National Industry Trade Shocks, Local Labor Markets and Agglomeration Spillovers*

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Abstract

Using a broad set of national industry trade shocks, I provide a novel approach to estimate agglomeration effects by exploiting within industry variation in indirect exposure to the other local industries' (national) trade shocks across local labor markets. This variation stems from differences in local industry composition. I find considerable employment spillovers from other tradable industries' trade shocks and even stronger effects within the same sector. Spillovers are larger for industries employing similar workers and are triggered predominantly by shocks to high technology industries, indicating that place based policies are likely to be more successful when attracting high technology firms.

Keywords: Agglomeration, Local Labor Markets, Trade Shocks
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1 Introduction

Economic activity is spatially concentrated in many countries. Well known examples of spatial concentration are the clustering of high-tech firms in Silicon Valley or the clustering of auto manufacturers and their suppliers in Detroit.

One explanation for the observed level of clustering is the existence of agglomeration economies, whereby firms benefit from productivity or cost advantages when they locate near other firms. Cost advantages can arise due to a reduction in transport costs for firms with input-output linkages. Productivity advantages can arise from knowledge spillovers or an increase in matching quality because of a larger local labor market size (e.g. Marshall (1890)). In Silicon Valley for example, the existence of many high skilled workers potentially leads to an increase in knowledge exchange both at the workplace and across firms. Additionally, the presence of many high skilled workers might attract new high-tech firms as the available labor pool is larger and hence they are likely to get better workers there. Car manufacturers and their suppliers likely cluster together as this leads to a reduction in transport costs and simplified communication amongst firms.

In this paper I provide a novel approach to estimate agglomeration effects: I identify and estimate agglomeration externalities using a broad set of national industry shocks. I first document the existence of local spillovers from national industry shocks and that these spillovers magnify the direct local effects of these shocks. I then analyze heterogeneities in spillovers focusing on three main questions: What role does economic proximity between industries play for the strength of spillovers? Which industries create spillovers? And which industries benefit from spillovers?

The national industry shocks I exploit for identification are trade shocks to German industries stemming from two sources: trade integration of Eastern Europe after the fall of the iron curtain and trade integration of China in the course of its WTO accession. These events led to gradual reductions in trade barriers between Germany and China and Germany and Eastern Europe and consequently to a substantial increase in import competition and export demand for many German industries producing tradable goods over time.[1] These national industry trade shocks constitute shocks to local industry labor demand that are not correlated with other region specific factors jointly affecting local industry labor demand in all industries in the region. This makes them well suited to analyze the existence of agglomeration spillovers. More specifically, I estimate agglomeration spillovers by relating changes in local industry employment to indirect exposure to the other local industries' (national) trade shocks exploiting within industry variation in exposure across local labor markets. This variation comes from initial differences in local industry structure within the tradable sector. Workers in the same industry but in regions with different local industry structures may hence be differentially affected by indirect exposure to the other local industries' trade shocks.

What effects do we expect to arise from indirect exposure to the other local industries' national industry level shocks and more particularly from trade shocks? For tradable industries, indirect trade exposure potentially leads to two opposing effects at the regional level: reallocation effects

[1] See Figure 1 for the evolution of German national imports and exports from and to China and Eastern Europe.

and agglomeration spillovers.[2] If the other local industries are hit by a positive trade shock, they will demand more labor which, if workers are not perfectly mobile across regions, will lead to an increase in regional wages. The industry under observation will hence want to decrease employment - the reallocation effect. However, if the increase in labor demand of the other local industries is satisfied partly through workers moving into the region and consequently local labor market size increases, the industry under observation might benefit from this increase in labor market size for at least two reasons. First, the available labor pool increases which potentially results in better worker-firm matches. Second, the inflow of new human capital into the region and an increase in worker flows across local industries might lead to knowledge spillovers. Furthermore, the industry under observation might benefit if it shares input-output relations with the industries hit by the trade shock, as it can meet the increased demand for services and intermediate goods in a cheaper and faster way than suppliers in other regions. Consequently, indirect trade exposure might lead to positive spillovers which, if the agglomeration economies are strong enough, can outweigh the reallocation effect.

To give an example in the German context, consider the German aircraft industry. Demand for airplanes in China grew considerably over the last decade. German exports of airplanes to China grew from around 80 million EUR in 1998 to around 1.61 billion in its peak in 2006. The aircraft industry is a highly clustered high technology industry employing overproportionally high skilled workers. One of these clusters is located in Hamburg where in 1998 about 21% of all aircraft industry workers in Germany were employed. However, Hamburg is not only known as an aircraft industry cluster, but more generally as a high-tech cluster, as the presence of the aircraft industry goes hand in hand with the existence of other high technology industries, such as the information technology industry. In the presence of agglomeration economies, an increase in demand for airplanes in China may consequently not only increase employment in the aircraft industry itself – and hence high skilled employment in the region – but potentially be beneficial for other high technology firms as well. These firms might for example benefit from a growing high skilled labor market through thick market effects.[3] Alternatively, the increase in high skilled workers in the region might increase knowledge exchange between firms and workers. Furthermore, suppliers of aircraft manufacturers in Hamburg might benefit, as local demand for their goods and services increases.

I start the analysis by providing a simple model of agglomeration economies. The model generates an equilibrium labor demand equation where local industry labor demand depends on the other local industries' employment levels through productive benefits from co-locating. I then use the model to derive empirically testable predictions on how trade shocks can trigger employment spillovers in other local industries in the presence of agglomeration economies: First, trade shocks need to positively affect local employment of the industries directly affected by the shocks. Second, if local labor supply is less than infinitely elastic, trade shocks should increase local wages. Third,

[2] Additionally indirect trade exposure might lead to national product demand shocks. I abstract from these here, as the focus of the analysis is on local spillovers. I also abstract from local multiplier effects on non-tradable industries, as the main focus is on spillovers to tradable industries.

[3] The high skilled employment share increased from 13 to 18% between 1998 and 2006.

the overall indirect effect of trade shocks to the other local industries is ambiguous and depends on the strength of agglomeration forces and the strength of the reallocation effect (that is endogenous wage adjustments) which affect local industry employment in opposite directions.

For the empirical analysis I combine data from two sources. For the local labor market outcomes I use administrative data from Germany which contain the population of firms and workers covered by the social security system. Information on trade flows comes from the UN Comtrade Database. I estimate local spillovers from trade shocks controlling for the own industry trade shock and potential national indirect product demand spillovers. In particular, I relate changes in local industry employment at the 3-digit industry x commuting zones level for three time periods between 1988 and 2008 to changes in indirect trade exposure accounting for national industry time varying shocks and local industry and regional characteristics potentially affecting local industry employment growth. To account for the fact that changes in Chinese and Eastern European trade flows to and from Germany can also be driven by German specific shocks, such as technology shocks to certain industries, I follow Autor et al. (2013) and instrument changes in German trade flows by changes in trade flows of other high income countries.

I first document that (positive) trade shocks positively affect employment in industries directly affected by the trade shock and that the joint regional trade shocks positively affect local employment. These results are a precondition for the existence of agglomeration spillovers that are assumed to work through the size of the local labor market, such as thick market effects and knowledge spillovers working through increased worker mobility.

For the estimation of spillover effects, I then construct a measure of indirect trade exposure that quantifies a local industry worker's exposure to the joint trade shocks of the other tradable industries in the region. I find considerable positive spillovers from other tradable industries' net trade shocks and even stronger effects within the same broad sector. These spillovers contribute about 38 percent to the joint direct and indirect local employment effects of trade shocks. Further, based on the simple model outlined above, these estimates imply an agglomeration elasticity of 0.18, an estimate comparable to the elasticities reported by Gathmann et al. (2016) and Kline and Moretti (2014).

To investigate which of the sources of agglomeration economies is responsible for the observed spillover effects in employment, I then refine the measure of indirect trade exposure by rescaling the strength of the other local industries' trade shocks according to three measures of economic proximity: share of inputs used from the industry under observation, share of outputs provided to the industry under observation and share of workers exchanged with the industry under observation. I find that predominantly worker transitions between industries lead to employment spillovers indicating that knowledge spillovers or thick market effects are most important to create spillovers. In contrast, input-output relations seem *not* to matter much.

I then turn to analyzing heterogeneities in spillovers across industries. Here I focus in particular on differences between high and low technology industries. I find that high technology industries benefit most from spillovers from trade shocks to other tradable industries in the region. Low technology industries still benefit, but spillovers to high technology industries are about twice as large. To analyze heterogeneities in creating spillovers, I distinguish between the effects of indirect exposure to shocks to high technology versus indirect exposure to shocks to low technology industries. The findings suggest that predominantly trade shocks to high technology industries trigger spillovers in other industries, while trade shocks to low technology industries do not generate spillovers. The absence of spillover effects from shocks to low technology industries provides additional evidence that indirect product demand shocks to industries connected by input-output linkages may not be the main driver of spillover effects, as low technology industries are substantially linked by input-output relations and consequently shocks to low technology industries should lead to spillovers if input-output relations were an important source of agglomeration economies.

Overall the findings indicate that national trade shocks lead to considerable agglomeration spillovers. Consequently, regional effects of national industry shocks are larger than would be expected if only taking into account the direct effects of national industry shocks. Spillovers are largely generated by high technology industries (or industries employing high skilled workers) and act primarily between industries that share common worker requirements. These findings suggest that governments should take into account local industry structure when implementing place based policies and aim to attract high technology firms to increase the chance that place based policies are successful. Further, if not regional policy is the primary interest, but rather national welfare, the results suggest that national governments should move subsidies away from low technology industries and towards high technology industries, as these are more likely to create additional employment through regional spillovers.

The paper is structured as follows. In Section 2 I relate my analysis to the existing literature. Section 3 sets out the theoretical mechanisms through which trade shocks can lead to agglomeration spillovers. Section 4 introduces the empirical strategy to assess the strength of agglomeration spillovers triggered by trade shocks. Section 5 describes the data and gives some descriptive statistics. Section 6 reports the main results and robustness checks. Finally, Section 7 discusses the implications of the analysis and concludes.

2 Related Literature and Contribution

This paper contributes to three strands of the literature: the literature analyzing the existence, strength and sources of agglomeration economies, the literature analyzing the effects of place based policies and the literature analyzing employment effects of globalization using trade shocks.

Recent advances in the literature analyzing the existence and strength of agglomeration economies include the use of natural experiments.[4] Natural experiments can induce sizable shocks to local

[4]There exists a large body of literature analyzing the relationship between regional (or local industry) density and productivity to infer about the existence of agglomeration economies (see for example Ciccone and Hall (1996) for a seminal paper or Combes and Gobillon (2015) for an overview over the literature and its challenges in identifying agglomeration effects). An alternative and more indirect approach is analyzing patterns of industry coagglomeration and its reasons (see e.g. Ellison and Glaeser (1999) or Ellison et al. (2010)).

economies which can be argued not to be otherwise correlated with the outcome of interest. Greenstone et al. (2010), for example, analyze how large plant openings affect total factor productivity of incumbent plants located in the same region. For identification they exploit information about the runner-up locational choice, the region that just lost the competition to attract the plant. They find that five years after the plant opening incumbent plants' productivity is 12% higher in regions with plant openings compared to runner-up regions. Gathmann et al. (2016) analyze the converse event by analyzing how large mass layoffs affect regional labor market outcomes. They find that local labor markets affected by mass layoffs lose many more workers than through the initial layoff. Kline and Moretti (2014) analyze how a place based policy aimed at attracting manufacturing employment and providing investment in public infrastructure affects local employment in the long run. They find sizable long run effects on manufacturing employment and explain these with the existence of agglomeration effects.

