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Abstract

In the European Union's (EU) gas transmission system the relative prices of short-term transmission capacities are specified via factors called multipliers. Previous literature indicates that, depending on the region, there exist optimal multiplier levels that can allow transport tariffs to be reduced and consumer surplus to be maximised. However, since multiplier levels in a region can cause externalities in other regions, it is not clear if individually optimal multipliers in regions would also lead to a joint optimum. In order to provide insight into optimal multiplier levels in different regions in the EU we use a numerical optimisation model to simulate the European gas dispatch. We analyse the effects of multipliers in regional clusters; identify and differentiate between internal and external effects. We show that those effects and the individually optimal multiplier levels vary among regions depending on factors such as demand structure and storage availability. Our analysis confirms that individually adjusting multipliers in a region can cause external effects in other regions, depending largely on the location along the gas transport chain. With 92 million EUR per year, the potential EU consumer surplus gains with individually optimal multipliers is found to be 9% lower than the maximum achievable EU consumer surplus gains via multipliers. Hence, we show that because of the external effects of multipliers, individually optimal multipliers do not result in the EU optimum.

Keywords: gas transmission networks, entry-exit tariffs, multipliers, numerical optimisation model

JEL classification: L51, L95, Q41

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1. Introduction

When a region decides on network pricing, different circumstances lead to different optimal tariff settings. In this context, two questions arise in particular: First, how does the optimal tariff setting vary among different regions? And second, because networks connect multiple regions, do the individual regional optima contribute to the joint optimum or do they cause negative externalities such that only a superordinate regulator can achieve the joint optimum?

These questions also arise in the case of the gas transmission network of the European Union (EU), which connect different regional networks called market areas. To finance the networks in the individual market areas the transmission system operators (TSO) charge transmission tariffs. Regulation (EC) 2009/715 introduced a tariff regime that obligates gas traders to book entry and exit capacity when transporting gas from one market area into another.[1] In this context, traders are offered capacity products with varying run-times: long-term (LT) yearly products, and the short-term (ST), quarterly, monthly, daily, and intra-daily products. Regulation (EC) 2009/715 allows each national regulator to define their relative price of ST versus LT capacities within specified ranges. The relative prices of the ST capacities are defined by factors called multipliers, i.e, the ST capacity prices are equal to the LT capacity price multiplied by the corresponding multipliers. The levels of those multipliers are found to affect the proportion of ST to LT capacity booking and consequently impact the infrastructure utilisation, prices, and welfare distribution (Çam and Lencz, 2021).

The effects of multipliers in the EU gas system are expected to become more amplified in the coming decades. A major contributor in this regard will be the expiration of old long-term bookings.[2] For instance, between 2016 and 2019, about 80% of the total capacity used by traders stemmed from existing long-term bookings which were undertaken before the current system of LT and ST capacities were introduced (ACER, 2020b). For some connections between market areas these old long-term bookings exceeded the demand for capacity, inducing marginal transmission costs of zero. As those old bookings are about to expire over the period 2020–2035, the prevalent situation of overbooked capacities, and the sunk costs associated with them, will start disappearing.[3] In the future, the cost of new bookings will represent the actual opportunity costs,

[1] Capacities are booked in capacity auctions performed on trading platforms (such as PRISMA, GSA, RBP) in which the reserve prices correspond to the transmission tariffs. In a large share of the capacity auctions in the EU, demand for capacity remains below the offered capacity (ACER, 2019b). In the remaining cases where demand for capacity exceeds the offered capacity, a congestion premium occurs.

[2] A large share of current transmission capacity is booked by previous LT bookings at a time when ST capacity products did not exist. Those long-term bookings covered usually multiple years upfront.

[3] ACER (2020b) states that more than a third of such old long-term capacity bookings in place at the end of 2019 will have expired by the end of 2023, while more than 60% of them will no longer be in place by 2028. Old long-term contracts will almost completely expire by the end of 2035.

a development that is also mentioned in a study commissioned by the EU on gas market design (EY and REKK, 2018).

Our paper is strongly motivated by Çam and Lencz (2021), which has analysed the effects of multipliers on gas infrastructure utilisation, prices, and welfare using a theoretical model within a stylised setting. Applying the stylised theoretical model with two time periods and two regions, where pipeline and storage capacities were assumed to be unlimited, Çam and Lencz (2021) showed that a multiplier value of 1 leads to highest total welfare and multipliers greater than 1 cause welfare loss. The paper found that higher multipliers can nevertheless maximise the consumer surplus depending on the cost of gas transport and storage. This indicates that the consumer-surplus-maximising multiplier levels can differ between individual regions. In this respect, it is plausible to assume that EU would rather aim to maximise the consumer surplus instead of total welfare, since a substantial share of the surpluses generated by producers, storage operators, and traders arise outside the EU. Hence, we refer to consumer-surplus-maximising multipliers as optimal multipliers.

In a more complex setting with multiple time periods, multiple regions and limited infrastructure capacities—such as in the case of the EU gas transmission system—there are additional aspects that would influence the optimal multiplier levels. For instance, the temporal profile of gas demand in a region could substantially influence the proportion of LT to ST bookings. In countries that have relatively flat demand profiles throughout the year, gas imports and bookings would be at similar levels during winter and summer, allowing for a very high share of LT bookings. In this case, effects of multipliers can be limited if LT bookings are preferred irrespective of the multiplier levels. In contrast, in regions with highly seasonal demand but limited storage capacities, booking ST capacities could be preferred. With sufficiently high multipliers, booking ST capacities to cover the peak winter demand could eventually become more expensive than booking only LT capacity. In this case, traders could choose to book only LT capacity while letting some capacity during the summer months remain unused. Multipliers could therefore exacerbate this type of booking patterns in such regions. Hence, due to having different features as mentioned above, individual regions can be affected differently by multipliers and can have varying optimal multiplier levels. In order to determine the individually optimal multiplier levels, it is necessary to represent these regional features and analyse the internal effects of multipliers in a more realistic model setting.

In addition to inducing internal effects, multiplier levels in a region can cause externalities in other regions due to the fact that gas is transported through different regions. It is commonly acknowledged that tariff adjustments in a country can cause external effects in another country within the EU gas network, depending on their location along the gas transport chain. For instance, Cervigni et al. (2019) points out that national regulators can impact the sharing of transport costs between the consumers of individual countries through their selection of entry and exit tariff levels. It is argued that a transit country can transfer the cost of transmission investments, which largely benefit its own citizens, to a downstream country's consumers via its choice of entry-exit tariffs at the interconectors. Similarly, Petrov et al. (2019) mentions that the tariff adjustments in Germany (in the context of the REGENT regulation) can cause significant costs in the neighbouring market areas of Czechia and Italy when the costs of the network tariff change are passed on to the gas consumers in these regions. Since multipliers influence the relative tariff levels of ST capacities, it is therefore natural to think that they can also cause external effects. Therefore, it is not clear whether a multiplier level that is optimal for a region would also be optimal for the whole system. If not, then the question arises whether the individual multipliers should rather be set by a superordinate regulator. These questions can be answered by analysing the external effects of multipliers in a more realistic model setting that considers the spatial characteristics of the gas network.

In order to identify the internal and external effects of multipliers in different regions in the EU, and to provide insight into optimal multiplier levels, we use for our analysis the numerical simulation model, TIGER.[4] The TIGER model optimises the gas dispatch in Europe under perfect foresight and perfect competition. We extend the model by including the costs of capacity booking and specifying the necessary restrictions. The model has a monthly temporal resolution, where yearly, quarterly, and monthly capacity products are offered. Six regional clusters of countries are considered: Central Europe, British Isles, South East Europe, Italy, Iberia, and Baltics. The aggregation of countries takes into account the geographical location of individual countries, existence of interconnecting pipelines, and at what stage a country lies in the gas transport chain (i.e. transit, downstream or peripheral). We simulate the gas dispatch for the gas year of 2017–2018 and analyse and quantify the effects of the multipliers on infrastructure utilisation, prices, and welfare distribution.

We identify significant regional effects with regards to multipliers. Our analysis shows that in regions characterised by relatively flat gas demand profiles (such as Spain and Portugal), multipliers do not have notable effects, as LT capacities are preferred irrespective of the multiplier levels. In contrast, in regions that have a highly volatile demand but limited supply flexibility via storages (e.g. Britain), multipliers can have a strong impact on the base and peak prices, as they determine the marginal supply costs. Therefore,

[4]A detailed formulation of the model can be found in Lochner (2012).

when specifying multipliers in such regions, regulators would also have to consider the strong distributional effect on the allocation of consumer surplus between the base and peak consumers.

We find that adjusting multipliers in a region can cause external effects in other regions. Consumer surplus gains in transit regions (e.g. Central Europe) due to multipliers are passed on to regions that lie downstream (e.g. Italy). We show that downstream regions can influence the transit regions indirectly by affecting the storage utilisation in the transit regions. Peripheral regions (e.g. South East Europe), which receive their gas directly from the production regions, can also influence other regions by affecting procurement prices in the production regions. Because of those external effects of multipliers, we find that individually optimal multipliers do not lead to the maximum total EU consumer surplus. Despite that, when comparing the gains in consumer surplus from applying multipliers, individually optimal multipliers result in about 12% higher consumer surplus gains in the EU compared to an optimal uniform EU-wide multiplier level. Hence, the current EU regulation of specifying allowed multipliers in ranges instead of absolute values is appropriate and can increase the EU consumer surplus. However, we show that the surplus gains achieved by individually optimal multipliers are about 9% lower than the maximum achievable EU consumer surplus gains by multipliers. This indicates that letting national regulators set the multipliers may not lead to an EU optimum.

Our paper is related to two streams of literature. The first relevant literature stream includes the analysis or modelling of capacity bookings in the European gas markets. Keller et al. (2019) analyses historical capacity bookings in German gas market areas. Using historical data from the PRISMA capacity booking platform for the year 2016, the paper shows that network users make efficient booking decisions and choose transport alternatives with the lowest tariffs. Grimm et al. (2019) presents a mathematical framework depicting the entry-exit gas markets. The paper shows that, under perfect competition, the booking and nomination decisions can be analysed in a single level and that this aggregated market level has a unique equilibrium. Dueñas et al. (2015) develops a combined gas-electricity model, which simulates the gas procurement and capacity booking of a gas-fired generation plant under residual demand uncertainty. The analysis shows that the capacity booking behaviour of the individual generator is significantly affected by how risk-averse it is.

The second relevant stream of literature analyses gas markets using numerical simulations based on cost minimisation models. It is common within this literature stream to analyse the effects of various developments on the gas infrastructure, identify possible bottlenecks and simulate potential effects on prices. In this context, previous versions of the TIGER model are applied to address various questions (Lochner, 2011a,b, 2012; Dieckhöner, 2012; Dieckhöner et al., 2013). Dieckhöner et al. (2013) for instance simulates the European gas dispatch under different scenarios and analyses the level of market integration and potential congestions. Using a similar model, Hauser et al. (2019) investigates whether increasing natural gas demand in the power sector could cause congestions in the German gas grid. Eser et al. (2019) combines a Monte-Carlo simulation model for annual gas sourcing with a cost minimisation model that optimises the detailed hourly gas dispatch.

The contribution of our paper with regards to the above-mentioned literature can be summarised as follows: The capacity booking system and the effects of multipliers have not been yet analysed in the literature using numerical simulation models of gas dispatch. Thus, by integrating capacity booking into a cost minimisation model and simulating the European gas dispatch, we show that the level of multipliers can significantly impact infrastructure utilisation, prices, and welfare distribution. We identify and differentiate between internal and external effects of multipliers over a range of regional clusters, and provide insight into those effects that influence the optimal multiplier levels in the EU.

2. Identifying the main drivers

When a region adjusts its multipliers, it can affect the gas dispatch, regional prices and welfare within that region. This is shown by Çam and Lencz (2021) using a stylised model containing one demand region and two periods. The paper also finds that optimal multiplier levels for maximising consumer surplus can vary depending on the storage and transport costs. In addition, demand structures among regions vary, which can also play an important role on the effects of multipliers. It is therefore natural to assume that different regions could be affected differently from multipliers and would have varying optimal levels of multipliers. However, it is not clear if individually optimal multipliers would also be optimal for the whole system, since multipliers can additionally cause external effects. This would imply that the adjustment of multipliers in one region can affect market results in other regions. In this section, building upon the theoretical findings of Çam and Lencz (2021), we extend the discussion on internal effects of multipliers by highlighting several aspects which were not considered in that paper. We then present some intuition on the potential external effects of multipliers.

2.1. Internal effects of multipliers

A multiplier value of 1 results in a pricing regime similar to commodity pricing. In this case, traders, who transport gas from one market area into another, would book a combination of ST capacities that would perfectly satisfy their demand profile and pay for the exact amount of volumes they transported.[5] Higher multipliers incentivise traders to avoid ST capacities, encouraging them to book yearly (LT) capacities and flatten their winter and summer transports by increasingly storing gas in the demand regions. When multipliers reach a certain threshold, traders book solely LT capacity and behave as being exposed to a capacity pricing regime, irrespective of the costs of LT capacity and storage. Applying the finding from Çam and Lencz (2021) to the twelve-period model used in our current analysis, such multipliers are found to be 4 for quarterly and 12 for monthly capacity (see Lemma Appendix A.1 for proof).

