countries would remain being ignored. To establish which countries would optimally be the important nodes in the European network from a European Union perspective, we recommend a fully internationally focused investment analysis should be undertaken.

In this study, we suggest a practical approach to account for the cross-border effect of gas infrastructure investments. The methodology proposed by ENTSOG (see Section 2) only includes cross-border impacts after the project's implementation. We particularly focus on one component which is not yet included in this proposed methodology; assessing the cross-border impacts of investment expenditure itself. In this respect, our analysis contributes to a better understanding of the impacts along the international value chain of the expenditure related to alternative investment plans. Multi-regional input-output modeling can play a role in the assessment methodology as it provides detailed sector-level socio-economic impact estimates of the investments.

Table 7
Employment generated in other EU countries, by skill-level, in million hours.

investor	Austria			Belgium			France			Germany			The Netherlands		
impact in:	l-s†	m-s†	h-s†	l-s	m-s	h-s	l-s	m-s	h-s	l-s	m-s	h-s	l-s	m-s	h-s
Austria	–	–	–	2%	2%	2%	2%	2%	2%	7%	4%	5%	2%	2%	2%
Belgium	2%	1%	2%	–	–	–	6%	6%	8%	4%	3%	4%	7%	6%	8%
Czech Rep.	8%	**10%**	9%	4%	5%	5%	3%	4%	3%	**13%**	**15%**	**14%**	5%	6%	5%
France	3%	3%	4%	9%	**12%**	**15%**	–	–	–	5%	6%	9%	5%	6%	8%
Germany	**32%**	**28%**	**31%**	**23%**	**21%**	**21%**	**20%**	**18%**	**18%**	–	–	–	**27%**	**25%**	**25%**
Hungary	3%	7%	4%	1%	2%	2%	1%	2%	1%	3%	6%	4%	1%	2%	1%
Italy	8%	**11%**	**12%**	8%	**11%**	**12%**	**13%**	**18%**	**17%**	9%	**12%**	**14%**	6%	9%	10%
Netherlands	2%	1%	2%	**11%**	8%	10%	6%	5%	**10%**	4%	3%	4%	–	–	–
Poland	9%	**12%**	7%	7%	10%	6%	6%	8%	4%	**18%**	**22%**	**14%**	9%	**12%**	7%
Romania	9%	6%	5%	3%	2%	1%	5%	4%	3%	7%	5%	3%	4%	3%	2%
Slovak Rep.	5%	5%	5%	1%	2%	1%	1%	1%	1%	3%	4%	3%	2%	2%	1%
Spain	2%	2%	2%	6%	4%	4%	**10%**	9%	8%	5%	4%	4%	6%	4%	4%
UK	6%	4%	7%	**14%**	**10%**	**14%**	**16%**	**13%**	**18%**	9%	7%	**11%**	**15%**	**12%**	**17%**
Total	90%	91%	90%	90%	90%	92%	90%	90%	92%	87%	89%	89%	90%	89%	90%

† l-s=low-skilled, m-s= medium-skilled, h-s= high-skilled Values larger than 10% are in bold face. Values lower than 3.85% are in italic font. The value 3.85% is 100%/26, the percentage each country would be associated with in a completely equal distribution over all 26 EU partner countries. Only partners with at least one value over 3.85% are represented here.

We find that there are pronounced differences between countries regarding domestic value added embodied in investment expenditure and cross-border leakages to other countries. When looking at the distribution of the intra-EU cross-border spillovers, it is clear that the cross-border impacts are concentrated in a few countries. We also show the cross-border impacts in terms of employment compensation, and in terms of hours of employment. Under full employment, the impacts on employment and the subsequent wage effects will cancel out. However, unemployment rates are just starting to recover from the global financial crisis of 2007/2008 and these impacts should therefore be considered.

This paper highlights the additional information that can be attained from performing an impact analysis through multi-regional input-output modeling. The drawbacks of this method are related to the assumption of fixed input coefficients (both the technology and the trade coefficients) and the limited role of prices. However, most expenditure related to an investment project take place within a couple of years, so rigidity in the input coefficients can be defended. Alternatively, one could consider expanding the analysis with the help of spatial computable general equilibrium modeling. Computable general equilibrium models are a class of economic models that use actual economic data to estimate how an economy might react to changes in policy, technology or other external factors. Another limitation is that our study focuses on one important, and often neglected, element of a complete investment assessment. We do not consider the benefits of the investment and the impacts due to operation, and our results therefore do not directly support the investment decision. Further, we did not account for market power and uncertainty. To extend the cost-side scope, a comparable study could be undertaken after defining the yearly expenses of operation and maintenance. However, as the bulk of gas infrastructure expenditures are related to the initial investment, our study gives a good first impression of the distribution of the economic impacts of the investment. After the investment project is carried out, the operation and maintenance costs are relatively low. Of course, these should be taken into account when deciding upon alternative investment proposals.

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Appendix A. Supplementary material

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.enpol.2017.05.010.

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