The use of natural experiments provides a plausible identification strategy for the analysis of the existence and strength of agglomeration economies. However, these recent studies all exploit relatively specific events at the local level. I will add to this literature by using a broader approach to identify agglomeration spillovers that allows me to convincingly control for region specific shocks. A major difference between the identification strategy in this paper and the identification strategy applied in the recent studies mentioned above is that I fix the national industry shock per worker (every worker in a given industry is affected by the same national industry shock) and exploit differences in local industry structure, while for example Greenstone et al. (2010) and Gathmann et al. (2016) fix local industry structure and exploit variation in per worker shocks across regions. In particular, I exploit a quasi experiment leading to a large set of national industry trade shocks. While there arguably still exist particularities when using national industry trade shocks to estimate agglomeration effects, I argue that the identification strategy can be applied to various other kinds of national industry shocks. In addition, to my knowledge it has not been shown before that national industry shocks can lead to such kind of regional spillovers.[5]

Furthermore, I can exploit variation in shocks both within and across industries, which allows me to study heterogeneities across industries in more detail than for example Greenstone et al. (2010) and Gathmann et al. (2016). This allows me to distinguish between spillovers triggered by shocks to high technology industries and spillovers triggered by shocks to low technology industries. In that sense, I also add to the literature analyzing the effects of place based policies (see for example Busso et al. (2013), or Becker et al. (2010)). Governments at least partially justify place based policies by the existence of agglomeration spillovers (see for example Glaeser and Gottlieb (2008)). However, evidence on the effects of place based policies is mixed likely because of heterogeneities in the policies provided and the characteristics of the places they aim at. Nevertheless, evidence on heterogeneous effects is still scarce. Notable exceptions are Briant et al. (2015) who detect heterogeneities in the effects of the French Enterprise Zone program and Becker et al. (2013) who analyze regional

[5] However, Acemoglu et al. (2016) hint to that by analysing how macroeconomic shocks propagate through the economy pointing to the importance of national input-output networks and local networks of industry collocation.

heterogeneities in the effects of the European Structural Funds. The results on heterogeneous effects are consequently important from a policy perspective, as they give new evidence on which firms governments should aim to attract when implementing place based policies and to which areas they should be attracted to.

The study is also related to the literature analyzing employment effects of globalization using trade shocks.[6] Autor et al. (2013) analyze the effects of rising Chinese import competition due to China's transition into a market oriented economy on US local labor markets. They find that about 25% of the reduction in manufacturing employment in the US between 1990 and 2007 can be attributed to rising Chinese import competition. In a follow up paper, Acemoglu et al. (2015) additionally analyze the effects of rising import competition on employment in upstream and downstream industries on national industry level, hence accounting for indirect *national* product demand spillovers and find that these spillovers make up for about 50% of the total national employment loss due to Chinese import competition. Dauth et al. (2014) conduct a similar study as Autor et al. (2013) in the German context. However, to better accommodate the setting to the German context, Dauth et al. (2014) additionally include trade shocks from Eastern European countries triggered by the fall of the iron curtain and analyze local employment effects of shocks to both export demand and import competition. While most of the literature analyse medium run effects, Dix-Carneiro and Kovak (2016) are able to study the evolution of the effects of trade liberalization on local labor markets in Brazil over time and can thus focus on adjustment processes.[7]

I exploit the same type of shocks as Dauth et al. (2014). I add to the literature by giving additional insights into one particular aspect determining the local employment impact of trade shocks - the existence of agglomeration economies - that to my knowledge has been largely ignored by the literature so far.[8] I consequently open up the black box of local employment effects estimated by Autor et al. (2013) and Dauth et al. (2014) and show that local employment effects are composed of both direct effects of trade shocks and indirect effects through local employment spillovers.

3 Theoretical Framework

In this section, I will first describe the sources of agglomeration economies that have been brought forward by the literature and describe how these sources can lead to spillovers following trade shocks. I then build a simple theoretical model incorporating agglomeration economies. From the model I derive empirically testable predictions on how trade shocks affect local industry employment in the

[6] In related work Bloom et al. (2016) analyze the impact of Chinese import competition on broad measures of technical change, such as patenting, IT and TFP, for several countries in Europe and find that trade induces technical change.

[7] Dix-Carneiro and Kovak (2016) analyze the local impact of changes in trade policy exploiting differences in trade liberalization intensity across industries (see also for example Topalova (2010)). Kovak (2013) provides a theoretical foundation for this approach.

[8] A notable exception is Dix-Carneiro and Kovak (2016) who show that the observed local adjustment processes following trade liberalization are driven by slow capital adjustment and agglomeration economies, applying the method I develop in this paper for the estimation of agglomeration economies.

presence of agglomeration economies.

3.1 Sources of Agglomeration Economies

As first hypothesized by Marshall (1890), there exist several reasons of why industries may enjoy productivity or cost advantages from co-locating. Productivity advantages can arise through knowledge spillovers or thick labor market effects. A positive trade shock to one industry can lead to productivity spillovers through both of these mechanisms. First, the trade shock leads to an increase in labor demand in the industry directly affected by the shock causing the industry to increase its workforce and consequently local labor market size (as long as local labor supply is not completely inelastic). In a labor market with search frictions and heterogeneous firms and workers, this increase in local labor market size may make worker-firm matches of other local industries more productive as now more firms offer jobs and more workers look for jobs in the local labor market (see e.g. Helsley and Strange (1990)).[9] Knowledge spillovers might take place, because the increased demand for labor of the local industry directly affected by the trade shock increases worker flows and hence mobility across local industries. In addition, the increase in local labor market size brings new human capital and consequently new knowledge into the region. Formal and informal interactions among these individuals may then lead to sharing of this knowledge, generating positive production externalities (see e.g. Lucas (1988); Glaeser (1999); Serafinelli (2016)).

Positive trade shocks to one industry can further lead to cost advantages for other local industries through input-output relations: upstream suppliers located in the same region are likely to benefit more from the resulting product demand shock than suppliers in other regions. This is because they can meet the increased demand for services and intermediate goods in a cheaper and faster way.

In the modeling framework below, I capture agglomeration effects in a simple, reduced form way through a local industry specific productivity shifter which is assumed to be a function of employment in all local industries in the region. This captures the idea that knowledge spillovers and thick market externalities (and also transport costs) depend on the size of the local labor market.

3.2 A Model of Agglomeration Economies

I will now outline a simple theoretical model incorporating localized spillovers between industries from which I derive predictions on how trade shocks affect local industry employment in the presence of agglomeration economies to base the empirical strategy on a theoretical background.

[9] A larger labor market may in addition provide insurance against idiosyncratic shocks, for both firms and workers (see e.g. Krugman (1991) or Overman and Puga (2010)). Following an increase in local labor market size due to a trade shock the likelihood that a firm cannot fill a vacancy following an idiosyncratic labor supply shock or a worker cannot find another job when her employer is hit by an idiosyncratic negative demand shock may hence be reduced.

Set-Up and Baseline Equilibrium

The model economy is assumed to consist of many regions r and many industries j. Each industry produces an industry specific good whose price p_j is determined nationally and is hence assumed to be exogenously given.

In each industry output (Y_{jr}) is produced according to a Cobb-Douglas production function using labor (L_{jr}), capital (K_{jr}) and a non-tradable resource ($\bar{R}_{jr}$):

$$Y_{jr} = A_j A_{jr} L_{jr}^{\alpha} K_{jr}^{(1-\alpha)\mu} \bar{R}_{jr}^{(1-\alpha)(1-\mu)} \tag{3.1}$$

Firms choose labor (L_{jr}), capital (K_{jr}), which is fully flexible and provided at an internationally determined price i, and the amount of resources ($\bar{R}_{jr}$) used in production to maximize profits, taking local and national industry specific productivity (A_{jr} and A_j), output prices (p_j), non-tradable resource prices (q_{jr}) and local wages (w_r) as given.[10] The non-tradable resource ($\bar{R}_{jr}$) is assumed to be fixed at the local industry level. Assuming that local industry production includes a fixed resource ensures that regions can compete for multiple industries despite differences in local industry productivity and is common in spatial equilibrium models incorporating multiple local industries (see for example Kline and Moretti (2014) or Hanlon and Miscio (2016)). Such a fixed resource can be thought of as fixed industry specific capital or some natural resource input.

Solving the maximization problem at the local industry level, the local industry labor and capital demand conditions are given by

$$w_r = \alpha p_j A_j A_{jr} L_{jr}^{(\alpha-1)} \bar{R}_{jr}^{(1-\alpha)(1-\mu)} K_{jr}^{(1-\alpha)\mu} \tag{3.2}$$
$$i = (1-\alpha)\mu p_j A_j A_{jr} L_{jr}^{\alpha} \bar{R}_{jr}^{(1-\alpha)(1-\mu)} K_{jr}^{(1-\alpha)\mu-1}. \tag{3.3}$$

Using these two conditions (equations (3.2) and (3.3)) I can then solve for labor demand at the local industry level:[11]

$$\begin{aligned} ln\left(L_{jr}\right) = \frac{1}{(1-\alpha)(1-\mu)} & \left[ln\left(A_{jr}\right)\right. \\ & + \left(ln\left(A_j\right) + ln\left(p_j\right)\right) \\ & \left. - \left(1-\mu(1-\alpha)\right) ln\left(w_r\right)\right] \\ & + ln\left(\bar{R}_{jr}\right) + C_1 \end{aligned} \tag{3.4}$$

To close the model I need to make an assumption about local labor supply. To keep the model simple I assume that local labor supply is exogenously given by

$$ln\left(L_r\right) = \frac{1}{\eta} ln\left(w_r\right), \tag{3.5}$$

[10] Note, for simplicity, I assume wages are determined locally implying that workers are perfectly mobile across industries within a location.

[11] $C_1 = \frac{\mu(1-\alpha)}{(1-\alpha)(1-\mu)} ln\left(\alpha \frac{(1-\alpha)\mu}{i}\right)$ is a constant only determined by exogenously given parameters.

where η is the inverse local labor supply elasticity. This elasticity measures the local employment response to local wage changes. If $\eta \to 0$ local labor supply is perfectly elastic and hence individuals do not have preferences for regions, if $\eta > 0$ individuals have preferences for regions (or face migration costs).[12] The local labor supply elasticity also determines how shocks to local labor demand of both industry j and the other local industries $k \neq j$ affect local wages w_r. If local labor supply is fully flexible, local industry labor demand shocks will not affect regional wages w_r. If individuals are however not perfectly mobile across regions ($\eta > 0$), then a positive local industry labor demand shock will affect local wages.

Agglomeration Forces and the Indirect Impact of National Industry Trade Shocks

As mentioned above, I assume that agglomeration forces and hence localized spillovers between industries are captured by the local industry specific productivity shifter A_{jr} and work through the size of employment in all industries in the local labor market. Specifying agglomeration spillovers to be working through regional (or local industries') employment is common in the literature and captures the idea that knowledge spillovers and thick markets externalities depend on the size of the local labor market.[13] In particular, the local industry specific productivity shifter A_{jr} is assumed to depend on local industry employment in the following way:

$$ln\left(A_{jr}\right) = \sum_{k} \left[\lambda_{jk} ln\left(L_{kr}\right)\right] \tag{3.6}$$

λ^{jk} represents the agglomeration elasticity between industries j and k ($\frac{\partial lnA_{jr}}{\partial lnL_{kr}} = \lambda_{jk}$). The elasticity should be thought of as a reduced form parameter reflecting all three sources of agglomeration spillovers discussed in Section 3.1, that is thick market effects, knowledge spillovers and input-output relations. It measures how strongly an employment increase in industry k affects productivity in industry j (and vice versa) and hence represents the strength of agglomerative forces between industry j and industry k. I assume $\lambda_{jk} \geq 0$. If $\lambda_{jk} = 0$, industries j and k do not benefit from being located in the same region, if $\lambda_{jk} > 0$, they do.