Çam and Lencz (2021) shows that, due to the relative costs of transmission and storage, in the majority of the situations already lower multipliers can induce a capacity pricing regime. This means that traders would book only LT capacity to cover their yearly peak demand, resulting in them paying for the capacity rather than the energy.[6] When only LT capacity is booked, increasing the multipliers does not affect market results. This is because LT tariffs are not affected since TSO revenues remain unchanged.

According to Çam and Lencz (2021), multipliers also affect gas prices, which in turn impact overall consumer surplus as well as its distribution among base and peak consumers. In this case, the minimum demand level is assigned to base consumers, which is constant throughout the considered time periods. Any demand that is above this minimum level is then defined as peak demand and is attributed to peak consumers.

When storage capacity is abundant, gas prices are affected by the LT transmission and storage tariffs. When multipliers are increased, TSOs can charge higher tariffs for ST capacity, allowing them to reduce the price for LT capacity. Thereby, gas prices decrease such that peak and base consumers profit. However, this effect is counteracted by bookings shifting from ST towards LT capacity. When supply flexibility from storages is restricted, Çam and Lencz (2021) finds that peak prices are determined by the price for short-term capacity. Hence, with increasing multipliers, peak prices increase. Off-peak prices on the other hand are found to decrease, reinforcing the distributional effect between base and peak consumers.

The above-mentioned findings are derived from the analysis presented in Çam and Lencz (2021), which uses a stylised theoretical model with two regions and two time periods. However, additional internal effects with respect to multipliers are to be expected in a more complex setting with multiple regions, multiple time periods, and more than one type of ST capacity product—such as in the case of the EU. It is to be expected

[5] Multiplier levels below 1 would neither change the optimisation rationale of the traders nor the market results (see Çam and Lencz (2021) for a more detailed discussion). For this reason, and since the EU regulation NC TAR 2017 does not allow for multipliers below 1, the minimum multiplier value considered in this paper is equal to 1.

[6] For a more detailed discussion of capacity pricing and commodity pricing aspects of multipliers, please see Çam and Lencz (2021).

that in regions with relatively flat demand profiles comparably less ST capacities would be booked, making the effect of multipliers limited. In contrast, in regions with volatile demand structures, multipliers would have a much higher impact on the proportion of bookings and, consequently, on the prices and welfare.

An additional effect that would be observed in a more realistic setting would be related to the costs of gas storages. Çam and Lencz (2021) assumes constant storage costs for the stylised model. In reality, gas storages have varying operating costs depending on their physical characteristics (Neumann and Zachmann, 2009). With higher multipliers, as more of the storage capacities are used, the more expensive storage types would be utilised. This means that marginal cost of storage would increase, causing higher temporal spreads in regional prices. While increased spreads would not affect the overall costs for base consumers, peak consumers would end up paying more.

The fact that storage capacities as well as the injection/withdrawal rates are limited in reality, which were assumed to be unlimited in Çam and Lencz (2021), can result in multipliers causing additional effects. When supply flexibility from storage capacities is exhausted, the seasonal spread in regional prices is not defined by the cost of storage, but by the cost of importing gas in the short term, which increases the temporal spread in prices even further. In such a setting, booking solely LT capacity while letting some seasonal capacity remain unused[7] can be optimal when multipliers reach a certain threshold (see Lemma Appendix A.2 for proof)—an effect which cannot be observed in the simplified two-period model with unlimited capacities. Overall, as outlined above, additional internal effects due to multipliers would be observed in a more complex setting.

2.2. *External effects of multipliers*

When regions adjust their multiplier levels they may also affect other regions. To what extent a multiplier adjustment would have an external effect largely depends on how a region is located along the gas transport chain. In this context, a region can be classified into one of the four region types, as schematically shown in Figure 1: production, transit, downstream, and peripheral. Gas is transported from a production region (e.g. Russia) through a transit region (e.g. Central Europe) to downstream regions (e.g. Italy). Countries which do not lie downstream of a transit region but receive their gas directly from the production region can be referred to as peripheral regions (e.g. Baltic countries). While a transit region imports and re-exports substantial amount of gas volumes, downstream and peripheral regions import but do not re-export significant volumes.

[7] Letting some booked capacity remain unused is also referred to as capacity wasting.

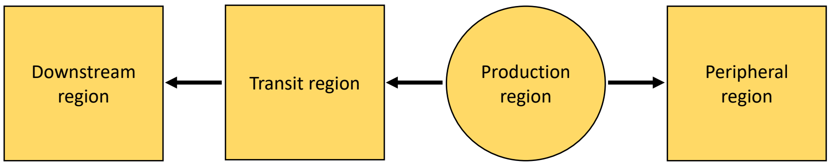


Figure 1: Schematic representation of the types of regions

When traders transport gas through several borders, tariffs are accumulated, which is commonly referred to as tariff pancaking (EY and REKK, 2018). Due to pancaking, downstream regions are generally affected by the tariff structures and the ensuing effects over the whole transport chain. Therefore, price and welfare effects caused by changes in multiplier levels in transit regions would also likely be passed on to the connected downstream regions. Additionally, traders who want their gas to be shipped from a transit region to a downstream region have to procure capacity for exiting the transit region. Increasing multipliers in the transit region would therefore incentivise traders to book long-term and to flatten transports from the transit region to downstream regions. As a result, at what levels the multipliers are set in the transit regions can create direct external effects on the downstream regions. In contrast, any changes in multiplier levels in the downstream or peripheral regions would not have direct external effects on other regions, as changes in tariffs are not passed through to other regions. Nevertheless, it is possible that multiplier levels in any region can also cause external effects in other regions indirectly. By influencing the seasonal gas procurement patterns, multipliers can affect the temporal spreads in the regions where gas is imported from, as also shown in Çam and Lencz (2021). This would in turn influence the price levels in other regions which import gas from the same region.

Due to the above-mentioned internal and external effects, it is likely that different regions in the EU could be affected differently from multipliers, hence having varying optimal levels of multipliers. Then the question arises whether the individually optimal multipliers would also be optimal for the whole EU, since countries individually specifying multipliers could cause externalities in other countries. In this paper, we aim to address these questions with the help of a gas dispatch optimisation model.

3. Methodology

3.1. Model

To analyse the effects of multipliers in the EU we apply and extend the TIGER model developed at the Institute of Energy Economics (EWI) at the University of Cologne.[8] TIGER simulates the gas dispatch

[8]For a comprehensive formulation of the model see Lochner (2012).

in Europe in a setting with perfect competition and perfect foresight. The model is formulated as a linear optimisation problem with the objective function of minimising total system costs. It models the producers, consumers, traders and storage operators and includes the production capacities, demand regions, pipeline network, gas storages and LNG terminals.

The TIGER model is extended by including the costs of capacity booking in the objective function and specifying the necessary restrictions. A complete notation of the model extension is presented in Table 1.

Table 1: Notation used in the TIGER model extension

Sets	$t \in T$	Points in time
	$i, j \in N$	Nodes in the pipeline network
	$p \in P$	Capacity products (defined by duration, start and end date)
Parameters	m_p	Tariff multiplier per capacity product
	$\tau_{i,j}$	Base entry/exit tariff
Variables	$C^{Tra}_{t,i,j,p}$	TSO revenue (Gas transport costs)
	$CB_{t,i,j,p}$	Booked capacities per product type
	$TR^{CB}_{t,i,j,p}$	Volumes transported per product type
	$TR_{t,i,j}$	Total volumes transported
	$CB^{Map}_{i,j,p}$	Capacity booking mapping parameter

The objective function corresponds to minimisation of total costs (C^{Tot}). Total costs are equal to the sum of production costs (C^{Pro}), transport costs (C^{Tra}), storage costs (C^{Sto}) and costs associated with LNG imports and regasification (C^{LNG}).

$$\min C^{Tot} = C^{Pro} + C^{Tra} + C^{Sto} + C^{LNG} \tag{1}$$

Gas transport costs at time t from node i to j for a particular capacity product p equal the level of booked capacities $CB_{t,i,j,p}$ multiplied with the base entry-exit tariff $\tau_{i,j}$ and the corresponding product multiplier m_p. Like in the EU, traders have to procure entry and exit capacity when transporting gas between market areas where entry-exit tariffs are applied.[9] Furthermore, we assume storage operators to be fully exempt from transmission tariffs when withdrawing or injecting gas in the transmission network.[10]

[9] In the EU gas markets, traders are able to trade booked capacities in secondary markets. We assume in our analysis these secondary markets to be perfect. Therefore, under the model assumption of perfect foresight, the total booked capacities of individual traders would be identical to the booked capacities of a single competitive trader who faces the cumulative demand of all these traders. For a detailed discussion of secondary markets see Çam and Lencz (2021).

[10] Storages are commonly exempted from transmission tariffs in the EU to a varying extent with the goal of inducing positive externalities such as reducing pipeline investment costs and increasing security of supply (ACER, 2019a). For example, several

$$C^{Tra}_{t,i,j,p} = CB_{t,i,j,p} \cdot \tau_{i,j} \cdot m_p \tag{2}$$

TSOs are regulated entities and are allowed certain revenue caps. If adjusting the multipliers causes the revenues of a TSO to change, then the TSO would adjust the entry-exit tariffs accordingly to reach the same revenue cap. This fact is considered in our analysis. As each TSO's revenue should be independent from the multipliers applied, the base entry-exit tariff $\tau_{i,j}$ has to be adjusted such that a TSO's revenue (C^{Tra}) for each entry-exit point remains constant. This results in a quadratic function that cannot be solved in a linear model. Therefore, an iterative approach is applied to solve the model. In the first run, the $\tau_{i,j}$ is kept constant, resulting in increased TSO revenue for high multipliers. In the next iteration $\tau_{i,j}$ is adjusted in order to reach the intended TSO revenue for each multiplier level. As the adjusted tariff levels may result in an adjusted booking behaviour, the procedure is repeated until the revenues of all TSOs equal the intended individual levels.[11]

Booked capacities at each entry-exit pipeline are required to be greater than or equal to the transported volumes associated with the particular capacity product (Equation 3). Each capacity product (e.g. quarterly capacity for October, November and December) is valid only in its dedicated time period. (e.g. $t = 1, 2, 3$). Therefore, for the model with monthly resolution, one yearly, four quarterly and twelve monthly capacity products are offered for each entry-exit point.

$$CB_{t,i,j,p} \geq TR^{CB}_{t,i,j,p} \tag{3}$$

To ensure that each capacity booking is booked with the same level of capacity for the whole period it is valid in, a mapping equation is introduced as in Equation 4. This equation forces the booked capacities ($CB_{t,i,j,p}$) to be equal to the same value for each t it is valid in.

$$CB_{t,i,j,p} = cb^{Map}_{i,j,p} \tag{4}$$

Finally, the physically transported volumes on a pipeline must be equal to the sum of flows per capacity products.

$$TR_{t,i,j} = \sum_{p} TR^{CB}_{t,i,j,p} \tag{5}$$

EU countries grant full exemption (e.g. Spain and Denmark). Storages are exempted by at least 50% due to NC TAR regulation in other countries; however, most countries apply higher exemptions (ENTSOG, 2019).

[11] Due to the convexity of the problem the converged solution is a global optimum.

3.2. Assumptions and data

For the purposes of this paper, the TIGER model is adjusted with regards to its spatial resolution where six regions are considered in order to be able to identify robust regional effects. The regional aggregation takes into account the geographical location of individual countries, existence of pipelines between them and whether a country is transit, downstream or peripheral. A transit country imports gas from a production region and re-exports significant volumes of gas to a downstream region. A downstream country imports from the transit region but does not re-export significant volumes. A peripheral country imports directly from the production region, but does not import significant volumes from a transit region and also does not re-export. Hence, despite the lower spatial resolution, the aggregation aims to represent the inter-regional gas flow patterns in a realistic manner. The spatial structure of the model as well as the considered regions and the countries they include can be seen in Figure 2.

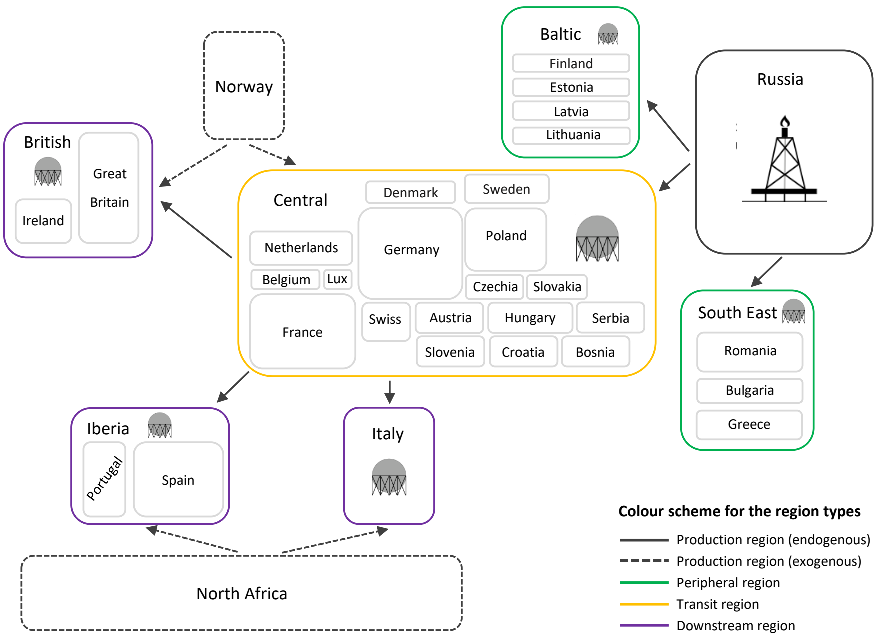


Figure 2: Schematic representation of the spatial model structure

The transit Central region receives gas from the Norwegian and Russian production regions and can transport gas to southern downstream regions such as Italy and Iberia. Those regions also receive gas over North Africa. The downstream British region is connected to Norway and the Central region. The peripheral Baltic and the South East regions receive pipeline gas only from the Russian production region.

Furthermore, all demand regions can import gas through their LNG regasification terminals. All demand regions have gas storage as well.

The model covers the historical gas year of 2017–2018, which starts on 1. October 2017 and ends on 30. September 2018. The gas year of 2017–2018 is chosen due to being the most recent gas year with publicly available data at the time of our analysis.[12] The model has a monthly temporal resolution. Correspondingly, yearly, quarterly and monthly capacity products are offered in the model. We assume that traders book their capacity in the analysed year. Historical capacity bookings are not considered, which allows us to assess the effects of multipliers more generally.[13]

The existing pipeline network, storages and LNG import capacities of 2018 are considered. The pipelines connecting individual regions are assigned their historical capacities based on TSO information and ENTSOG data for pipelines (ENTSOG, 2019). Within regions, pipeline capacities are assumed to be not restricted.[14]

Storage data, such as maximum storage volume as well as maximum injection and withdrawal rates for all storages in Europe, is based on Gas Infrastructure Europe (GIE, 2018) as well as storage operators' data. Similarly, data for LNG import terminals are obtained from ENTSOG and GIE LNG map (GIE, 2019). Thereby, LNG import, regasification and storage capacities are considered. The costs for storing gas are based on several studies (Redpoint, 2012; Le Fevre, 2013; Enervis, 2012) and consider the cost variation among different types of storages. We assume linear increasing marginal costs for storages, implementing it into the model as a step-wise linear function. Tariffs for the entry-exit zones are historical values observed in 2018 and are acquired from ACER (2019a).

Gas demand is assumed to be perfectly inelastic and is specified as an exogenous parameter. Historical country-level consumption data for the analysed period is used.[15] The Russian production region is the only flexible gas producer in the model. The Russian supply function to Europe is assumed to be linear increasing and is integrated into the model as a step-wise linear function.[16] Annual production capacities for other producers are assumed to be equal to their historical production levels observed in 2018 (BP, 2019) and are specified as exogenous parameters.

[12] The methodology is nevertheless not only applicable to different gas years but can also consider multiple consecutive years. Optimising multiple consecutive years would not change the rationale of the model since long-term capacity booking decisions are made on a yearly scale.

[13] This situation will be more prevalent from the year 2035 onward when historical long-term capacity bookings are almost completely expired (ACER, 2020b).

[14] The majority of the interconnection points in the EU are physically not congested, making this assumption plausible. According to ACER (2020a), physical congestion was likely to have happened in 2019 only in the 7 interconnection points among the 239 interconnection points considered in the study.

[15] Consumption data is sourced from EUROSTAT and websites of TSOs.

[16] The cost function is calibrated with respect to historical import volumes and prices and implicitly considers the transmission costs to Ukraine and Belarus. See Appendix B for the reference case and model validation.

The model considers a simplified LNG supply structure due to several reasons. The previously explained iterative approach to have constant TSO revenues requires yearly import and export levels to be unaffected by changes in multipliers, since otherwise TSO revenues would not converge. If LNG provision would be modelled as in the case of Russian supply, the level of LNG and Russian supply would be affected by multiplier levels. This would in turn result in yearly import and export levels to vary and prevent the model results to converge. Therefore, LNG imports are modelled in the following manner: While yearly LNG imports are fixed to historical levels, LNG imports are allowed to be shifted within the year. For example, if high multipliers incentivise flatter pipeline import profiles, then LNG imports can be shifted to months with high gas demand. Such shifts of LNG imports are associated with costs. Hence, the stronger the deviation from the historical import profile, the higher the associated costs.

4. Results

In this section, we investigate the internal and external effects of multipliers. For this purpose, we apply the model presented in Section 3 and optimise the gas dispatch with different multiplier levels. The multiplier levels ($m1$, $m2$, ..., $m10$) we chose for the quarterly and monthly capacity products for the analysis are presented in Table 2. The quarterly and monthly multiplier pairs used in this analysis are derived with an exponential function in order to represent a realistic range of the currently applied multiplier levels in the EU while also including the extreme levels that per definition induce commodity or capacity pricing.[17] We take the German multiplier levels ($m4$) according to the BEATE regulation as reference, which are also representative of the EU average of multipliers (ENTSOG, 2018).

Note that the multiplier level $m1$ corresponds to the case of commodity pricing, as both products have a multiplier of 1. The multiplier level $m10$, where the quarterly multiplier is greater than 4 and the monthly multiplier is greater than 12, corresponds to capacity pricing. From 01.01.2019 onward the EU regulation 2017/459 limits quarterly and monthly multipliers to 1.5; therefore, the $m5$ level represents the maximum allowed multipliers in the EU.

[17] The formula used for deriving the multiplier pairs is as follows: $m_n = (m_{n-1})1.88 + 1$ for $n \geq 3$, where n is the multiplier pair number $n \in \{1, 2, ..., 10\}$. The m_2 level is specified manually as 1.03 for the quarterly product and as 1.07 for the monthly product.

Table 2: The chosen multiplier levels for the analysis

	Quarterly	Monthly
$m1$ (commodity pricing)	1.00	1.00
$m2$	1.03	1.07
$m3$	1.05	1.13
$m4$ (default)	1.10	1.25
$m5$	1.19	1.47
$m6$	1.35	1.88
$m7$	1.66	2.66
$m8$	2.25	4.12
$m9$	3.35	6.87
$m10$ (capacity pricing)	5.42	12.04

In order for the results to have explanatory power, the model is first validated comparing the simulated prices, import volumes, and storage utilisation with the historical values observed over the considered time period. For this purpose, uniform multipliers equal to the default BEATE levels are assumed for the whole EU. Since many countries in the EU have multipliers similar to the BEATE levels, this is a realistic approximation. Results for model validation are presented in Appendix B.

If a region individually adjusts its multipliers, it induces internal effects in the region itself. However, as highlighted in Section 2, it is possible for it to cause external effects on other regions. In order to identify those internal and external effects in this section we first consider a case where regions individually and independently adjust their own multiplier levels.

4.1. Internal effects

In a first step we investigate the internal effects of multipliers. For this purpose, we vary the multipliers in each of the six regions individually while keeping the multipliers in the other regions constant.[18] The internal effects in each region on capacity bookings, infrastructure utilisation, prices and consumer surplus are analysed.

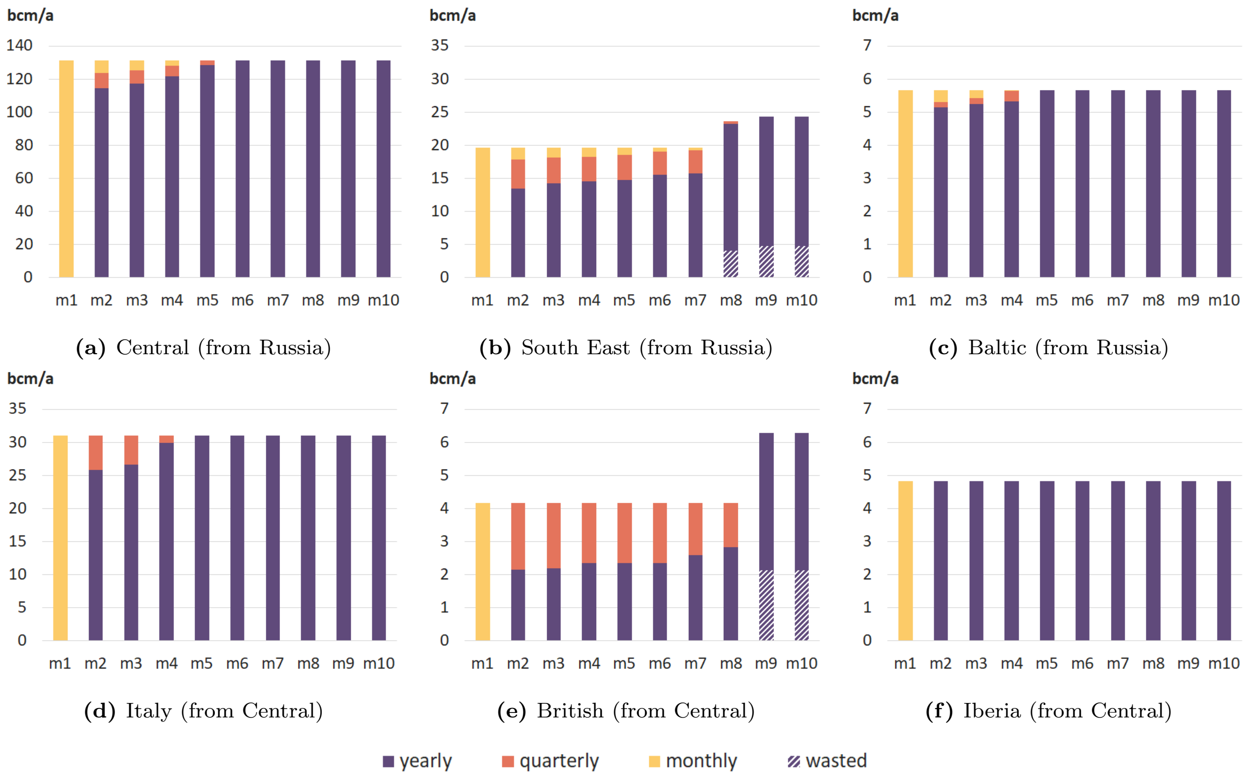
4.1.1. Capacity bookings

The change in the volumes of booked capacities with respect to varying multipliers in the considered regions is plotted in Figure 3. The absolute height of the bar charts represent the total booked capacities, corresponding to the sum of yearly, quarterly and monthly bookings. It can be seen that when regions individually increase their multipliers, the share of ST bookings (i.e. monthly and quarterly) in these regions decreases, while the proportion of yearly bookings increases. This is as expected, since higher multipliers

[18] Multipliers are fixed to the default $m4$ level as this represents the average multipliers in the EU according to ENTSOG (2018).

make ST capacities proportionally more expensive and incentivise the booking of LT capacities instead. It is also observed that when multipliers reach high enough levels, such as the $m6$ level in Central, they indirectly induce a capacity pricing regime and cause only LT capacities to be booked. The individual level of multipliers that induce capacity pricing differ among the regions. For example, while a higher multiplier level of $m9$ causes capacity pricing in South East, a lower level of $m5$ is enough to cause capacity pricing in the Baltic region and Italy. These findings are in line with the theoretical findings of Çam and Lencz (2021).

Note that in South East and the British region, traders waste LT capacity when multipliers reach $m8$ and $m9$, respectively. This is because in those regions traders cannot fully flatten their monthly imports due to limited storage capacities, resulting in some LT capacity to remain unused, i.e. to be wasted (shown with dashed lines in the figure). Hence, unlike the theoretical model used in Çam and Lencz (2021) with two time periods and unlimited storage capacities, capacity wasting can occur in a realistic setting with multiple time periods and limited storage capacities.