How then do national industry trade shocks affect local industry employment? National industry trade shocks constitute shocks to industry product demand. These shocks can affect local industry employment in two ways, both directly through the own industry trade shock and indirectly through agglomeration spillovers. Within the model the impact of such shocks on local industry employment both in the industry directly affected by the shock, as in the other local industries in the region can be analyzed by looking at how changes in goods prices affect local industry employment.[14] Let us first focus on the direct effect of a trade shock to industry j and hence a change in the price of the

[12] If $\eta \to 0$ the spatial equilibrium condition implies that the utility of all individuals is equalized across local labor markets, if $\eta > 0$ only utility for the marginal individual in the region needs to be equalized across local labor markets.

[13] See for example Moretti (2011) or Hanlon and Miscio (2016).

[14] Alternatively, one could analyze how changes in industry specific productivity (A_j and A_k) affect local industry employment, as for example Bustos (2011) and Lileeva and Trefler (2010) have shown that market size matters for innovation and hence for productivity. The predictions from the model would however stay the same.

good produced by industry j, p_j, on local industry employment in industry j. The effect of such a price change can be analyzed by totally differentiating equation (3.4) with respect to p_j:

$$\frac{dlnL_{jr}}{dlnp_j} = \underbrace{\frac{1}{(1-\alpha)(1-\mu)}}_{\text{(+) direct effect}} + \underbrace{\frac{1}{(1-\alpha)(1-\mu)}\sum_k \lambda_{jk}(\frac{dlnL_{kr}}{dlnp_j})}_{\substack{\text{(+/-) second order}\\ \text{agglomeration spillovers}}} - \underbrace{\frac{1-\mu(1-\alpha)}{(1-\alpha)(1-\mu)}\frac{dlnw_r}{dlnp_j}}_{\substack{(-)\text{ endogenous}\\ \text{wage adjustment}}} \geq 0 \qquad (3.7)$$

A change in the (national) price of the good produced by industry j affects local industry employment in industry j in three ways: through the direct effect (first term), through second (and higher) order agglomeration spillovers (second term) and through endogenous wage adjustments (third term). Conditional on local industry size (relative to region size) the first term will affect local industry employment in the same way across all regions.[15] The second term captures spillovers that affect industry j, because the change in p_j affects industry employment in the other industries in the region (first order spillover, see also equation (3.8)) and this in turn leads to spillovers in industry j again (second order spillover). The sign of the second order spillover is apriori not clear as it captures both the effects through agglomeration spillovers as through additional endogenous wage adjustments because of employment adjustments in the other industries in the region. The overall effect of the price change is non-negative.

Now, how does a trade shock to another local industry k' affect local employment in industry j? The mechanisms can be analyzed by totally differentiating equation (3.4) with respect to $p_{k'}$:[16]

$$\frac{dlnL_{jr}}{dlnp_{k'}} = \underbrace{\frac{1}{(1-\alpha)(1-\mu)}\lambda_{jk'}(\frac{dlnL_{k'r}}{dlnp_{k'}})}_{\substack{\text{(+) first order}\\ \text{agglomeration spillovers}}} + \underbrace{\frac{1}{(1-\alpha)(1-\mu)}\sum_{k\neq k'} \lambda_{jk}\left(\frac{dlnL_{kr}}{dlnp_{k'}}\right)}_{\substack{\text{(+/-) second order}\\ \text{agglomeration spillovers}}} - \underbrace{\frac{1-\mu(1-\alpha)}{(1-\alpha)(1-\mu)}\frac{dlnw_r}{dlnp_{k'}}}_{\substack{(-)\text{ endogenous}\\ \text{wage adjustment}}}. \qquad (3.8)$$

Changes in the price of the good produced by industry k' will affect local employment in industry j through two opposing effects: agglomeration spillovers (first and second term) and reallocation effects, that is endogenous wage adjustments (third term).

In the presence of agglomeration spillovers, that is $\lambda_{jk} > 0$, changes in $p_{k'}$ can positively affect employment in industry j through both the direct effect of an increase in $p_{k'}$ on employment in industry k' (first order spillover, first term) and through spillovers affecting industry j, because

[15] This implies that in the estimation of spillover effects the direct effect can be accounted for by national industry x period fixed effects conditional on local industry size (relative to region size). These national industry x period fixed effects will also pick up potential within industry spillovers.

[16] In the model it is assumed that $\frac{dlnp_j}{dlnp_{k'}} = 0$ for all $k' \neq j$. That is prices are assumed to be exogenous and hence there are no indirect product demand shocks affecting prices in industry j after a shock to prices of industry k'. Yet, if industry j and k' are related through input-output linkages, it is possible that industry k' increases its demand for goods produced by industry j, in response to a positive labor demand shock and hence the increase in demand of goods produced by industry j affects national prices in industry k'. Additionally, national prices could be affected if goods j and k' are substitutes. In the empirical specification national industry x period fixed effects will account for these national indirect product demand shocks.

the change in $p_{k'}$ affects industry employment in the other industries in the region (industries $k \neq k'$) in turn leading to additional spillovers in industry j (second order spillovers, second term). This is however only the case, if the shock to industry $k's$ labor demand increases employment in the local industry k', that is $\frac{dlnL_{k'r}}{dlnp_{k'}} > 0$. The direct effect on local employment in industry k', $\frac{dlnL_{k'r}}{dlnp_{k'}}$, is stronger if local labor supply is more elastic (see equation 3.7, third term) and hence the strength of these spillovers depends on the local labor supply elasticity $\left(\frac{1}{\eta}\right)$. As discussed above, the strength of the (endogenous) wage adjustment (third term) also depends on the local labor supply elasticity. If local labor supply is fully flexible ($\eta = 0$), regional wages w_r will not be affected by a demand shock to industry k' and hence not directly affect labor demand in industry j (as then $dln(w_r) = \eta dln(L_r) = 0$). If individuals are however not perfectly mobile across regions ($\eta > 0$), then a positive labor demand shock to industry k' will increase local wages and reduce industry $j's$ labor demand (as $-(1-\mu(1-\alpha))\, dln\,(w_r) < 0$). The joint effect of reallocation effects and agglomeration spillovers hence depends on both the flexibility of local labor supply ($\frac{1}{\eta}$) and the strength of agglomeration forces (λ_{jk}).

In Appendix B.1, I derive a version of local industry labor demand and the effects of a price change of the good produced by industry k' on local employment in industry j that depend only on exogenous parameters. The implied reactions are the same.

The model consequently leads to three main empirical predictions: First, for positive agglomeration spillovers to take place after a shock to the prices of goods of the other industries in the region, the direct effect of a price shock to industry k' on local employment in industry k' must be positive, that is $\frac{dlnL_{k'r}}{dlnp_{k'}} > 0$. Second if local labor supply is less than infinitely elastic local wages should be increasing following a price shock to a local industry. Third, the overall effect of shocks to goods produced by other industries is ambiguous and depends on the strength of agglomeration forces and the strength of the reallocation effects which affect local employment in industry j in opposite directions. However, if $\frac{dlnL_{jr}}{dlnp_{k'}} > 0$ then agglomeration forces must outweigh reallocation effects.

In the model changes in prices are used to analyse how product demand shocks triggered by national industry trade shocks affect local industry employment. In the empirical estimation I will however exploit national industry trade shocks directly, that is I analyse the effects of changes in quantities instead of changes in prices. This allows me to capture all margins of reductions in trade barriers following trade integration jointly, such as tariff reductions, better bilateral relations or increases in trust, but also for example the elimination of barriers to foreign investment.

4 Empirical Framework and Identification

The key econometric challenge in estimating agglomeration effects is to distinguish spillover effects from other factors jointly affecting employment in all industries in the region. The solution I propose in this paper is to use observed national industry level shocks affecting local industry labor demand that are not correlated with other region specific shocks. In the next section, I will argue that national industry level trade shocks affecting local industries constitute such shocks and describe the specific shocks I am exploiting. In Section 4.2, I will then outline the empirical strategy, describe more in detail how I exploit these shocks to estimate agglomeration effects and address some challenges for identification.

4.1 Trade Shocks

The national industry shocks I exploit to identify agglomeration spillovers are shocks reducing trade barriers between Germany and China and Germany and Eastern Europe that led to substantial increases in import competition and export product demand for many German industries.[17]

China's transition to a market oriented economy is by now well documented in the literature (see for example Naughton (2007)). As described by Autor et al. (2013), this transition has involved substantial rural-urban migration, access for Chinese industries to foreign technologies, capital goods and intermediate inputs and the possibility for multinational firms to operate in China. These factors, together with China's WTO accession in 2001, led to a considerable increase in competitiveness of Chinese industries giving rise to a substantial increase in imports of Chinese goods by high income countries. Further, the increase in competitiveness increased demand of Chinese firms and consumers for high income country products leading to substantial increases of high income country exports to China. As can be seen in the left panel of Figure 1, this is especially true in the case of Germany, one of the world's largest exporters. German imports from China and German exports to China rose substantially between 1988 and 2008 from about 3.2 to 55 billion EUR (or 1700%) and from about 3.5 to 32 billion EUR (or 900%) respectively.

In the aftermath of the fall of the iron curtain in 1989 most of the Eastern European countries intensified economic relations with the West. In 1995, the Czech Republic, Hungary, Poland, Slovakia, Bulgaria and Romania joined the WTO. At the same time bilateral agreements with other Eastern European countries and Russia were established. The process culminated in the European Union accession of the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, and Slovakia in 2004 and Bulgaria and Romania in 2007.[18] Because of Germany's proximity to Eastern Europe, these intensified relations led to substantial increases in both German imports from Eastern Europe and German exports to Eastern Europe (see Figure 1, right panel).

Both China's transition to a market oriented economy and the fall of the iron curtain can hence be seen as quasi experiments leading to substantial import and export shocks exogenously affecting labor demand in many German industries. These shocks are well suited to estimate agglomeration spillovers, as they should not be correlated with other region specific shocks jointly affecting local employment in all industries in the region.

[17] I define Eastern Europe as Bulgaria, Czechoslovakia, Hungary, Poland, Romania, the USSR and their successor countries.

[18] In addition in 2004 Cyprus, Malta and Slovenia joined the European Union.

4.2 Empirical Strategy

I will estimate agglomeration spillovers by relating changes in local industry employment to indirect exposure to the other local industries' trade shocks. In the following I will first explain how I construct the indirect trade exposure measures used to estimate agglomeration effects and then describe the main empirical specification. In Appendix A I provide an example to give some intuition for the identification strategy.

Measuring Local Indirect Trade Exposure

I measure local indirect trade exposure as an industry j worker's exposure to the other local industries' trade shocks. The measure is constructed in three steps. First, as I exploit information on trade flows on national industry level, I use a Bartik type approach attributing the share of industry k trade flows to regions according to the local industry's share on national industry employment.[19] Second, to get a measure of indirect per worker exposure of industry j workers to the industry k trade shock, I normalize the local industry k trade shock by industry j employment. The local indirect trade shock of industry k to a worker in industry j in region r is then given by

$$TrShock^{j}_{krt} \quad = \quad \frac{1}{L_{jrt}} \left(\frac{L_{krt}}{L_{kt}} TrShock_{kt} \right).$$

Because the measure is normalized by industry j employment it is comparable across industries and regions of different sizes. The final step of constructing the baseline measure of industry j local indirect per worker trade exposure is then to sum the local indirect trade shocks up over the other local industries in the tradable sector excluding the own industry trade shock, that is over industries $k \neq j$, such that:

$$TrShockIndir_{jrt} \quad = \quad \sum_{k \neq j} \frac{1}{L_{jrt}} \left(\frac{L_{krt}}{L_{kt}} TrShock_{kt} \right). \tag{4.1}$$

In practice, local indirect per worker trade exposure is measured as indirect net trade exposure, where net trade exposure is defined as the difference between changes in exports and imports between period t and period $t+1$, that is $\Delta Net^{GER}_{kt} = \Delta Exp^{GER}_{kt} - \Delta Imp^{GER}_{kt}$.[20] Consequently, the baseline measure will be given by

$$TrShockIndir_{jrt} = \Delta NetIndir_{jrt} \quad = \quad \sum_{k \neq j} \frac{1}{L_{jrt}} \left(\frac{L_{krt}}{L_{kt}} \Delta Net^{GER}_{kt} \right) \tag{4.2}$$

[19] Thus an important assumption for the identification of spillover effects is that local industry structure in the tradable sector at time t is not correlated with future trade shocks. Further, accruing trade flows to local industries according to their national employment shares avoids endogeneity problems faced when observing actual local industry trade flows.