(a) Central (from Russia) **(b)** South East (from Russia) **(c)** Baltic (from Russia)

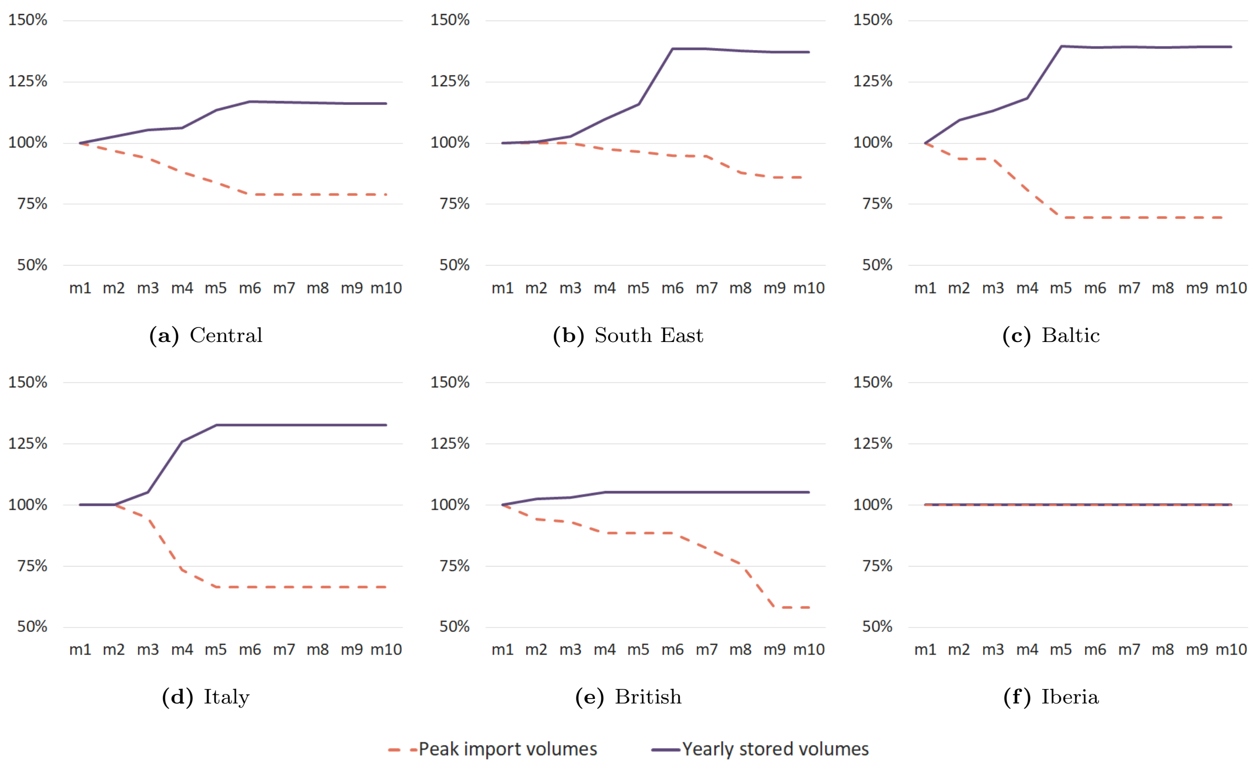
(d) Italy (from Central) **(e)** British (from Central) **(f)** Iberia (from Central)

Figure 3: Capacity bookings by run-time and wasted capacity in each region when adjusting their multipliers

In Iberia, as soon as multipliers reach $m2$, only yearly capacity is booked. This is due to two reasons. On the one hand, Iberia is a downstream region, connected to the transit region Central. Hence, it is still subject to the default multipliers ($m4$) set in Central. On the other hand, the seasonal demand profile is relatively flat (i.e. low winter-summer demand spread) such that even very low multipliers are sufficient to fully flatten the transports between Central to Iberia. Therefore, it can be deduced that the structure of the demand profile in a region can greatly influence how multipliers affect capacity booking.

4.1.2. Infrastructure utilisation

In Figure 4, the yearly stored gas volumes and the monthly peak import volumes per region are plotted against varying multiplier levels. The monthly peak import in a region corresponds to the highest monthly volumes imported by that region in the considered year. In all the analysed regions except Iberia, a general trend can be observed: As the multipliers increase, the transported peak volumes decrease. In parallel with this, the stored volumes increase. These findings are in line with Çam and Lencz (2021) and occur due to higher multipliers strengthening the capacity pricing aspect. In Iberia, infrastructure utilisation is not affected by multipliers since capacity booking is independent of multiplier levels, as shown previously.



(a) Central **(b)** South East **(c)** Baltic

(d) Italy **(e)** British **(f)** Iberia

Figure 4: Relative change in import volumes in the peak-demand month and yearly storage volumes in each region when adjusting their multipliers

4.1.3. Prices

In a competitive market, regional prices are determined by marginal costs of gas provision. Çam and Lencz (2021) shows that average marginal costs of gas provision are equal to the costs of gas procurement plus the costs for long-term (i.e. yearly) import transmission capacity. Hence, when multipliers affect yearly import (entry-exit) transmission capacity tariffs they also influence the average prices in regions.

Model results on the effects of multipliers on prices are plotted in Figure 5 for each individual region. In all regions where both LT and ST products are booked (see Figure 3), increasing multipliers up to a sufficient level causes the average prices to decline. This is because increasing the multipliers allows TSOs to reduce the tariff for their LT product.

In South East and the British region, however, the average price levels remain constant after they reach their minimum, which is caused by the capacity wasting that occurs in these regions with high multipliers. In Iberia, as only LT capacities are booked irrespective of multiplier levels, no price effects are observed.

As can be seen in Figure 5, multipliers not only have an impact on the average price levels, but also affect the temporal price volatility i.e. the standard deviation of the prices. When flexibility from storage and LNG imports is not fully utilised, the maximum price spread is defined by the marginal costs of such flexibility in the respective region. We have shown previously (see Figure 4) that multipliers increase the volumes stored in storages. As more expensive storage capacities start being used, the regional prices in peak months increase because marginal costs of storage increase. Since the differences in marginal storage costs are limited, the effect on temporal spreads is less pronounced for regions where storage capacities are not fully utilised (i.e. Central, Italy, Baltic).

In contrast, in British and South East regions, flexibility from storage capacities as well as LNG is fully utilised when the multiplier level reaches $m4$ and $m6$, respectively. In these cases, the maximum price spread is determined by the marginal costs for ST (i.e. monthly) capacity. As increasing multipliers result in higher prices for monthly capacity bookings, the maximum price spread increases. This process stops as soon as booking yearly capacity—which is not subject to multipliers—gets cheaper than booking monthly capacity. For the British and South East regions this is the case when multipliers reach $m9$ and $m8$, respectively.

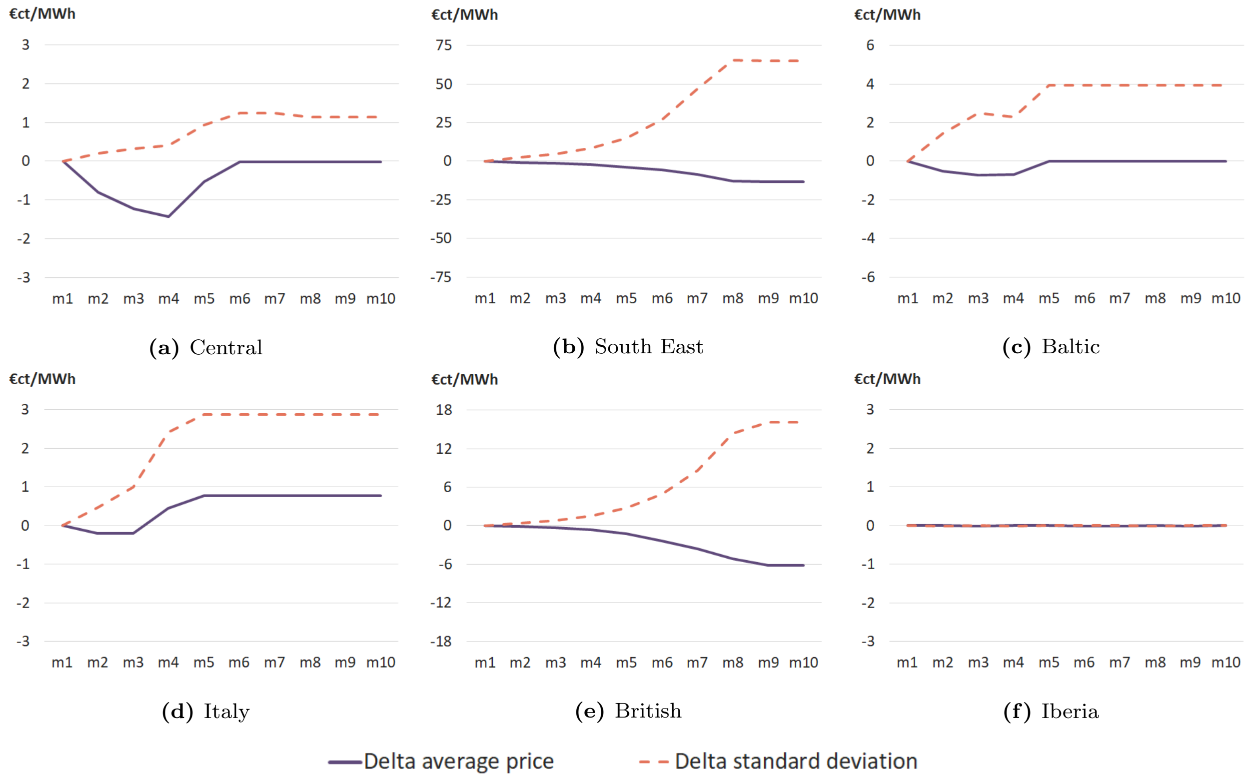


Figure 5: Absolute change in the average price (i.e. delta LT tariff) with respect to m1 level and the absolute change in the standard deviation in each region when adjusting their multipliers individually

Multipliers also affect the regional price spreads, as the average regional price spread corresponds to the yearly transmission tariff. Therefore, multipliers that minimise the average price also minimise the average regional spread with respect to the region exporting gas. Furthermore, we find that higher multipliers increase the volatility in regional price spreads, thus, confirming the findings of Çam and Lencz (2021). We identify two effects which drive the volatility in regional spreads. The price volatility in a region that increases its multipliers rises. At the same time, the increase in multipliers tends to decrease the temporal volatility in the exporting region. As a result, these two effects combined together amplify the volatility of the price spread between those two regions. A detailed analysis of the regional price spreads can be found in Appendix C.

4.1.4. Consumer surplus

We have shown that multipliers affect the average price levels as well as the peak prices. As such, they directly affect the consumer surplus in the individual regions and how it is distributed between different types of consumers with varying demand patterns (i.e. base vs peak). In Figure 6, the change in consumer surplus in each region with respect to multipliers is plotted. The consumer surplus is defined relative to the

$m1$ level. Since the gas demand is inelastic, consumer surplus corresponds to the change in prices multiplied with the demand. Further, we distinguish between base consumer surplus and the peak consumer surplus. Base consumer surplus corresponds to change in average prices multiplied by the base demand. Base demand is assumed to be constant throughout the year and equals the overall minimum monthly demand of a region. Any demand above this base level is then defined as peak demand. Thus, peak consumer surplus corresponds to the peak demand multiplied by the change in the corresponding prices.

Consumer surplus and its distribution between base and peak consumers are affected differently in each region with increasing multipliers, depending on which of the following three effects dominates:

- **Effect 1**: The first effect is the change in average prices due to tariff adjustment, which affects the overall consumer surplus. In this case, both base and peak consumers benefit if the tariffs are reduced or both consumer types lose if the tariffs are increased.
- **Effect 2**: The second effect is the increased spreads between off-peak and peak prices caused by higher storage utilisation. With higher storage utilisation, more expensive storages are used, which increase the spread between peak and off-peak prices. In this case, base consumers are not affected, while peak consumers lose.
- **Effect 3**: In case that flexibility from storage and LNG imports is exhausted, there exists a third effect: The prices in the peak periods are determined by the price of ST capacity, resulting in increased peak prices. Therefore, as multipliers increase, peak prices also increase, causing the peak consumer surplus to decrease.

In Central, the reduction in the average price causes both the base and peak consumer surplus to increase and reach a maximum at the multiplier level of $m4$ (Effect 1). Nevertheless, both peak and base consumer surplus decrease with higher multipliers as the LT tariff is increased due to the shift to LT capacity. Peak consumer surplus decreases additionally because of higher storage utilisation (Effect 2).

In the South East and Baltic regions, base consumers also increasingly benefit from the average price reduction with higher multipliers (Effect 1) while the peak consumers lose due to higher peak prices caused by increased storage utilisation (Effect 2). In South East, flexibility from storages is exhausted at $m6$ and from then onward Effect 3 dominates, causing a large decrease in the peak consumer surplus and reducing the overall consumer surplus substantially. In both the South East and Baltic regions, low multipliers ($m1$) maximise the overall consumer surplus, which is due to the relatively small size of those regions in terms of gas demand as well as their position as peripheral regions. When the two regions increase their imports in summer and decrease them in winter because of higher multipliers, prices in Russia are affected (lowering effect on winter prices and raising effect on summer prices). However, the transit Central region mitigates the effect on Russian prices almost fully when it exploits the lowered temporal Russian price spread. The mitigating effect is more pronounced since imports of the transit Central regions are five times higher than the sum of both peripheral regions' imports. Hence, Effect 2, which reduces peak consumer surplus, is reinforced such that optimal multipliers in the peripheral regions Baltic and South East are found to be low.

In Italy, the decrease in average prices causes a slight increase in the total consumer surplus, which reaches a maximum at the multiplier level of $m2$. Due to the peak price effect caused by higher storage utilisation (Effect 2), peak consumer surplus decline is steeper than the decline in base consumer surplus. Effect 2 is reinforced by Italy's relative position as a downstream region from Central. As Italy flattens its import profile from Central, gas storage is shifted from Central to Italy, reducing the summer-winter price spread in Central. In response, Central adjusts its import behaviour and imports more gas during winter. This mitigates the effect on the temporal price spread in Central, which further causes increased storage utilisation in Italy.

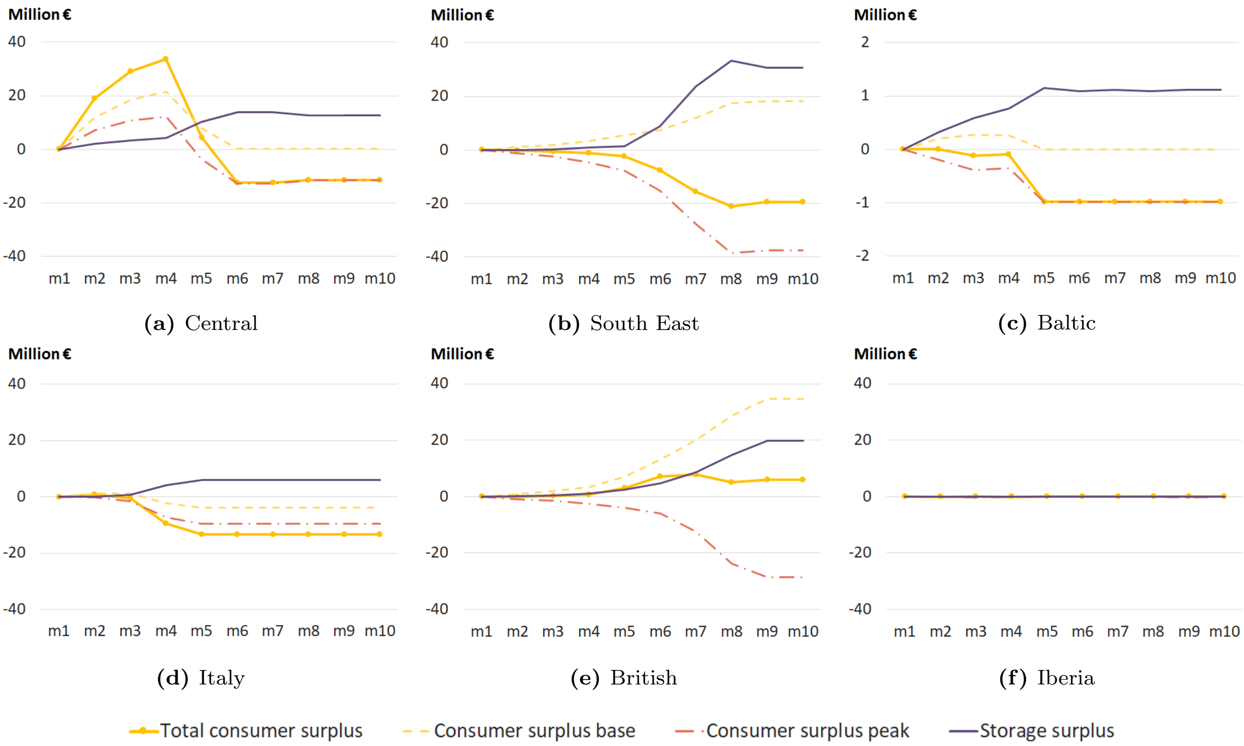


Figure 6: Consumer and storage operator surplus in each region when adjusting their multipliers individually

In the British region, the effects are similar to those observed in South East. However, in contrast to South East, import tariffs can be reduced to a larger extent, such that Effect 1 dominates and total consumer surplus is maximised at $m7$. This is because, irrespective of multipliers, imports occur predominantly in winter. As the TSO revenue is kept constant, LT tariffs can be reduced significantly, limiting the increases in ST tariffs. In Iberia, the consumer surplus is unaffected since only LT capacity is booked irrespective of the multiplier level.

4.2. External effects

As highlighted in Section 2, if a region individually adjusts its multipliers, it is possible for it to also cause external effects on other regions. Those external effects can be direct or indirect, and depend on whether the regions that adjust their multipliers are transit, downstream or peripheral.

4.2.1. Transit region adjusts its multipliers

In this case, the transit Central region is allowed to vary its multipliers while all the other regions have unchanged multipliers equal to the default ($m4$) levels. Adjusting multipliers in the Central region has direct effects on the peripheral regions that are connected and lie downstream such as Iberia, Italy and the British region. Figure 7 shows the changes in consumer surplus and storage surplus in these regions with respect to multiplier levels in the Central region.

The first direct external effect arises from the change in average prices in Central which is passed on to the downstream regions (arising from Effect 1 in Central). This external effect can be clearly observed in Iberia, where minimum average prices in Central for $m4$ also lead to lowest prices (i.e. highest consumer surplus) in Iberia.

For Italy and the British region, changes in multipliers also impact the booking behaviour and the gas dispatch for transports from Central, which induces additional external effects in the downstream peripheral regions. These effects depend on which of the previously discussed three effects ensue and dominate.

In Italy, the consumer surplus of peak consumers falls significantly with increasing multipliers. This is because higher multipliers for exporting gas from Central to Italy incentivise the flattening of transports from Central to Italy. The required utilisation of more expensive storages in Italy increases the peak prices in Italy, reducing the peak consumer surplus (Effect 2). In combination, the sum of the two external effects (Effect 1 and Effect 2) is highest for $m3$.

Similarly, when transporting gas from Central to the British region, traders are also incentivised to flatten transports with higher multipliers. In the case of the British region, as flexibility from storage and LNG is limited, a full flattening of transports is not possible. Hence, in peak periods the cost of ST capacity determines the prices, causing significant decline in the peak consumer surplus (Effect 3). Similar to the individual adjustment case, base consumer surplus increases due to tariff reduction (Effect 1). Overall, the highest positive external effect from Central on the British region arises for $m3$ due to combination of Effect 1 and Effect 3.

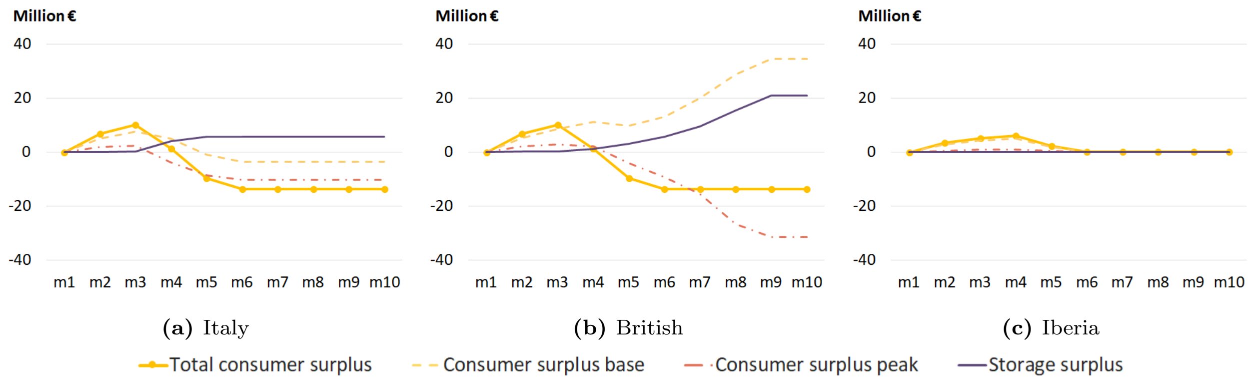
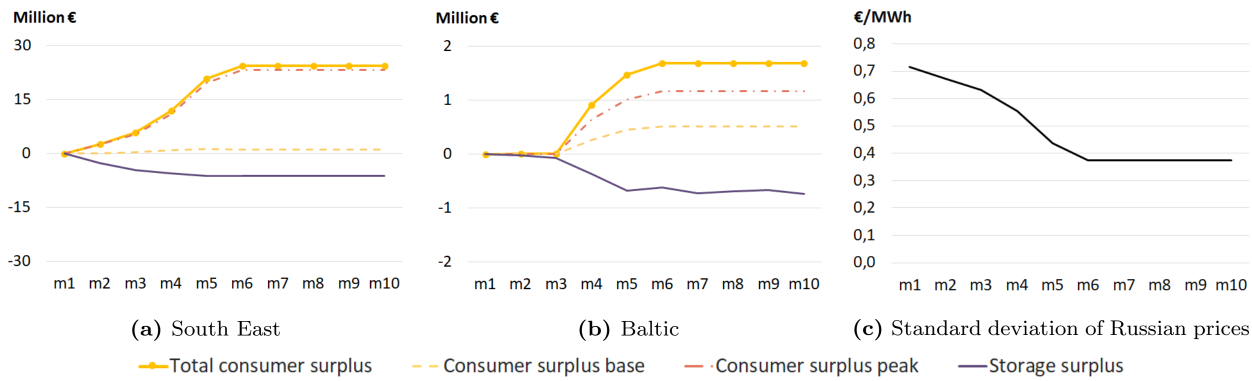


Figure 7: Changes in the consumer and storage operator surplus in the regions which lie downstream of Central when Central adjusts its multipliers: (a) Italy, (b) British, (c) Iberia

Adjusting multipliers in the transit Central region also induces indirect external effects on the peripheral regions which are not directly connected with it such as the South East and the Baltic regions. Figure 8 shows the development of consumer and storage surplus in South East and Baltic with respect to changing multipliers in Central. Increasing the multipliers in Central causes the spread between peak and off-peak procurement prices in the Russian production region to decrease, i.e. off-peak prices increase and peak prices decrease. As a result, in the South East and Baltic regions, peak consumer surplus increases.[19]

[19] Due to cheaper procurement prices during the peak period, more ST products are booked in South East and Baltic regions to transport Russian gas to cover the peak demand. The increased share of ST bookings allows the TSOs to slightly reduce their transport tariffs, such that the overall prices in the South East and Baltic regions sightly decrease, benefiting both the peak consumers and the base consumers. Here, this effect can be more easily seen in the case of the Baltic region.



(a) South East **(b)** Baltic **(c)** Standard deviation of Russian prices

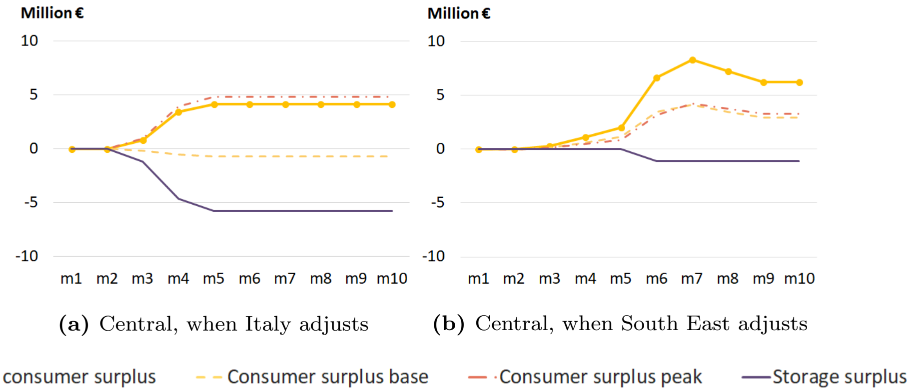
Figure 8: Changes in the consumer and storage operator surplus in the regions which are not directly connected to Central when Central adjusts its multipliers: (a) South East, (b) Baltic, and (c) the corresponding development of the standard deviation of Russian prices

4.2.2. Downstream or peripheral region adjusts its multipliers

When downstream or peripheral regions adjust their multipliers, they can also cause external effects on other regions. Figure 9 shows the changes in storage and consumer surplus in Central with respect to the multiplier levels in Italy and South East, respectively. In the case of Italy, multipliers in Italy are varied while other regions have the default multiplier level. Similarly, in the case of South East, only the multipliers in South East are varied while other regions have the default multiplier level. In both cases, we observe significant impact on the Central region.

In the case of adjustments in Italy, higher storage utilisation in Italy due to increased multipliers results in storages in Central to be utilised less. As a result, peak prices in Central decrease and peak consumer surplus increases consecutively.

The overall impact from changes in the multipliers in South East on the consumer surplus in Central arises from a combination of two specific effects: Increasing the multipliers in South East causes the spread between peak and off-peak procurement prices in the Russian production region to decrease, i.e. off-peak prices increase and peak prices decrease. At the same time, due to cheaper procurement prices during the peak period, more ST products are booked in Central to transport Russian gas to cover the peak demand. Increased amount of ST bookings allows the TSO to reduce the transport tariffs. Consequently, overall prices in Central decrease, benefiting both the peak consumers and the base consumers.