[20] I use indirect net trade exposure instead of indirect export and import exposure separately, because the indirect import and export exposure measures are highly correlated with a correlation of about 0.94.

and measures by how much a worker in industry j is affected by the net trade shocks to the other industries in the region.

A concern with this baseline measure of indirect trade exposure may be that start of period local industry employment shares may be correlated with future trade shocks. In Appendix C.2, I provide a robustness check where employment levels used to distribute national industry trade flows to the local industries are 1988 employment levels in all periods and indirect trade exposure is normalized by 1988 employment of the industry under observation to account for this concern. This has little impact on the findings.

Estimation Method - Two Stage Least Squares

To estimate agglomeration spillovers I then relate local industry employment in industry j and region r to the local indirect trade shock to industry j in region r keeping own industry and tradable sector size constant and exploiting within industry variation in indirect trade exposure across local labor markets:

$$\Delta ln\left(L_{jrt}\right) \quad = \quad \beta_{indir} TrShockIndir_{jrt} + \theta_{jt} + \pi_1 \frac{L_{Trad,rt}}{L_{rt}} + \pi_2 \frac{L_{jrt}}{L_{rt}} + \pi_3 X_{jrt} + \nu_{jrt} \tag{4.3}$$

$\Delta ln\left(L_{jrt}\right)$ measures log changes in local industry employment from period t to $t+1$ (in practice t to $t+1$ will span a seven year period). $TrShockIndir_{jrt}$ measures indirect local industry trade exposure as defined above. The specification further controls for time varying national industry shocks through national industry x period fixed effects (θ_{jt}). Hence, the empirical strategy exploits within industry variation in indirect trade exposure that comes from differences in initial local industry structure within the tradable sector across regions. This implicitly controls for both indirect national product demand shocks to linked industries and for the *direct* per worker trade exposure of industry j.[21] In addition, the equation controls for the initial share of tradable employment in the region ($\frac{L_{Trad,rt}}{L_{rt}}$) and the initial share of industry j employment ($\frac{L_{jrt}}{L_{rt}}$). This ensures that the within industry variation in indirect trade exposure across local labor markets is only driven by the initial industry composition of the other tradable industries in the region and not by differences in their relative joint size. Finally, the X_{jrt} are a set of time varying local industry and regional characteristics, such as regional and local industry skill shares (low, medium and high skilled), period x federal state fixed effects (10 federal states in West Germany) and the share of female and foreign workers in the region.[22] The parameter of interest is β_{indir}. It measures the joint effect of agglomeration spillovers and reallocation effects. That is, in the baseline specification, instead of estimating a large number of parameters for each industry pair, I only estimate a single parameter capturing average spillovers across industries. I will relax this in Section 6.2.2 when

[21] Accounting for direct trade shocks on national level is sufficient for identification, as also the indirect trade exposure measure is built using only national industry trade shocks.

[22] The results are robust to controlling for commuting zone x period fixed effects instead of federal state x period fixed effects (see Appendix C.2).

more closely looking at the mechanisms driving spillover effects and in Section 6.2.3 when analyzing heterogeneities across industries.

A concern for identification is that not China and Eastern Europe specific factors drive increases in trade flows between Germany and these countries, but unobserved factors within Germany.[23] A positive product demand shock for goods of a certain industry might for example be positively correlated with both increases in imports of the good from China and Eastern Europe, as with employment in that industry. This would understate the true impact of import shocks. Further, a positive technological shock to a certain German industry could increase demand for its goods in China and Eastern Europe. At the same time, industries with a strong export demand shock from China and Eastern Europe might be industries doing less well otherwise, for example experiencing a decline in domestic (or world) product demand. While the former would overstate the effect, the latter would again lead to a downward bias. To account for these unobserved German specific factors, I follow Autor et al. (2013) and employ an instrumental variable strategy instrumenting German trade flows with trade flows of other high income countries with China and Eastern Europe:[24]

$$TrShockIndir^{IV}_{jrt} = \sum_{k \neq j} \frac{1}{L_{jr,t-1}} \left(\frac{L_{kr,t-1}}{L_{k,t-1}} TrShock^{Other}_{kt} \right) \tag{4.4}$$

Note that I additionally use lagged employment instead of start of period employment when constructing the measure. Using lagged employment helps alleviating two further concerns. First, contemporaneous employment might already be affected by anticipated trade with China and Eastern Europe. Second, by shifting the normalization one period back, I alleviate problems due to using start of period employment on both sides of the estimation equation in the second stage.

The instrumental variable strategy will then identify spillover effects due to Chinese and Eastern European specific factors, if the unobserved shocks are not correlated across high income countries, for example because of a world trade demand shock. In Appendix C.2, I will provide a robustness check controlling for changes in German world trade to control for potentially correlated shocks across high income countries. This has little impact on the results.

More particularly, indirect net trade exposure will be instrumented using import and export shocks of other high income countries separately, that is $TrShockIndir^{IV}_{jrt} = \Delta ExpIndir^{IV}_{jrt} +$

[23] This refers to unobserved factors correlated with the industry k direct trade shock and hence indirectly affecting industry j. Correlation of the indirect trade shocks with unobserved factors affecting industry j employment would need to be within industry and across local labor markets. However, it is unlikely that local industry region specific shocks are correlated with the indirect trade shocks that are created using the national industry direct trade shocks.

[24] I use the full set of high income countries used in Autor et al. (2013) and Dauth et al. (2014), but excluding Japan. The countries are listed in Appendix Table C1. Dauth et al. (2014) exclude Denmark and Switzerland because they are neighboring countries and Finland and Spain as they are in the Eurozone. I prefer including these countries in the main specification, as their trade exposure with respect to Eastern Europe should arguably be more similar to Germany, than for example New Zealand's or Singapore's trade exposure. I exclude Japan, as Japan would dominate the instrument and as Japanese industries are likely to be in high export competition with German industries. Consequently, the correlation in exports to China and Eastern Europe between Germany and Japan is likely to understate the true correlation. This might lead to an underestimate of the spillover effect. I perform extensive robustness checks excluding certain sets of instrument countries and including Japan in Appendix C.2.

$\Delta ImpIndir_{jrt}^{IV}$, where

$$\begin{aligned} \Delta ExpIndir_{jrt}^{IV} &= \sum_{k \neq j} \frac{1}{L_{jr,t-1}} \left(\frac{L_{kr,t-1}}{L_{k,t-1}} \Delta Exp_{kt}^{Other} \right) \\ \Delta ImpIndir_{jrt}^{IV} &= \sum_{k \neq j} \frac{1}{L_{jr,t-1}} \left(\frac{L_{kr,t-1}}{L_{k,t-1}} \Delta Imp_{kt}^{Other} \right). \end{aligned} \tag{4.5}$$

I use the import and export shocks separately as instruments, as this is less restrictive and exploits more of the variation in the trade shocks than the net measure. These measures are however highly correlated, with a correlation of about 0.92 between $\Delta ExpIndir_{jrt}^{IV}$ and $\Delta ImpIndir_{jrt}^{IV}$ (0.94 between $\Delta ExpIndir_{jrt}$ and $\Delta ImpIndir_{jrt}$), which is the reason why I turn to using net indirect trade exposure in the second stage.

5 Data Sources and Descriptive Overview

5.1 Data Sources

For the empirical analysis I combine data from two sources: from German Social Security records and from the UN Comtrade database. For the local labor market outcomes I use data from German Social Security records. In particular, I use aggregated data on 3-digit industry x commuting zone level for the years 1978 to 2008. The underlying data comprise the whole population of workers covered by the social security system in Germany.[25] Information on employment at the individual level is reweighted into full time equivalent units giving a weight of 0.6 (0.3) to part time employed individuals that work 18 to 30 hours (less than 18 hours) and excludes marginal employment. Employment is measured at the 30th of June of each year. That is, I observe fulltime equivalent employment aggregated on 3-digit industry x commuting zone level as of 30th of June of a given year. Furthermore, I have information about skill group shares (low, medium, high skilled), age groups (16-25, 26-50 and 51-65), the share of female and foreign workers and average wages in these cells. The underlying individual wage observation contains the average daily wage of the employment spell containing the 30th of June and is right censored at the social security limit. Before aggregating, wages are first deflated to 1995 prices. Then, right censored wages are imputed assuming the error term in the wage regression is normally distributed and allowing for separate variances by commuting zone, year and gender. For data confidentiality reasons, I only observe information on the 3-digit industry x commuting zone cells if these cells contain at least 20 individual observations. Because of this restriction I observe about 96.9 percent of total social security covered employment.

Information on imports and exports comes from the UN Comtrade Database. This database contains detailed information on trade flows between countries for a huge number of reporter countries,

[25] The data does not include the self-employed, civil servants and military personnel. In 1995, 79.5 percent (Bundesagentur fuer Arbeit) of workers in West Germany were covered by the social security system.

amongst them all countries used in the analysis. Information is available on detailed commodity level. I use the SITC3 classification on 4-/5-digit level.[26] The total number of commodities on 4-digit level in the SITC3 classification that is either imported or exported by German industries is 1031.

I merge the local industry labor market data to the trade flow data using correspondence tables between SITC3 4-/5-digit commodity level and NACE1 3-digit industries.[27] I drop all industries related to fuel, oil and gas, as these have high price fluctuations. In the following, the tradable sector will be defined as all remaining 3-digit industries with world exports higher than 50 Million EUR in 1988. In total these are 102 industries. All other industries will be defined as non-tradable.[28] The main analysis will be conducted with tradable industries only.

5.2 Estimation Sample and Descriptive Overview

In this section, I will further describe how the estimation sample is constructed and provide some summary statistics describing the data.

As the fall of the iron curtain started in 1989 and China's transition into a market oriented economy started in the 1990s, I will follow Dauth et al. (2014) and use observations from 1988 to 2008, that is the analysis period starts shortly before the fall of the iron curtain. I will fit three 7-year equivalent periods into that time span: 1988 to 1995, 1995 to 2001 and 2001 to 2008.[29] The first year of a period corresponds to t and the last year to $t+1$. Lagged employment $(t-1)$, which is used for constructing the instrumental variables will be 1981, 1988 and 1995 respectively.

In the main part of the empirical analysis I will focus on West Germany, as employment data for East Germany is only reliably available from 1993 onwards and I expect German national industry trade flows to better predict West German local trade flows as West German trade flows make up for more than 90% of total German flows (German Federal Statistical Office (2014)). I will examine spillover effects within commuting zones. Commuting zones are defined on the basis of commuter flows implying that at least 65% of individuals living in the commuting zone must be employed in the same commuting zone and travel times within a commuting zone cannot exceed 45 minutes. There exist 204 commuting zones in West Germany, with an average employment level of about 95.000 in the data. As in some commuting zones employment in the tradable sector is dominated by a single industry (or firm), I drop the regions with the highest 3 percent share of a single industry on employment in the tradable sector in 1988. These are regions with a single industry accounting for

[26] SITC3 classification data for the US and Singapore is only available from 1989 onwards. I hence use the 1989 data for these two countries.

[27] I use correspondence tables from the world bank. These are very similar to the tables used in Dauth et al. (2014), but additionally provide information on 5 digit SITC level for a subset of commodities. I reestimated the results using correspondence tables from Dauth et al. (2014). These are very similar.