(a) Central, when Italy adjusts **(b)** Central, when South East adjusts

Figure 9: Changes in the consumer and storage operator surplus in Central when (a) Italy adjusts its multipliers, (b) when South East adjusts its multipliers

The external effects of multiplier adjustments in Italy and South East on other regions except Central are found to be very small. Any multiplier adjustment in the British region is found to have negligible impact on other regions because a large share of gas consumption is produced within the region or imported by LNG. Baltic region is found to cause similar external effects as the other peripheral region South East, albeit at a much smaller scale, because the imported volumes are comparably low. Iberia, having shown that no internal effects ensue with respect to multipliers, does not cause any external effects either. Those cases are not shown in this section explicitly but can be found in Appendix D, where the external effects of multiplier adjustments of all the regions are presented.

4.3. Overall distributional effects

We have shown that multipliers can cause both significant internal and external effects in various regions in the EU by influencing the price levels and the consumer surplus. Higher multipliers were also shown to cause increased storage utilisation (storage surplus), resulting in flattened import profiles from the Russian production region. These effects would also have an impact on the producer surplus and the trader surplus. As such, multipliers would influence the welfare and its distribution in the EU and in the production regions.

In order to clearly show the overall distributional effects of multipliers in the EU and in the production regions, we assume in a first step that the multipliers are specified in the EU by a superordinate regulator and every region has the same uniform multiplier level. In Figure 10, the changes in surplus of the consumers, producers, traders and storage operators as well as the change in overall welfare with increasing multipliers are plotted. All the values are defined and plotted in relation to the case where multipliers are equal to 1 ($m1$). Hence, at $m1$ the change in surpluses and welfare are zero. It can be seen that the overall consumer surplus increases significantly with higher multiplier levels and reaches a maximum of about 82 million EUR at $m4$. Peak-load consumers receive a much smaller share (31% at $m4$) of this additional consumer surplus compared to base-load consumers (69% at $m4$).

Producer surplus decreases substantially with increasing multipliers. The reason for that is the rise in yearly bookings and a corresponding decrease in purchased volumes from Russia in the peak periods. The producer surplus decreases as the purchased volumes in the peak and off-peak periods converge. At the consumer-surplus-maximising multiplier level of $m4$, Russian producers incur a loss of 69 million EUR compared to the $m1$ level.

Storage operators have surplus gains with higher multipliers due to increased storage utilisation, as more of the expensive storages are used that set the price of storage. At $m4$, the storage operator surplus equals 5 million EUR. When multipliers reach $m6$ and storages are fully utilised in the British and South East region, storage operators can charge bottleneck prices, increasing the storage operator surplus up to 77 million EUR for multiplier levels of $m9$ and $m10$, almost 15 times greater than the surplus observed with $m4$.

Trader surplus equals the revenue from selling gas to consumers minus the costs of gas provision, i.e., the costs for gas procurement, transport and storage. When the uniform multipliers increase to $m4$ levels, traders make less profit (-43 million EUR) as consumer prices decrease while at the same time booking costs remain constant. For higher multipliers, trader surplus increases again. This happens mainly due to increased consumer price levels. In addition to the consumer price effect, traders profit from lower gas procurement costs but bear higher costs for storing natural gas. Those two effects largely cancel each other out.

Welfare is defined as the sum of all surpluses and is highest for $m1$. Higher multipliers increase the distorting effect of transmission tariffs, causing the gas dispatch to further deviate from an optimal dispatch that is based on short-run marginal costs, as was also shown in Çam and Lencz (2021). Higher multipliers reduce welfare by causing additional costs, which occur as a result of two opposing effects. On the one hand, total costs of gas production decrease as gas is produced more evenly. On the other hand, total costs of storing gas increase. However, as the increase in storage costs is higher than the decrease in production costs, welfare declines with increasing multipliers. For multipliers higher than $m6$, welfare becomes mostly independent from increases in multipliers, as traders start to behave as being subject to capacity pricing in an increasing number of regions as shown previously, such that increases in multipliers do not affect procurement or storage volumes.

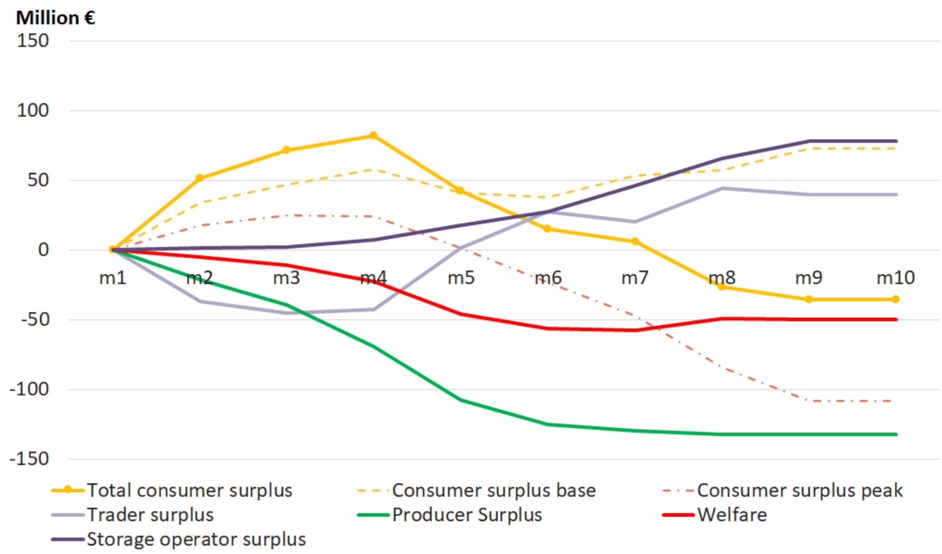


Figure 10: Changes in the consumer, producer, trader, and storage surplus and welfare with respect to multipliers in the EU

4.4. Comparing different optimal multiplier levels

A major research question of this paper is whether multipliers in the EU should be set by a superordinate regulator or whether individually optimal multipliers can lead to a joint (i.e. EU-wide) optimum. In this part of our analysis we aim to answer those questions. To do so, we compare consumer surpluses for three cases: (1) EU-wide uniform optimal multiplier level, (2) individually optimal multipliers that maximise the consumer surpluses in the individual regions, and (3) multipliers for individual regions that lead to a joint optimum. Optimal multipliers in this context correspond to multipliers that maximise the consumer surplus.

From Section 4.3 we know that the EU-wide uniform multiplier level resulting in the highest consumer surplus is $m4$. Furthermore, we have shown previously in Section 4.1.4 that the individually optimal multiplier levels vary among the analysed regions. For Central, the optimal level was found to be $m4$ while for Italy $m2$ was shown to be optimal. In South East and Baltic regions, optimal multipliers should be as low as possible; namely equal to $m1$. In contrast, in the British region, multipliers as high as $m7$ were found to be optimal. In Iberia no effects with respect to multipliers were observed.

To find the multiplier levels resulting in the EU-wide joint optimum, we vary the multiplier levels of the four regions that were found to cause significant external effects (i.e. Central, South East, Baltic and Italy) in combination. With 4 regions and 10 multiplier levels, this corresponds to 10^4, namely, 10000 combinations. Multiplier level in the British region is set to its individually optimal level of $m7$, while Iberia is set to the default level of $m4$. We find that individually optimal multipliers for Central and Italy also lead to the joint optimum. In contrast, the jointly optimal multiplier level for the peripheral regions, South

East and Baltic, differ from their individually optimal levels and are found to be $m6$ and $m5$, respectively. The optimal multiplier levels in the three cases are summarised in Table 3.

Table 3: Multiplier levels maximising consumer surplus

Region	Uniform multipliers	Individual optimum	Joint optimum
Central	$m4$	$m4$	$m4$
South East	$m4$	$m1$	$m6$
Baltic	$m4$	$m1$	$m5$
Italy	$m4$	$m2$	$m2$
British	$m4$	$m7$	$m7$
Iberia	$m4$	$m4$	$m4$

Figure 11 shows the corresponding change in consumer surplus for the optimal multiplier levels in the three cases. The delta consumer surplus is calculated relative to the consumer surplus resulting from uniform multipliers in all regions equal to $m1$. It can be seen that the uniform optimal multiplier level of $m4$ increases consumer surplus substantially compared to a uniform multiplier level of $m1$. The overall gains in consumer surplus amount to 82 million EUR. The optimal uniform multiplier level of $m4$ is also the individually optimal multiplier of the Central region. Since Central was shown to cause the highest internal and external effects, the uniform $m4$ level results in a significant increase in the EU-wide consumer surplus.

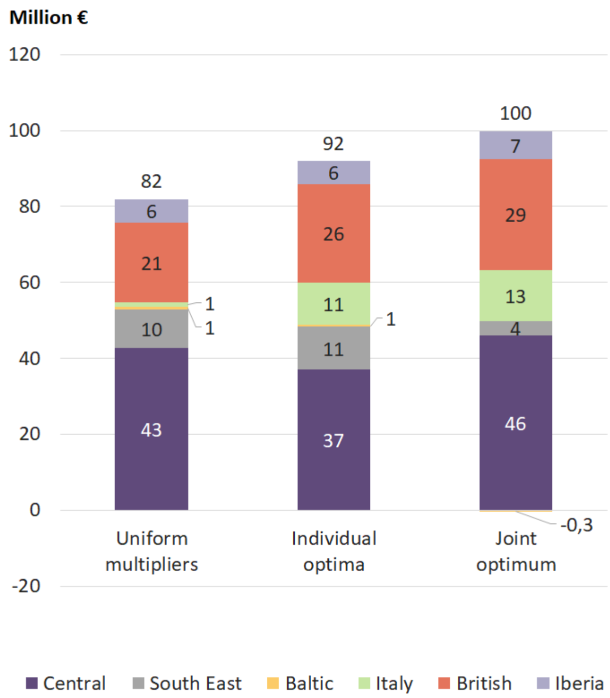


Figure 11: Changes in regional consumer surplus with respect to how the multipliers are specified

When regions specify their individually optimal multipliers, total consumer surplus in the EU increases by 10 million EUR compared to the maximum consumer surplus achieved with uniform multipliers. Hence, the internal increase in consumer surplus by setting multipliers individually outweighs the negative external effects. However, consumers in Central are worse off. This occurs mainly because Italy sets lower multipliers, shifting storage utilisation from Italy to Central. As more expensive storages are utilised in Central, peak prices increase, reducing peak consumer surplus in Central.

In the case that regional regulators specify the multipliers in order to maximise the joint EU-wide consumer surplus, total consumer surplus increases by another 8 million EUR. The effect is limited, because for the majority of regions the individually and jointly optimal multiplier levels coincide. For Central, this occurs as downstream regions profit from lower average prices in Central such that both external and internal effects due to multipliers are highest for $m4$. For Italy, the positive internal effect on consumer surplus outweighs the negative impacts on the consumer surplus in Central. For British and Iberia, multipliers are found to have negligible external effects such that the individual and joint optima also coincide. Whereas, in South East and Baltic regions, jointly optimal multipliers ($m6$ and $m5$) diverge from the individually optimal multiplier level $m1$. Hence, the positive external effects from setting multipliers relatively high in South East and Baltic outweigh the negative internal effects. As outlined previously, this occurs because high multipliers in peripheral regions reduce the temporal price spread in the Russian production region, from which the other gas importing regions profit.

5. Discussion

5.1. Overall effects

Our analysis has shown several adverse impacts that multipliers can have on the overall gas dispatch. A multiplier of 1 is shown to be the optimal multiplier level that maximises overall welfare. This is not surprising, since higher multipliers reinforce the capacity pricing aspect and cause the gas dispatch to further deviate from an ideal dispatch that would be based on short-term marginal costs. Therefore, increasing multipliers more than necessary would also increase the inefficiency in gas dispatch and cause welfare losses as our analysis has shown. Furthermore, higher multipliers are shown to increase volatility of prices and regional price spreads. Hence, unnecessarily high multipliers may be detrimental to the integration of the EU gas market.

Despite the above-mentioned inefficiencies associated with multipliers, multipliers that are sufficiently high can nevertheless be favoured by the regulators for several reasons. We have shown that multipliers determine how gas transmission capacity is booked, in turn affecting how gas infrastructure is utilised.

Overall, higher multipliers were shown to decrease the peak transport volumes and increase the volumes stored in gas storages. In this respect, it can be argued that higher multipliers may strengthen the security of supply of the system by reducing the volatility of gas import volumes and promoting storage. Furthermore, the ensuing flatter gas import profiles may also reduce the need for future capacity extensions, potentially resulting in higher long-term efficiency.

Regulators can also favour higher multipliers due to their distributional effect. Multipliers that are sufficiently high can maximise consumer surplus by allowing transport tariffs to be reduced. Setting the multipliers for the purpose of maximising consumer surplus penalises the traders and the producers while benefiting the storage operators. The producers in this case are the Russian gas production companies and the traders would be the various EU and non-EU energy and trading companies. Storage operators are predominantly EU companies with some storages owned by non-EU firms (e.g. Gazprom). Therefore, from an EU perspective, setting the multipliers to maximise consumer surplus would likely be optimal as it would largely benefit the consumers in the EU while penalising the non-EU producers.

5.2. Regional effects

National regulators can set the multipliers accordingly to maximise the consumer surplus. However, we have shown that the effects of multipliers vary significantly among regions. According to our analysis, the issue of choosing optimal multipliers becomes less important in regions with a relatively flat demand profile such as Iberia (Spain and Portugal), since in these regions exclusively LT capacities are booked in the model. In reality, due to decision-making under uncertainty—especially with respect to highly uncertain and volatile LNG prices—ST capacities are observed and imports from continental Europe via pipeline are less flat. The fact that overall LNG imports may be affected by multipliers may also contribute to the observation of ST bookings.

In regions with limited storage flexibility such as in the British region (United Kingdom and Ireland) and South East Europe (Romania, Bulgaria and Greece), we find that higher multipliers can cause substantial increases in the temporal price spread, benefiting base consumers while penalising peak consumers. When specifying multipliers, regulators in these regions would also have to take into account this strong distributional effect on the allocation of consumer surplus between the base and peak consumers.

In South East Europe and the British region, we have shown that wasting of booked capacities can occur with sufficiently high multipliers. This means that a portion of the booked capacities remain unused because traders cannot fully flatten their monthly import profile due to limited storage capacities. In our model, this occurs only with very high multiplier levels that lie out of the range suggested by the EU. In reality, due to decision-making under uncertainty, the capacity wasting effect of multipliers could occur even in regions with sufficient storage flexibility and with lower multipliers, being much more prevalent than what our model with perfect foresight projects. Therefore, regulators may opt for lower multipliers if it is desired to reduce the wasting of booked capacities.

Our analysis indicates significant variation in the individually optimal multiplier levels for maximising the consumer surplus in the respective regions. We have shown that these multiplier levels are influenced by three main effects. The first effect is the reduction of the overall regional price due to TSOs being able to reduce the transport tariffs. The second effect is the increase in peak prices due to higher storage costs caused by increased storage utilisation. And the third effect is the increase in peak prices when storage flexibility is limited as the prices in this case are determined by the cost of ST capacities. For the Central region considered in the model, which is an aggregation of numerous transit countries in Central and West Europe, we find that the first effect dominates. Whereas, in Italy, a downstream region with abundant storage capacities that imports gas from the transit Central region, the second effect plays an important role. In the downstream British region as well as the peripheral South East and Baltic regions with limited storage flexibility, the third effect is found to be the dominant effect. Thus, our analysis indicates that multipliers can reinforce different effects in different regions.

5.3. External effects and the EU optimum

National regulators can set the multipliers accordingly to maximise the consumer surplus. However, our results confirm that adjusting multiplier levels in a region does not only cause effects in that region itself but can also induce external effects in other regions. We have shown that consumer surplus gains in transit regions are directly passed on to regions that lie downstream of the transit regions (i.e. import gas from the transit region). In contrast, a direct transfer of consumer surplus gains in the downstream and peripheral regions to transit regions does not occur. Nevertheless, our results show that multiplier adjustments in the peripheral and downstream regions can still influence the transit regions in more indirect ways, such as via affecting the procurement prices in the production region or affecting the storage utilisation in the transit region itself, respectively. Consequently, setting multipliers to maximise the consumer surplus in the individual regions, i.e. setting individually optimal multipliers, does not maximise the total EU consumer surplus.

We find that individually optimal multipliers nevertheless result in a significantly higher EU consumer surplus compared to an optimal EU uniform multiplier level that applies in every region. In our analysis, the maximum EU potential consumer surplus gains via a uniform multiplier level is 82 million EUR per year while the individually optimal multipliers increase this value by 12% to 92 million EUR. In this sense, we find it appropriate that EU regulation provides an allowed range of multipliers and not absolute values. Yet, we show that this allowed range can be too restricting for some regions. While the individually optimal multipliers in the majority of regions considered in the model lie lower than the maximum allowed multipliers in the EU, the British region is found to have a much higher optimal multiplier. Hence, our results imply that the current range of allowed multipliers can be too restricting for this region, limiting the potential consumer surplus gains.

When multipliers are set in individual regions with the purpose of maximising the total EU consumer surplus, the surplus gains increase by 9% to 100 million EUR. This indicates that letting national regulators set the multiplier levels—as is the case with the current EU regulation—may not lead to an EU optimum. In the EU optimum case, we have shown that the consumers in the transit and downstream regions benefit while those in the peripheral regions are worse off compared to the individually optimal case. As such, national regulators in the peripheral regions would have little incentive to choose EU-optimal multipliers. Therefore, incentivising those regions would require some of the EU consumer surplus gains to be redistributed to peripheral regions.

The maximum consumer surplus gains in the EU of almost 100 millions EUR estimated by our model are relatively low when compared to overall EU gas market costs. The yearly EU internal gas market purchases alone are estimated to be 100 billion EUR in total (ACER, 2020b). However, contemplating those gains via multipliers with the total costs associated with the entry into the EU and entry-exit between EU market areas is more meaningful. In our model such costs amount to 4.6 billion EUR. Hence, multipliers that maximise overall consumer surplus shift approximately 2.2% of the transmission costs from the consumers to the producers and traders compared to the situation without multipliers.[20]

In our analysis, we group several market areas into individual regions and ignore the transmission costs within the regions that occur in reality. Because of that, real-world transmission costs would be higher than those in our model. Cervigni et al. (2019) estimate the total costs associated with the entry into the EU and entry-exit between EU market areas to be 5.7 billion EUR for the year of 2017. These transmission costs are 24% higher than the corresponding costs in our model, supporting the notion that the overall effects of multipliers on the consumer surplus would be higher in reality due to additional transmission costs within the regions. Another aspect which would further reinforce the effects of multipliers in reality is the presence

[20] Trader surplus decreases even further as traders also bear the costs from increased storage utilisation. Producer surplus also decreases further due to reduced profits from selling less gas in peak periods.

of uncertainty. Compared to in our model with perfect foresight, traders in reality would be more inclined to book short-term capacities when there is short-term uncertainty with respect to their capacity demand. Since multipliers increase the prices of short-term capacities, the distributional effects of multipliers could be more pronounced in this case. We assume in our analysis all storages to be fully exempt from transmission tariffs. While the majority of countries in the EU either fully exempt storages from transport tariffs or apply very large discounts up to 90%, there are also countries where tariff discounts for storages are not as high. In these regions, the effects of multipliers on storage utilisation would be less pronounced and comparably more short-term products would be booked. This would allow long-term tariffs to be further decreased, increasing potential consumer surplus gains via setting multipliers optimally.

Despite the above-mentioned aspects, potential consumer surplus gains via optimal multipliers could in some cases be smaller in reality due to existing long-term bookings. In our analysis, we ignore the historical long-term capacity bookings that are already in place. In regions with particularly high proportion of historical long-term bookings, multipliers would have overall less impact due to less demand for short-term capacities. This would especially be the case where historically booked capacities exceed the demand for capacity such that traders face zero marginal costs for transmission. Nevertheless, since the historical capacity bookings will almost completely expire until 2035, it will eventually become less of a factor.

6. Conclusion

In the European Union's gas transmission system, the relative prices of short-term transmission capacities are specified via multipliers. Multipliers can have varying internal effects in different regions, resulting in consumer-surplus-maximising multipliers to differ between the regions. Moreover, even if individual regions specify their own optimal multipliers, it is not obvious if it would lead to an EU optimum. This is because multiplier levels in one region can cause external effects in other regions. In order to address these issues, this paper analyses the effects of multipliers on regional prices, infrastructure utilisation, and welfare. A numerical simulation model is used to simulate the European gas dispatch and quantify the effects of multipliers in a spatial setting with six different representative regional clusters in Europe.

Overall, our results show that sufficiently high multipliers can help maximise consumer surplus by allowing transport tariffs to be reduced. Hence, optimal multiplier levels that maximise consumer surplus on a regional level or in the whole EU do exist. Nevertheless, we show that multiplier effects and consequently optimal multiplier levels depend strongly on regional characteristics. In regions with relatively flat demand profiles, i.e. with low winter-summer variation in demand, such as Portugal and

Spain, only long-term capacities are booked under the model assumption of perfect foresight, irrespective of the multiplier level. In reality, under the presence of uncertainty, ST bookings are also observed. Nevertheless, our results indicate setting multipliers optimally is comparably less of an issue in such regions with flat demand profiles. In contrast, we show that in regions with limited supply flexibility via storages, such as Britain and South East Europe, higher multipliers significantly reduce the consumer surplus of peak consumers while base consumers profit. In such regions, the effects on the internal redistribution of consumer surplus between peak and base consumers should also be taken into account when specifying the multipliers.

Our analysis indicates that multiplier levels in a region can cause external effects in other regions. In transit regions, which import and re-export significant gas volumes (e.g. Central Europe) consumer surplus gains are passed on to regions that lie downstream (e.g. Italy). We show that multipliers in downstream regions can influence the transit regions indirectly due to adjusted import structure, affecting the storage utilisation in the transit region. Peripheral regions (e.g. South East Europe) can influence other regions also by affecting the temporal price spreads in the procurement prices in the production regions (e.g. Russia). Because of those external effects caused by multipliers, individually optimal multipliers do not necessarily lead to the EU optimum.

Allowing the regions to set their multipliers individually, nevertheless, results in a much more optimal outcome with 92 million EUR consumer surplus gains annually, 12% higher than what can be achieved with a uniform multiplier level applied in all regions. In this respect, it is appropriate that the current EU regulation specifies allowed multipliers in ranges and not in absolute values, as it can allow for consumer surplus gains in the EU. Nevertheless, our results indicate that letting national regulators set the multipliers may not lead to an EU optimum since the consumer surplus gains with individually optimal multipliers is found to be 9% lower than the maximum achievable consumer surplus.

In our analysis we considered a simplified spatial structure with aggregated regions for the purpose of isolating and identifying effects. In reality, due to high number of individual transit countries interconnected with each other, multiplier levels in a transit region can have a more amplified impact on the downstream regions and the whole system due to the pancaking effect. Additionally, we assumed perfect foresight when simulating the gas dispatch and the capacity booking, which results in the capacities in our model to be booked optimally as necessary. In reality, because of uncertainty and forecast errors, not all booked capacities are optimal and wasting of booked capacities is a common occurrence. We have shown that higher multipliers can result in capacity wasting. In this context, regulators may have to take into account these aspects as well when specifying the multipliers.

In future work, the modelling framework could be extended to include stochasticity in order to consider the influence of imperfect information and uncertainty on the capacity booking behaviour and their impact on the effects of multipliers. Significant changes in the gas demand structure are expected to occur in the next decades. As the share of intermittent renewables in electricity generation increases as part of the energy transition to meet the climate targets, volatile residual load will be increasingly met by flexible gas-fired generation. This will correspond to increased demand for short-term transmission capacity, especially for daily and intra-daily capacities. Therefore, it would also be worthwhile to extend the analysis by including a more granular temporal resolution and modelling daily and intra-daily capacity bookings.

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Appendix A. Theoretical analysis

Lemma Appendix A.1. *With T being the total number of time periods, it is optimal to solely book long-term capacity covering all periods if the duration of the short-term capacities products multiplied by the respective multiplier exceed T.*

Proof. The cost for a short-term (ST) capacity product is equal to $t_p m_p \tau_c$, with t_p being the duration of the capacity product p, m_p being the multiplier of the respective capacity product and τ_c being the tariff for the long-term (LT) capacity. For LT capacity that covers all the periods, no multiplier is applied and the cost is equal to $T\tau_c$. It is clear that if $t_p m_p > T$ the cost for the ST capacity product becomes higher than the cost of LT capacity. In this situation, it is always optimal to book only LT capacity. This concludes the proof. □

In the paper at hand we assess the effects of multipliers in a setting with twelve periods, in which each period represents one month. A yearly (LT) capacity covering all the twelve periods, a quarterly capacity covering three periods and a monthly capacity covering one period are offered.

The cost of one unit of quarterly capacity, covering three periods, is equal to $3m_q \tau_c$, with m_q being the quarterly multiplier. For LT capacity, covering all the twelve periods, no multiplier is applied, so the cost is equal to $12\tau_c$. If $m_q > 4$, the cost of the quarterly capacity becomes higher than the LT capacity. The cost of one unit of monthly capacity, covering one period, is equal to $m_m \tau_c$, with m_m being the multiplier for monthly capacity. If $m_m > 12$, the cost of the monthly capacity becomes higher than the LT capacity. Therefore, in the setting with twelve periods, and multipliers of $m_q > 4$ and $m_m > 12$, it is always optimal for a cost-minimising trader to book only LT capacity.