[28] The non-tradable sector consequently also includes tradable services.

[29] The results do not depend on the choice of periods and are very similar when fitting two 10 year periods as in Dauth et al. (2014). However, due to the fact that industries with high indirect trade exposure are rather negatively selected as shown below, I prefer fitting more periods as this controls more flexibly for other changes in regional and industry level characteristics.

more than 52% of local employment in the tradable sector.[30] The sample consists of the remaining 198 commuting zones.

Summary statistics on local industry characteristics and indirect trade exposure measures are presented in Table 1. First, it should be highlighted, that tradable employment in Germany decreased considerably in the period from 1988 to 2008. In each of the three 7-year periods average local log industry employment in the tradable sector decreased by about 0.16 log points (see Table 1, Panel A).[31] Furthermore, the employment share in the tradable sector declined over time, implying that some of the employment loss in the tradable sector is absorbed by the non-tradable sector and the average local industry employment decline across all sectors is lower.

In Panel B of Table 1, summary statistics on the measures of indirect per worker trade exposure are presented. These are constructed as described in Section 4.2, equation (4.1), and measured in 1 million EUR per worker. Both indirect import and export exposure to trade shocks from Eastern Europe and China grow considerably over time, mirroring the picture of total national imports and exports in Figure 1. In the first two periods (1988 to 1995 and 1995 to 2001) indirect import and export exposure both grow at a similar level, implying average indirect net trade exposure per worker is about 0. However, there is variation in net trade exposure also in these two periods. In the last period from 2001 to 2008, indirect export trade shocks then outweigh indirect import trade shocks leading to an indirect per worker net trade shock of about 0.25 per 1 million EUR. Furthermore, indirect trade exposure from trade shocks to other industries within the same sector amounts on average to about one third of the total tradable sector trade exposure. This is about the same proportion as the average share of same sector employment on employment in the other tradable industries in the region.

Figure 2 looks more in detail into the variation in indirect per worker net trade exposure within 3-digit industries (and across commuting zones). The figure plots for each 3-digit industry the mean +/- the standard deviation of the residual of a regression of indirect per worker net trade exposure on period fixed effects and tradable and own industry employment shares. Consequently, variation in indirect net trade exposure comes only from differences in local industry composition of the other tradable sectors and not from differences in the relative joint size of the other tradable industries in the region. The figure shows considerable variation in indirect per worker trade exposure across commuting zones for basically all of the 3-digit industries. This is important for the estimation of spillovers, as identification in the main empirical specification (equation (4.3)) comes from *within* industry variation in indirect per worker trade exposure across commuting zones.

A concern of using within industry variation to identify spillover effects is that an industry (with a certain 3-digit code) located in a region with high indirect per worker net trade exposure might

[30] This drops commuting zones that include the districts Wolfsburg, where the car manufacturing industry makes up for 86 percent of tradable employment and Leverkusen, where the manufacturing of basic chemicals industry makes up for 74 percent of tradable employment. This does not affect the spillover effects results presented in Section 6.2, it does however affect the local employment effects estimated in Section 6.1. Dauth et al. (2014) instead control for the car manufacturing share in the region, which leads to similar results.

[31] The average percentage employment decline is about *8%*.

differ substantially in terms of its industry (and region) characteristics, for example in local skill structure or productivity, from an industry with the same 3-digit code located in a region with low indirect per worker net trade exposure. Consequently, the concern is that this industry potentially experiences an employment increase because of some favorable local industry characteristics, and not because of agglomeration spillovers from trade shocks to other local industries.[32] However, there are several points speaking against this concern. First, the 3-digit industry level is a relatively detailed classification of industries, such that it can be expected that these industries produce very similar goods. Second, to further dispel doubts that industry selection might cause local industry employment growth and not agglomeration spillovers, in Table 2 I present average industry characteristics for the whole sample, as well as for six further categories: industry observations with indirect net trade exposure below the 1st percentile, between the 1st and the 25th percentile, between the 25th and the 50th percentile, between the 50th and the 75th percentile, between the 75th and the 99th percentile and above the 99th percentile. The percentile measures are constructed within 3-digit industries and period and are employment weighted, that is within percentile groups the number of individuals employed is the same. Table 2 does not reveal a clear pattern in industry characteristics across percentile groups. Focusing on the groups between the 1st and the 99th percentile (Columns (3) to (6)), if at all, industries with higher indirect trade exposure seem to be negatively selected, as they have a lower average wage and a lower share of high skilled workers. However, the differences in average wage and high skill share are not statistically significant with respect to any of the other groups within the 1st and 99th percentile. The industry observations in the lowest and highest percentile of indirect trade exposure however seem to be negatively selected: their average wage and share of high skilled workers is considerably lower than in the other groups. To account for that, in Appendix C.2 I will provide a robustness check estimating spillover effects excluding observations in the lowest and highest percentile of indirect net trade exposure. This robustness check leads to slightly increased, but generally similar effects of indirect trade exposure on local industry employment.

6 Empirical Results

6.1 Direct and Local Employment Effects of Trade Shocks

I start the empirical analysis by examining whether direct effects from trade shocks exist and whether the joint regional trade shocks affect local employment and wages. Analyzing these effects is important, as a positive impact of trade shocks on both employment in the industry directly affected by the trade shock and on local employment are an important precondition for the observation of agglomeration effects following national industry trade shocks. This is because agglomeration spillovers due to thick market effects or increased knowledge exchange are expected to arise from

[32] The instrumental variable strategy does not account for this kind of correlation. It only accounts for correlation of the direct shock with other German specific factors affecting industry employment in the industry affected by the direct shock and consequently indirectly affecting employment in the other local industries through spillovers.

increases in local labor market size due to the industry directly affected by the shock expanding employment (see Section 3.1 and Section 3.2).

The direct effects are estimated based on equation (4.3) (and using 2SLS), but replacing indirect net trade exposure by the direct national per worker trade shock of industry j, $\frac{\Delta Net_{jt}^{GER}}{L_{jt}}$ (measured in 1000 EUR per worker).[33] This measure does not vary within 3-digit industry and consequently these regressions do not include national industry x period fixed effects. The results are shown in Table 3, Columns (1) and (2). Column (1) reports the effects of the direct trade shock on local industry employment. An increase in the national direct per worker trade shock of 1000 EUR increases local industry employment by 0.45 percentage points. Direct trade exposure did however not affect local industry wages (Column (2)).

For the estimation of local effects, I follow the literature estimating local employment effects of globalization using trade shocks, and construct the regional measure by summing up the local trade shocks across all local industries (including industry j) and normalizing the measure by overall local employment L_{rt}, that is $\sum_k \frac{1}{L_{rt}} \left(\frac{L_{krt}}{L_{kt}} \Delta Net_{kt}^{GER} \right)$ (measured in 1000 EUR per worker). This measure consequently represents regional per worker trade exposure to the joint trade shocks of *all* local industries. The specification is otherwise the same as for the estimation of direct effects in Columns (1) and (2), Table 3. Column (3), Table 3, shows that a 1000 EUR increase in the regional per worker trade shock leads to an increase in local industry employment of about 2.21 percentage points, but does not affect local wages.[34]

Having established that (positive) trade shocks positively affect local industry employment in the industry directly affected by the trade shock and increase local labor market size, in the next section I analyze if, as a consequence, agglomeration spillovers to other local industries in the region arise.

6.2 Agglomeration Spillovers from Trade Shocks

In the following sections I will present evidence for the existence of agglomeration spillovers triggered by national industry trade shocks. I start with examining the effects of local indirect per worker trade shocks on tradable sector industries. I will then analyze in more detail how economic proximity affects the strength of spillovers between industries and analyze heterogeneities across industries.

6.2.1 Baseline Results

In this section, I show estimates of spillover effects from trade shocks based on variants of the two stage least squares model presented in equation (4.3) instrumenting trade exposure of German industries with trade exposure of other high income country industries as explained in Section 4.2.

[33] National industry level direct effects of trade shocks on employment have previously been estimated by Acemoglu et al. (2015) and Pierce and Schott (2016). Both studies find significant direct effects of trade shocks on national industry level employment.

[34] Both the direct effects estimates and the estimates of local employment effects are robust to the inclusion of sector x period fixed effects (distinguishing between 17 sectors).

The sample consists of all tradable sector industries. Spillovers are assumed to be constant and symmetric across industry pairs, that is $\lambda_{jk} = \lambda \, \forall j, k$.

The results are presented in Table 4. In Column (1) the estimation includes the variable of interest, that is indirect net trade exposure $(\Delta NetIndir_{jrt})$, period x federal state fixed effects and the tradable and own industry employment shares to ensure that differences in indirect trade exposure come from differences in industry composition of the other tradable industries in the region and not from differences in the joint relative size of the other tradable industries. The coefficient in Column (1) is slightly positive but not significant (2.10 percentage points). Column (2) further adds the own industry national per worker import and export shock to control for the direct trade shock to industry j. This increases precision and the coefficient to 2.87 percentage points per 1 million EUR indirect per worker trade shock. This indicates that the own industry direct trade shock is *negatively* correlated with the indirect trade shock. Column (3) adds further control variables, which are local industry and regional skill shares (low, medium and high skilled) and the share of female and foreign workers in the region to control for local characteristics that might be correlated with indirect trade exposure and potentially affect employment growth. This slightly increases the coefficient, mirroring the impression in Table 2, that local industries with higher indirect trade exposure are rather negatively selected. In Column (4), results of the main baseline specification (equivalent to equation (4.3)) are presented, which includes national industry x period fixed effects to control for possible national indirect product demand shocks and other time varying national industry trends affecting local employment of industry j. Adding national industry x period fixed effects more than doubles the effect to 7.75 percentage points per 1 million EUR increase in indirect net trade exposure. This indicates that (national) industries with a higher indirect trade shock seem to otherwise do worse and would have adjusted employment downwards without the positive effects from the indirect trade shocks. A coefficient of 7.75 implies, that local industry employment increased on average by about 1.94 percentage points due to indirect trade exposure in the tradable sector in the period from 2001 to 2008 (indirect net trade exposure increased by 0.25 million EUR per worker).

For comparison the OLS results of estimating equation (4.3) directly without instrumenting indirect net trade exposure are presented in column (5). While the OLS results are still significantly positive, the coefficient is considerably smaller. One explanation for the difference between the OLS and 2SLS results is that positive technology shocks to German industries might increase demand for intermediate goods used as inputs by these industries, thus increasing imports from China and Eastern Europe independently of the increase in exposure to import competition from China and Eastern Europe. This would lead to downward biased OLS estimates. Secondly, industries that are more strongly affected by positive (net) trade shocks from China or Eastern Europe are industries that otherwise do less well, for example because of a decline in domestic (or world) product demand or because of other industry specific factors negatively affecting employment in these industries. The substantial increase in the estimated effects when moving from the specification controlling for the direct trade shocks (Column (3), Table 4) to the specification controlling for national industry x period fixed effects (Column (4), Table 4) seem to confirm that a strong negative correlation between the direct trade shocks and other factors affecting employment exists. An example for an industry facing such negative demand conditions outside of China and Eastern Europe is the car manufacturing industry, which faced a decrease in domestic demand for cars implying employment reductions, while at the same time the demand shock for German cars in China (and Eastern Europe) was one of the largest export demand shocks to a German industry stemming from trade integration of China and Eastern Europe.[35]

In Appendix C.2 I demonstrate that the findings presented in this section are robust to adding commuting zone x period fixed effects, controlling for the change in net world trade, normalizing indirect trade exposure by 1988 instead of start of period employment and to excluding the observations with the highest and lowest levels of indirect trade exposure (1st and 99th percentile).

6.2.2 Economic Proximity and Sources of Agglomeration Spillovers

The indirect trade exposure measure defined over all other tradable industries' trade shocks is arguably a very coarse measure. This is especially true in light of the mechanisms leading to agglomeration spillovers described in Section 3.1 which indicate that economically close industries should be more strongly affected by indirect trade exposure, as spillovers between these industries are stronger. In this section, I will analyze the importance of economic proximity between industries for the existence of agglomeration spillovers.

I start by decomposing the indirect trade exposure measure into indirect trade exposure from other industries in the same sector versus indirect trade exposure from industries in the other tradable sectors, distinguishing between 6 broad sectors within the tradable sector (that is $\Delta NetIndir_{jrt} = \Delta NetIndir^{Same}_{jrt} + \Delta NetIndir^{Other}_{jrt}$).[36] This implies, that I now allow the agglomeration elasticity to differ between industries in the same sector as industry j and industries in other sectors such that $\lambda_{jk} = \lambda_{\cdot, same}$ if industries j and k are in the same sector and $\lambda_{jk} = \lambda_{\cdot, other}$ if industries j and k are in different sectors. As industries in the same sector are likely to be economically closer to each other, one would expect that $\lambda_{\cdot, same} > \lambda_{\cdot, other}$. The results in Table 4 confirm this. Column (6) estimates the main specification including both regional controls and industry x period fixed effects (equivalent to the tradable sector specification in column (4)). The coefficient on the same sector measure indicates a positive employment spillover from indirect trade shocks to other industries in the same sector of 12.86 percentage points per 1 million EUR indirect per worker trade exposure. In contrast, spillovers from other tradable sector industries outside of the same sector are still positive, but with an employment increase of 5.08 percentage points per 1 million EUR indirect per worker trade exposure about 2.5 times smaller than the spillovers from trade shocks in the

[35] A further explanation for the difference in OLS and IV estimates may be that the impact of trade shocks on local industry employment is heterogeneous across industries. The fact that the IV results are estimated more precisely than the OLS results is indicating that heterogeneous effects may be present in this setting.

[36] These sectors are defined as the agricultural sector, the energy and mining sector, the food industry sector and the three manufacturing sectors: manufacturing of consumer products, manufacturing of producer goods and manufacturing of investment goods and durables.

same sector. This is a first indicator that economic proximity between industries is important for the existence of agglomeration spillovers between industries. But what are the mechanisms behind these spillovers? Do industries rather benefit from being located close to each other if they are connected through vertical linkages? Or do industries connected through sharing a common labor force benefit more, as they can benefit from better matches through thick labor market effects or from knowledge spillovers because of increased worker mobility across industries both within and across regions?

To investigate this question, I create three measures of economic proximity and use these measures to reweight the strength of trade shocks from other local industries. The first proximity measure is based on worker flows between industries and is calculated as the maximum of the share of workers leaving industry j and moving to industry k and the share of workers leaving industry k and moving to industry j over a 5-year window from $t-5$ to t. This measure gives a higher weight to indirect shocks from industries with increased worker exchange or similar worker requirements as industry j (w_{jkt}^{worker}). The other two measures reflect proximity through input-output linkages. These measures are computed using German input-output tables from 1995 which are available at the 2-digit industry level. The first input-output measure is calculated as the share of goods produced in industry k that is sold to industry j. It gives a higher weight to the indirect trade shock from industries that are upstream suppliers to industry j (w_{jk}^{up}). The second input-output measure is calculated as the share of goods produced in industry j that is sold to industry k. Consequently, this measure gives a higher weight to indirect trade shocks from industries that are downstream customers of industry j (w_{jk}^{down}). The new rescaled indirect trade exposure measures accounting for economic proximity between industries are then given by

$$\Delta NetIndir_{jrt}^{prox} \quad = \quad \sum_{k \neq j} \frac{1}{L_{jrt}} \left[w_{jkt}^{prox} \left(\frac{L_{krt}}{L_{kt}} \Delta TrShock_{kt} \right) \right], \tag{6.1}$$

where w_{jkt}^{prox} represents the three rescaling measures w_{jkt}^{worker}, w_{jk}^{up} and w_{jk}^{down}.[37]

In Table 5, I present results from estimating equation (4.3), but adding the reweighted version of the respective proximity measures, $\Delta NetIndir_{jrt}^{prox}$, to the regression. These measures are standardized to have mean 0 and standard deviation 1.[38] In columns (1) to (3), the effects of the rescaled indirect trade exposure measures are estimated one by one. In column (4) equation (4.3) is estimated including all three rescaled indirect trade exposure measures jointly, hence accounting for possible correlations across the three measures. The results indicate that agglomeration spillovers from trade shocks predominantly take place between industries that exchange more workers with each other (Column (1) and (4)), while input-output relations seem to matter less (Columns (2), (3) and (4)).[39] When using 2-digit input-output tables, to analyse the effects on vertically linked in-

[37]This implies that the agglomeration elasticity is now assumed to be given by $\lambda_{jk} = \lambda_{\cdot, prox}$, where $prox$ represents the corresponding economic proximity measure.

[38]In these regressions the baseline measure $\Delta NetIndir_{jrt}$ is also normalized to have mean 0 and standard deviation 1.

[39]It is unlikely that the slightly positive spillover effect triggered by trade shocks to upstream suppliers can be

dustries, part of the variation in input-output linkages might be missed. Unfortunately in Germany input-output tables at a finer level do not exist. Instead, in Appendix C.3, I repeat the exercise using US input-output tables at the 3-digit industry level as a proxy. The estimated results are very similar to the results in Table 5.

The results in both Table 5 and Appendix Table C3 indicate that increased worker exchange between industries is important to create spillovers from trade shocks. This result is particularly remarkable as also the reallocation effect in response to a positive trade shock to an industry with similar worker requirements should be stronger. It is however in line with recent findings by Greenstone et al. (2010). Larger spillovers between industries with increased worker exchange on the one hand indicate that thick labor market effects are an important driver of spillover effects, as industries with increased worker exchange have similar worker requirements. Hence, an increase in the size of one industry due to a positive net trade shock positively affects the available labor pool for the other industry potentially leading to an improvement in the quality of worker-firm matches. On the other hand, the inflow of new human capital into the region, and a higher level of worker mobility within the region, as a consequence of the expansion of employment in the industry hit by the positive trade shock, can imply a higher level of knowledge exchange and increase productivity in industries exchanging workers with that industry.

6.2.3 Heterogeneities across Industries: High versus Low Technology Industries

In the previous two sections, I showed that national industry trade shocks can lead to local industry employment spillovers, and that these spillovers are stronger for industries that are economically close to the industry hit by the trade shock, most notably for industries with similar worker requirements. But are these effects the same across tradable sectors? Or do high technology industries *benefit* more from spillovers from trade shocks than low technology industries? Do trade shocks to all types of industries lead to spillovers or are predominantly high technology industries able to *create* spillovers as knowledge spillovers may be more likely to take place in high technology industries? I will investigate these questions in this section.

To estimate differences in spillover effects between high and low technology industries I categorize industries as high or low technology following Grupp et al. (2000). Grupp et al. (2000) define high technology industries as industries whose R&D expenditure constitutes at least 3.5% of overall production. To give a few examples, high technology industries include the aircraft industry and the pharmaceuticals industry, while low technology industries for example include the textile industry and the paper industry.[40]

attributed to product demand shocks. Following an import shock to the upstream supplier, the industry under observation should rather benefit from reduced prices (see e.g. De Loecker et al. (2016) or Goldberg et al. (2010)), while an export shock to the upstream supplier potentially leads to an increase in the prices of the good the upstream supplier is producing and hence should reduce the industry's demand for this good. Both mechanisms should affect the coefficient of indirect net trade exposure to shocks from upstream suppliers negatively.

[40] The measures in Grupp et al. (2000) are similar to measures defined by the OECD, but account for differences in R&D intensity in Germany as compared to other OECD country industries.

Table 6, Panel A, Columns (2) to (3), presents results from estimations of spillover effects from indirect net trade exposure to the other tradable industries' trade shocks separately for high versus low technology industries (estimation using equation (4.3)). Column (1) presents for comparison the baseline results using the full sample of all tradable sector industries. The results show that both high and low technology industries benefit from indirect net trade exposure to the other tradable industries' trade shocks, however spillovers to high technology industries are twice as large as spillovers to low technology industries with an effect of 13.94 percentage points per 1 million increase in indirect per worker net trade exposure as opposed to 6.26 percentage points for industries in the low technology sector.

Why do high technology industries benefit so much more from agglomeration spillovers than low technology industries? Are also predominantly shocks to high technology industries creating spillovers? To investigate this question, in Columns (4) to (6) of Panel A in Table 6, I additionally split the indirect net trade exposure measure up to distinguish between indirect exposure to trade shocks to high technology versus low technology industries, that is $\Delta NetIndir_{jrt} = \Delta NetIndir_{jrt}^{High} + \Delta NetIndir_{jrt}^{Low}$.[41] Column (1), Panel A, presents results for the full sample of tradable industries, while in Columns (2) and (3) the sample is split up into high and low technology industries. The results are quite striking. Column (1) indicates that tradable industries only benefit from spillovers of trade shocks to high technology industries: While spillovers from shocks to high technology industries are strong with about 11 percentage points per 1 million indirect net trade exposure, the coefficient for spillovers from trade shocks to low technology industries is slightly negative and insignificant. This indicates that it is indeed predominantly shocks to high technology industries that trigger agglomeration spillovers, while shocks to low technology industries do not generate spillovers or at least they are not strong enough to outweigh the reallocation effects. Furthermore, in line with the results in Columns (2) and (3), high technology industries also benefit more from indirect exposure to the trade shocks of other high technology industries (19 percentage points), but low technology industries still benefit (8 percentage points).

In Panel B of Table 6, I split (national) industries in classes according to the share of high skilled workers employed in the industry as an alternative to splitting industries into high and low technology industries according to their R&D expenditure. High skilled industries are defined as the third of industries with the highest national share of high skilled employment in 1988. These are industries with a high skill share larger than 5.9 percent. The correlation between high skilled and high technology industries is 0.5 and thus relatively high. However, there are still differences: High skilled industries exist in all tradable sectors except in agriculture, while high technology industries only exist in the manufacturing of consumer products and manufacturing of investment goods sector, and about a third of industries that are high skilled are not high technology and vice versa. Furthermore, low skilled industries have a higher average indirect net trade exposure and a higher variation in indirect net trade exposure than low technology industries which alleviates

[41] That is $\lambda_{jk} = \lambda_{\cdot,\,high}$ for spillovers from trade shocks to high technology industries k and $\lambda_{jk} = \lambda_{\cdot,\,low}$ for spillovers from trade shocks to low technology industries k.

concerns that the results in Panel A are solely driven by the smaller variation in indirect net trade exposure in low technology industries. The results are fairly similar to the results in Panel A: High skilled industries benefit more from spillover effects than low skilled industries and high skilled industries are more strongly creating spillovers than low skilled industries, however it seems that shocks to low skilled industries can trigger spillovers to a certain extent.

The results in this section reinforce the proximity results in Section 6.2.2, as worker requirements between high technology industries should be more similar and hence thick labor market effects should be stronger amongst these industries. A further explanation for the pattern of results may be the existence of knolwedge spillovers, which may take place both within the high technology sector, as between high and low technology industries. Furthermore, the absence of positive spillovers from shocks to low technology industries provides additional evidence that input-output relations and hence local indirect product demand shocks may not be the main driver of spillover effects, as low technology industries are substantially linked by input-output relations and consequently shocks to low technology industries should lead to positive spillovers if input-output relations were an important source of agglomeration economies.

The results also complement recent findings in the literature on local multipliers, knowledge spillovers and place based policies: Moretti and Thulin (2013) find that local multipliers are higher when triggered by additional high skilled workers in the region or by additional jobs in the high technology sector. Serafinelli (2016) finds at least indicative evidence that workers in high skilled occupations transfer more knowledge when moving firms. And Becker et al. (2013) find that only regions with sufficient levels of human capital are benefiting from transfers of the European Union Structural Funds.