Lemma Appendix A.2. *If demand for transmission capacity is fully inelastic where it equals to $X - e$ in t_p periods and X in the remaining consecutive $T - t_p$ periods, under the condition $m_p > \frac{T}{T-t_p}$, only LT capacity is booked in the optimal solution and some capacity rights remain unused.*

Proof. A trader can either book a combination of LT and ST capacity or choose to book LT capacity only. In case it is decided to mix both types of capacities, the trader procures $X - e$ units of LT capacity, valid in all T periods, and buys additionally e units of ST capacity for the remaining consecutive $T - t_d$ periods with higher demand. t_p represents the duration of the ST capacity product p. Other combinations would result in higher costs. If it is decided to book only LT capacity instead, the trader books X units of LT capacity for the whole period. It would be optimal to book only LT capacity if the associated costs were lower, i.e. if the inequality below would hold:

$$\tau_c[(X - e)\, T + e\, (T - t_p)\, m_p] > \tau_c X\, T$$

which then simplifies to:

$$m_p > \frac{T}{(T - t_p)}$$

□

The situation of fully inelastic demand as assumed in the Lemma would occur if storages are exhausted. Applying the Lemma to a setting with twelve periods where each period represents one month—and a yearly capacity (LT) covers all the twelve periods, a quarterly capacity covers three periods and a monthly capacity covers one period—results in the following thresholds for multipliers:

In case demand equals X in eleven months and is lower in the remaining one month, solely LT capacity is booked if the monthly multiplier exceeds $m_p > \frac{12}{(12-1)} = 1.\overline{09}$. In case demand equals X in nine months and is lower in the remaining consecutive three months, solely LT capacity is booked if the monthly multiplier exceeds $m_p > \frac{12}{(12-3)} = 1.\overline{33}$. The multiplier threshold in this case is higher, as a larger share of LT capacity is wasted. The two examples show that, even in the presence of moderate multipliers, it can be optimal for traders to let some capacity remain unused.

If demand is not fully elastic, but transports are not fully aligned even in the presence of multipliers that induce a capacity pricing regime (see Lemma Appendix A.1), then multipliers causing only LT capacity to be booked would lie between the thresholds resulting from Lemma Appendix A.1 and Lemma Appendix A.2. This would be the case if flexibility is available but the marginal cost curve for flexibility is steep.

Appendix B. Reference case and model validation

We validate our model against historical results for the 2018 gas year covering the period 01. October 2017–30. September 2018. For this purpose, we consider the reference case where every region has the default EU average multiplier ($m4$) levels. The simulated storage levels, imports from Russia and the price levels are then compared with the historical levels.

In Figure B.12 the simulated monthly storage levels in the EU are plotted against the historical levels.[21] Note that LNG storages are not included. It can be seen that the simulated storage levels during the winter period lie slightly below the historical levels. Nevertheless, the storage levels then follow the historical levels very closely in the summer period.

[21] Historical storage levels for European countries are obtained from the AGSI+ platform (`https://agsi.gie.eu/`).

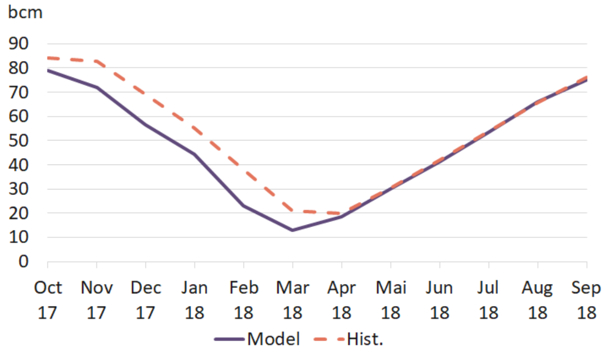

Figure B.12: Simulated and the historical monthly storage levels in the EU

In Figure B.13 the simulated monthly imported gas volumes from Russia are plotted against the historical volumes.[22] The simulated import volumes lie slightly above the historical volumes in the winter period, while they lie slightly below the historical volumes in the summer period. The difference between the simulated and the historical results in the total yearly imported volumes is less than 1%.

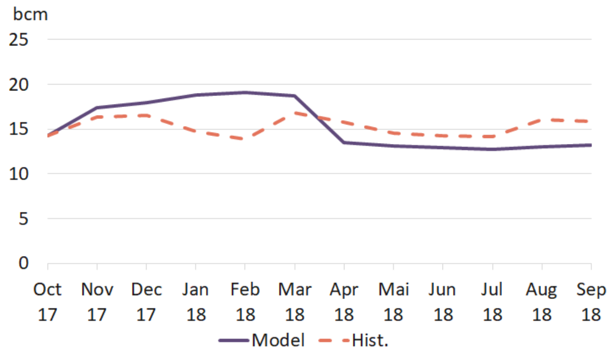

Figure B.13: Simulated and the historical monthly import volumes from Russia into the EU

In Figure B.14 the average prices in the considered regions for the gas year 2018 and the historical TTF price during this period are plotted. It can be seen that the average price in the Central region is very close to the average TTF price. The price levels in the other regions are higher than the price level in the Central and lie in realistic ranges. Note that the prices for the Baltic and the South East regions include on top of the simulated prices markups of 3 EUR/MWh and 1.5 EUR/MWh, respectively. This is done in order to represent the realistic price levels observed in these regions due to having less competitive market structures.

[22]Historical imports are derived from the IEA Gas Trade Flows (GTF) service (`https://www.iea.org/reports/gas-trade-flows`).

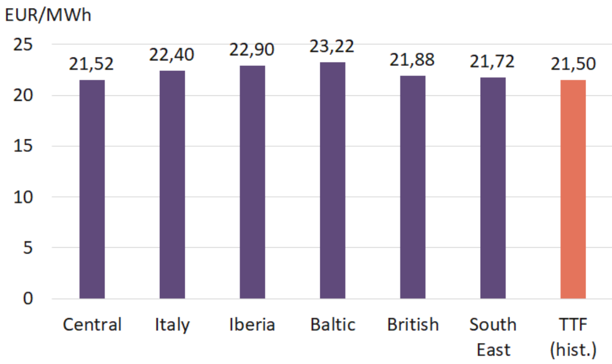

Figure B.14: Simulated regional price levels for the gas year 2018 and the historical TTF price in the corresponding period

Appendix C. Overview of regional price spreads

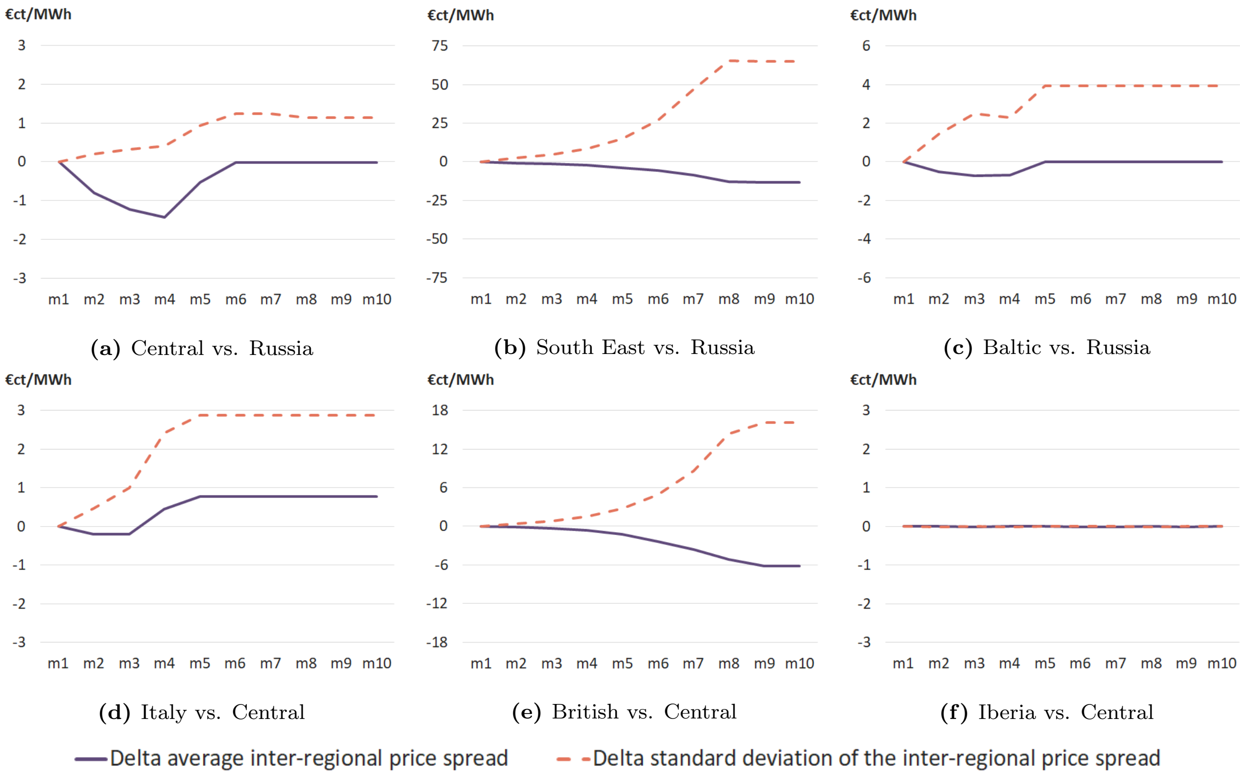

Figure C.15: Change in the average inter-regional price spread and its standard deviation with respect to import region when each region adjusts their multipliers individually

Figure C.15 plots the average inter-regional price spread as well as its standard deviation with respect to multipliers when regions adjust their multipliers individually in the default case. It can be seen that the change in the average regional price spreads directly follow the change in average prices due to tariff adjustments (see Figure 5). The standard deviation of the regional price spreads, which can also be referred to as the volatility of the regional price spreads, is shown to be increasing with multipliers in all regions except Iberia.

Appendix D. Overview of external effects on consumer surplus

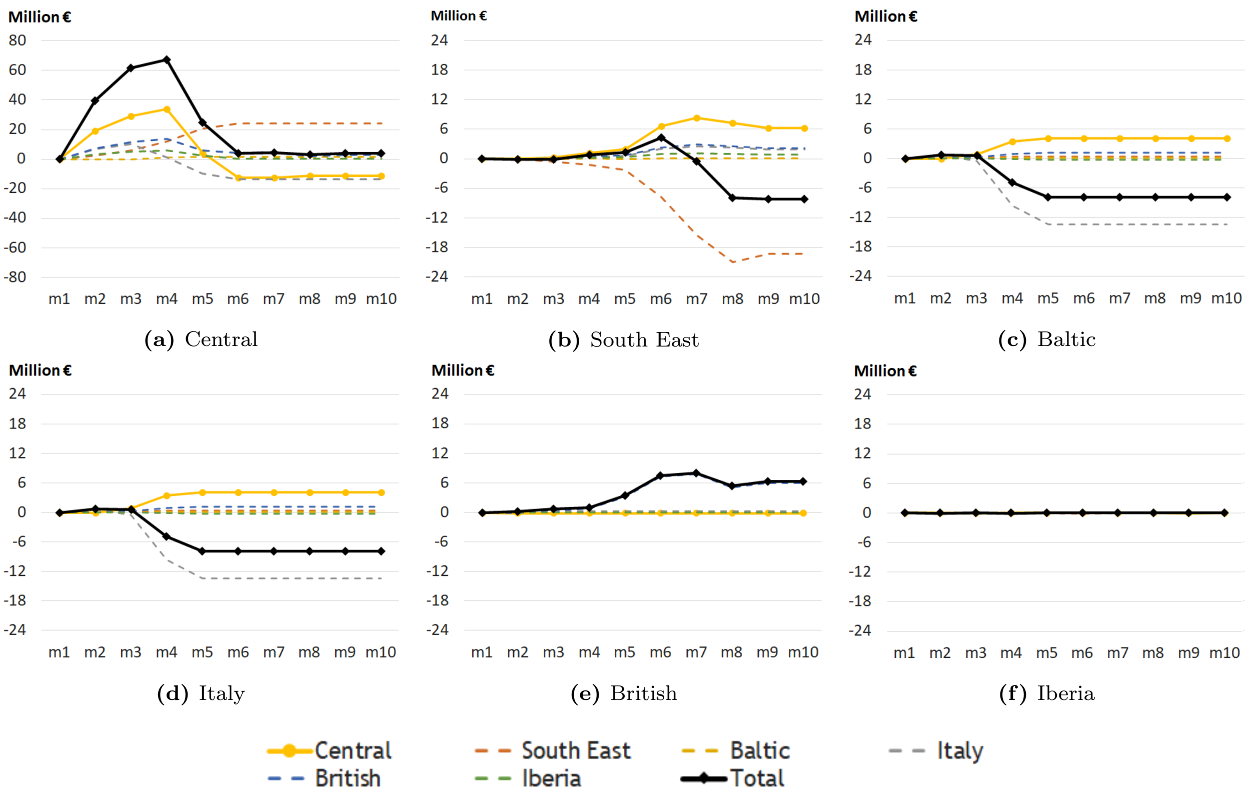

Figure D.16: The changes in consumer surplus in the regions and the total impact in the EU when multipliers are adjusted individually in the regions: (a) Central, (b) South East, (c) Baltic, (d) Italy, (e) British, (f) Iberia.