Overall the findings on the importance of economic proximity between industries and differences in the ability of high versus low technology industries to trigger agglomeration spillovers, suggest that governments should take into account local industry structure when implementing place based policies, and aim to attract high technology firms to increase the chance that place based policies are successful.

6.3 Magnitude of effects - comparison to existing estimates

How do the results of this study relate to the existing literature on both the local employment effects of globalization using trade shocks and the literature estimating agglomeration spillovers?

I first analyze how much local industry spillovers contribute to the joint (local) employment effects of trade shocks. To do so, I compare the spillover effects from indirect net trade exposure on local industry employment in both the tradable and non-tradable sector (7.60 percentage points per 1 million increase in indirect trade exposure) to the sum of the spillover effects from indirect net trade exposure and the direct effects estimated in Section 6.1 (0.45 percentage points per one thousand

EUR increase in direct trade exposure per worker, see Table 3, Column (1)).[42][43] I focus on the period 2001 to 2008, as import and export trade shocks in the two periods before more or less average out implying zero net exposure. Average direct net trade exposure in that period was equivalent to 4.67 thousand EUR per worker. This suggests that local industry employment increased on average by 2.1 ($= 0.45 * 4.67$) percentage points due to the effects on industries directly affected by increases in net trade with China and Eastern Europe. Indirect net trade exposure in the period 2001 to 2008 was 0.17 million EUR per worker. This suggests that agglomeration spillovers led to an increase in local industry employment of 1.3 ($= 7.60 * 0.17$) percentage points. Consequently, local industry spillovers contribute 38 percent ($= \frac{1.3}{2.1+1.3} \cdot 100$) to the joint local employment effects of trade shocks and hence constitute a substantial share of the local employment effects of trade shocks.

Now, what does this imply in terms of the agglomeration elasticity λ_{jk}? To analyze this, let us go back to the model in Section 3.2. Starting from equation (3.8) and assuming for simplicity that the agglomeration elasticity is constant across industries such that $\lambda_{jk} = \lambda \ \forall k, j$ and that trade shocks do not affect regional wages as indicated in Section 6.1 and Table 3, such that $dlnw_r = 0$, the agglomeration elasticity equals

$$\lambda \;=\; \frac{\frac{dlnL_{jr}}{dlnp_{k'}}}{\frac{dlnL_{k'r}}{dlnp_{k'}} + \sum\limits_{k \neq k'} \frac{dlnL_{kr}}{dlnp_{k'}}} (1-\alpha)(1-\mu).$$

A constant agglomeration elasticity and zero wage adjustment further imply that $\frac{dlnL_{k'r}}{dlnp_{k'}} = \frac{dlnL_{jr}}{dlnp_j}$ and $\frac{dlnL_{kr}}{dlnp_{k'}} = \frac{dlnL_{jr}}{dlnp_{k'}}$ for all $k \neq k'$. Consequently, it follows that $\lambda = \frac{\frac{dlnL_{jr}}{dlnp_{k'}}}{\frac{dlnL_{jr}}{dlnp_j} + \sum\limits_{k' \neq j} \frac{dlnL_{jr}}{dlnp_{k'}}} (1-\alpha)(1-\mu)$, which can be calculated by using the share of the indirect effects on the joint local employment effects of trade shocks scaled by the share of the fixed resource in production ($(1-\alpha)(1-\mu)$), that is $\lambda = \frac{\text{indirect effects}}{\text{direct+indirect effects}}(1-\alpha)(1-\mu)$. I follow Kline and Moretti (2014) and set the share of the fixed resource to 0.47.[44] As calculated above, the share of indirect effects on the joint local employment effects of trade shocks is 0.38. It follows that the agglomeration elasticity is 0.18 ($= 0.38 \cdot 0.47$).[45] This estimate is slightly smaller than the elasticities estimated in recent studies by Kline and Moretti (2014) and Gathmann et al. (2016), which estimate elasticities of 0.22 and 0.19 respectively. It is larger however than the estimates of earlier studies in the urban economics literature, such as Ciccone

[42] The estimate of the joint spillover effects in the tradable and non-tradable sector are not reported. The specification is equivalent to the tradable sector results specification used in Table 4, Column (4).

[43] Alternatively one can compare the spillover effects to the regional effects (of Table 3, Column (3)).

[44] Kline and Moretti (2014) assume that the labor demand elasticity $\left(\frac{1-\mu(1-\alpha)}{(1-\alpha)(1-\mu)}\text{, see equation (3.4)}\right)$ is equal to 1.5 and the share of capital in production ($(1-\alpha)\mu$) is equal to 0.3. From there it follows that the share of the fixed resource, $(1-\alpha)(1-\mu)$ is equal to 0.47.

[45] Comparing the spillover effects to the regional effects estimated in Section 6.1 (Table 3, Column (3)) instead gives an agglomeration elasticity of 0.22. In Appendix B.2, I derive an alternative expression for the agglomeration elasticity using the version of the labor demand function that only depends on exogenous parameters derived in Appendix B.1. The implied value for the agglomeration elasticity is virtually identical to the one derived in this section (that is 0.18).

and Hall (1996), who report an elasticity of 0.04 estimated by instrumenting density differences in a cross section of US states with past determinants of population density. This difference may be explained by two points. First, earlier studies look at how differences in a cross section or changes over time in local employment (in the tradable *and* non-tradable sector) or population (density) affect local productivity. I study the impact of shocks to tradable sector industries only and this is likely to lead to stronger agglomeration spillovers than shocks to non-tradable sector industries. Second, my results indicate that worker mobility across regions might be an important driver for agglomeration spillovers, as industries exchanging more workers are more strongly affected. Shocks to local industries may (at least in the short term) induce increased mobility across industries both within and across regions. In contrast, by comparing productivity differences across localities with different size or density in a cross section spillovers due to worker mobility will only be captured because of potential differences in general turnover between larger and smaller localities.[46] It is hence to be expected that agglomeration spillovers are larger following a shock.

7 Conclusion

This paper shows that national industry shocks affecting local industries can have substantial indirect effects on employment in geographically close industries because of the existence of agglomeration economies. The specific national industry shocks exploited are trade shocks to German industries stemming from trade integration of Eastern Europe after the fall of the iron curtain and trade integration of China due to its transition to a market oriented economy. The findings suggest, that these spillovers contribute about 38 percent to the joint direct and indirect local employment effects of trade shocks. Consequently, regional effects of national industry trade shocks are larger than would be expected if only taking into account the direct effects of these shocks. An important factor for the existence of these spillovers is economic proximity between industries: Spillover effects from trade shocks are particularly large for industries producing in the same sector and for industries that share common worker requirements. In contrast, input-output relations seem to matter less. Interestingly, only trade shocks to high technology industries trigger spillovers to employment in other local industries, but both high and low technology industries benefit from these spillovers. Overall, these findings are consistent with the existence of thick market effects or knowledge spillovers that are transmitted through workers switching jobs.

These findings suggest that governments should take into account local industry structure when implementing place based policies and aim to attract high technology firms to increase the chance that place based policies are successful. If not regional policy is the primary interest of governments, but rather national welfare, the results further suggest that national governments should move subsidies away from low technology industries and towards high technology industries, as these are

[46] A similar argument can be made to explain the difference in estimates to studies estimating spatial wage disparities by following workers across regions over time such as Combes et al. (2008), who estimate an elasticity with respect to density of 0.03.

more likely to create additional employment through regional spillovers.

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Tables and Figures

Table 1: Summary Statistics

	1988-1995		1995-2001		2001-2008	
7 year equivalents	mean	sd	mean	sd	mean	sd
Panel A: Local Industry Employment Characteristics						
Log Employment Change (Tradable Sector) (x100)	-18.04	39.65	-15.58	44.75	-16.97	38.15
Share Tradable Employment (x100)	38.24	9.04	33.68	8.55	31.79	9.04
Share 3-digit Industry Employment (x100)	3.09	4.15	2.52	3.39	2.43	3.24
Panel B: Trade Exposure Measures (in 1 Million EUR)						
German Indirect Trade Exposure						
Net Exposure (Tradables)	-0.038	0.245	0.000	0.297	0.252	0.836
Net Exposure (same Sector)	-0.009	0.133	0.003	0.169	0.089	0.393
Net Exposure (other Tradable Sectors)	-0.029	0.218	-0.003	0.270	0.163	0.703
Import Exposure (Tradables)	0.200	0.533	0.453	1.294	0.547	1.452
Import Exposure (same Sector)	0.056	0.178	0.147	0.549	0.171	0.550
Import Exposure (other Tradable Sectors)	0.144	0.421	0.306	1.088	0.376	1.198
Export Exposure (Tradables)	0.162	0.479	0.452	1.222	0.799	2.102
Export Exposure (same Sector)	0.048	0.182	0.149	0.496	0.261	0.833
Export Exposure (other Tradable Sectors)	0.115	0.401	0.303	1.017	0.538	1.743
Other High Income Countries Indirect Trade Exposure (Instruments)						
Import Exposure (Tradables)	0.120	0.382	0.672	2.053	1.063	2.795
Export Exposure (Tradables)	0.040	0.228	0.290	0.913	0.524	1.402

Notes: The Table shows means and standard deviations of employment characteristics and trade exposure measures for the time periods shown in the top row. Observations are on 3 digit industry x commuting zone level. Panel A shows employment characteristics of tradable industries. Panel B shows the various indirect trade exposure measures as defined in Equations (4.2) and (4.4). In Panel B, (*Tradables)* refers to exposure to the other local industries' trade shocks in the tradable sector, (*same Sector)* to exposure to the other local industries' trade shocks in the same sector and (*other Tradable Sectors)* to exposure to the other local industries' trade shocks in the tradable sectors outside the same sector. All observations are weighted by 3 digit industry x commuting zone employment.

Table 2: Descriptive Statistics by Percentiles of Net Indirect Trade Exposure (Tradables)

	Full Sample (1)	<1st Percentile (2)	>1st Percentile & <25th Percentile (3)	>25th Percentile & <50th Percentile (4)	>50th Percentile & <75th Percentile (5)	>75th Percentile & <99th Percentile (6)	>99th Percentile (7)
Indirect Net Trade Exposure	0.062	-0.829	-0.089	0.014	0.068	0.291	1.613
	(0.011)	(0.058)	(0.004)	(0.002)	(0.004)	(0.018)	(0.180)
Average Wage	83.26	75.74	83.52	83.76	84.53	81.94	71.45
	(1.65)	(1.53)	(2.60)	(2.17)	(1.81)	(1.42)	(1.41)
Share Low Skilled (x100)	23.23	21.73	23.17	23.55	23.33	23.02	20.56
	(0.45)	(0.86)	(0.58)	(0.71)	(0.74)	(0.79)	(0.76)
Share Medium Skilled (x100)	69.02	72.64	68.83	68.65	68.49	69.81	74.67
	(0.49)	(0.80)	(0.61)	(0.65)	(0.56)	(0.73)	(0.65)
Share High Skilled (x100)	7.75	5.63	8.00	7.80	8.18	7.16	4.77
	(0.66)	(0.52)	(0.90)	(0.94)	(0.81)	(0.43)	(0.27)

Notes: The table reports mean values and standard errors (in brackets) of the variables shown in the left column for observations at the 3-digit industry x commuting zone level by percentile groups of indirect net exposure to the other local industries' trade shocks. Percentile groups are separated as shown in the top row. The percentile groups are calculated within 3-digit industry and period and are employment weighted. Low-skilled individuals are those without a high school or vocational degree, the medium-skilled are those with high school or vocational degree and the high-skilled are those with a college or university degree. Wages are average daily wages in EUR adjusted to 1995 prices. All observations are weighted by industry x commuting zone employment.

Table 3: Direct and Regional Effects

	Direct Effects		Regional Effects (all)	
	Employment (1)	Wages (2)	Employment (3)	Wages (4)
Own Industry Net Exposure, 3 digit	0.447**	-0.021		
	(0.185)	(0.031)		
Regional Net Exposure, Tradables			2.216**	0.031
			(0.878)	(0.127)
F-Statistic	24.02		51.65	
N	25963		59391	

Notes: The table reports estimates of own industry and regional net trade exposure on local industry employment based on equation (4.3) including federal state x period fixed effects and regional and industry level controls. Observations are measured on 3-digit industry x commuting zone level. All columns are estimated using two stage least squares instrumenting German trade exposure with other high income country trade exposure as explained in Section 4.2. In Columns (1) and (2) the variable of interest is own industry net trade exposure and in Columns (3) and (4) regional net trade exposure, as defined in Section 6.1. Both net trade exposure measures are measured in 1000 EUR per worker (adjusted to 2005 prices). Reported first stage F-statistics are the Sanderson-Windmeijer F-Statistics. Standard errors are clustered on the level of 50 aggregated labor market regions. Significance levels 1%***, 5%**, 10%*.

Table 4: Agglomeration Spillovers, Indirect Net Trade Exposure

	Net Exposure Tradables					***Net Exposure Same/ Other Sector***		
	2SLS				***OLS***	***2SLS***		***OLS***
N=25963	only Share Trad & Share Industry Control	add national own Industry Imp/Exp Exposure	add further controls	add 3 digit industry x period FE	OLS equivalent to (4)	regional controls and 3 digit industry x period FE		OLS equivalent to (6)
	(1)	(2)	(3)	(4)	(5)	(6)		(7)
Indirect Net Exposure, Tradables	2.096	2.869**	3.283**	7.745***	1.176**			
	(1.315)	(1.385)	(1.570)	(1.756)	(0.460)			
Indirect Net Exposure, Same Sector						12.864***		2.106**
						(3.211)		(0.933)
Indirect Net Exposure, Other Tradable Sectors						5.080***		0.839*
						(1.757)		(0.431)
Share Tradable Employment (x100)	0.352***	0.379***	0.361***	0.306***	0.300***	0.304***		0.299***
	(0.093)	(0.093)	(0.120)	(0.091)	(0.092)	(0.092)		(0.092)
Share 3-digit Industry Employment (x100)	-0.672**	-0.792***	-0.713***	-0.433**	-0.452**	-0.421**		-0.449**
	(0.279)	(0.262)	(0.205)	(0.206)	(0.208)	(0.205)		(0.208)
Own Industry Import Exposure, 3 digit		-0.361***	-0.284***					
		(0.058)	(0.060)					
Own Industry Export Exposure, 3 digit		0.581***	0.578***					
		(0.079)	(0.075)					
Share Medium Skilled (in Industry, x100)			0.555***	0.342***	0.346***	0.339***		0.345***
			(0.051)	(0.064)	(0.065)	(0.064)		(0.065)
Share High Skilled (in Industry, x100)			0.044	-0.016	-0.06	-0.012		-0.059
			(0.094)	(0.122)	(0.125)	(0.122)		(0.126)
Share Medium Skilled (in Region, x100)			-0.705**	-0.633**	-0.669**	-0.633**		-0.669**
			(0.345)	(0.259)	(0.265)	(0.260)		(0.265)
Share High Skilled (in Region, x100)			-0.003	-0.369	-0.23	-0.359		-0.23
			(0.360)	(0.306)	(0.312)	(0.307)		(0.312)
Share Female Workers (in Region, x100)			0.391	0.317	0.245	0.311		0.245
			(0.406)	(0.308)	(0.309)	(0.309)		(0.309)
Share Foreign Workers (in Region, x100)			-0.952***	-1.014***	-1.038***	-1.017***		-1.038***
			(0.226)	(0.215)	(0.215)	(0.215)		(0.215)
First Stage Net Exposure						*Same*	*Others*	
Import Exposure IV, Tradables	-0.147***	-0.147***	-0.147***	-0.151***				
	(0.050)	(0.050)	(0.050)	(0.049)				
Export Exposure IV, Tradables	0.529***	0.527***	0.525***	0.514***				
	(0.107)	(0.107)	(0.107)	(0.105)				
Import Exposure IV, Same Sector						-0.195***	0.014	
						(0.043)	(0.017)	
Export Exposure IV, Same Sector						0.551***	-0.070**	
						(0.107)	(0.033)	
Import Exposure IV, Other Tradable Sectors						0.008	-0.148***	
						(0.009)	(0.051)	
Export Exposure IV, Other Tradable Sectors						-0.002	0.537***	
						(0.018)	(0.119)	
R2 (First Stage)	0.312	0.313	0.317	0.366	0.22	0.34	0.38	0.22
F-Statistic	31.35	31.30	30.68	27.99	-	13.95	27.12	-

Notes : The table reports estimates of indirect net trade exposure on local industry employment based on variants of equation (4.3). Observations are measured on 3-digit industry x commuting zone level. Columns (1) to (4) and Column (6) are estimated using two stage least squares instrumenting German trade exposure with other high income country trade exposure as explained in section 4.2, while Columns (5) and (7) estimate OLS regressions. All columns include federal state x period fixed effects. Columns (1) to (5) estimate the effect of indirect exposure to other local tradable industries net trade shocks on employment. Column (1) additionally includes the tradable sector and own industry share on regional employment, Column (2) further adds national direct export and import exposure (measured in 1000 EUR per worker) of the industry under observation, Column (3) adds further regional and industry controls and column (4) estimates the equivalent to equation 4.3 adding national (3-digit) industry x period fixed effects (direct national trade exposure is dropped in these regressions due to collinearity). Column (5) estimates the equivalent of Column (4) but using OLS. Column (6) estimates the equivalent of column (4), but allowing for separate effects of indirect net trade exposure from industries within the same sector and from industries in other tradable sectors (6 broad sectors in tradables). Column (7) estimates the OLS equivalent to Column (6). Indirect net trade exposure measures are measured in per 1 Million EUR per worker (adjusted to 2005 prices). Reported first stage F-statistics are the Sanderson-Windmeijer F-Statistics. Standard errors are clustered at the commuting zone level. Significance levels 1%***, 5%**, 10%*.

Table 5: Agglomeration Spillovers, Mechanisms

	Only Worker Transition Measure (1)	Only Upstream Measure (2)	Only Downstream Measure (3)	All Mechanisms (4)
Indirect Net Exposure Worker Transitions	7.818**			7.201**
	(3.425)			(2.819)
Indirect Net Exposure Upstream		2.507***		1.988**
		(0.838)		(0.974)
Indirect Net Exposure Downstream			0.302	-0.687
			(0.663)	(0.690)
Indirect Net Exposure (*normalized*)	-2.213	1.591***	2.700***	-2.723*
	(1.995)	(0.560)	(0.517)	(1.636)
F-Statistic Worker Transitions	23.36			20.68
F-Statistic Upstream		32.01		25.28
F-Statistic Downstream			22.49	29.34
F-Statistic Indirect Net Exposure	26.568	15.067	29.489	20.62
N	25963	25963	25963	25963

Notes: The table investigates whether employment effects of local indirect net trade exposure vary by economic proximity. Estimates are from two stage least squares regressions based on equation (4.3) including federal state x period fixed effects, national industry x period fixed effects and regional and industry level controls. Indirect net trade exposure is reweighted according to 3 measures of economic proximity (see equation 6.1): The maximum of the share of workers leaving industry j and moving to industry k and the share of workers leaving industry k and moving to industry j over a 5- year window from t-5 to t (Column (1), the share of goods produced in industry k that is sold to industry j (Column (2)), the share of goods produced in industry j that is sold to industry k (Column (3)). In Column (4), the 3 reweighted indirect net trade exposure measures are jointly included into the regression. All measures (including the baseline measure) are normalized to have mean 0 and standard deviation 1. Indirect net trade exposure is measured in per 1 Million EUR per worker (adjusted to 2005 prices). Reported first stage F-statistics are the Sanderson-Windmeijer F-Statistics. Standard errors are clustered at the commuting zone level. Significance levels 1%***, 5%**, 10%*.

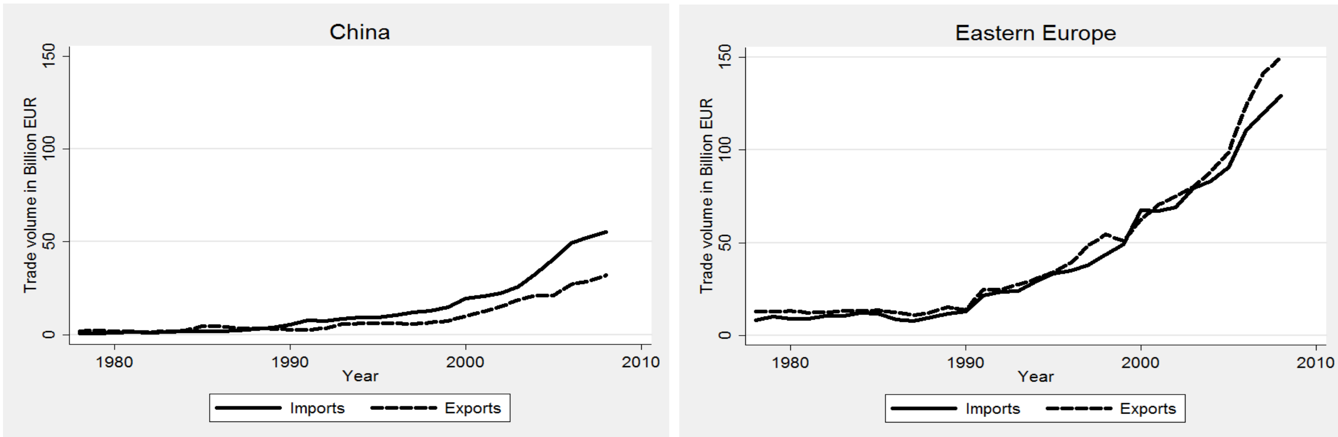
Table 6: Agglomeration Spillovers, High vs Low Technology and High vs Low Skilled Industries

	Baseline (1)	High Technology (2)	Low Technology (3)	Baseline (4)	High Technology (5)	Low Technology (6)
Panel A: High vs Low Technology Industries						
Indirect Net Exposure, Tradables	7.745***	13.935***	6.262***			
(Mean 0.062, SD 0.528)	(1.756)	(4.992)	(1.524)			
Indirect Net Exposure, Low Tech				-1.081	1.105	0.633
(Mean 0.000 , SD 0.238)				(4.651)	(9.630)	(4.133)
Indirect Net Exposure, High Tech				10.763***	21.631***	7.250***
(Mean 0.062, SD 0.391)				(2.180)	(6.288)	(1.687)
F-Statistic	27.99	9.11	35.29			
F-Statistic, Low Tech				19.94	16.98	19.91
F-Statistic, High Tech				48.78	28.43	60.90
N	25963	6690	19273	25963	6690	19273

	Baseline (1)	High Skilled Industries (2)	Low Skilled Industries (3)	Baseline (4)	High Skilled Industries (5)	Low Skilled Industries (6)
Panel B: High vs Low Skilled Industries						
Indirect Net Exposure, Tradables	7.745***	18.822***	4.696***			
(Mean 0.062, SD 0.528)	(1.756)	(6.329)	(1.091)			
Indirect Net Exposure, Low Skilled				4.818**	12.738*	3.142**
(Mean 0.027, SD 0.451)				(1.891)	(6.687)	(1.272)
Indirect Net Exposure, High Skilled				11.053***	22.442***	6.685***
(Mean 0.034, SD 0.238)				(3.197)	(7.798)	(2.115)
F-Statistic	27.99	8.46	42.66			
F-Statistic, Low Skilled				20.67	5.45	33.43
F-Statistic, High Skilled				30.82	15.44	40.99
N	25963	7431	18532	25963	7431	18532

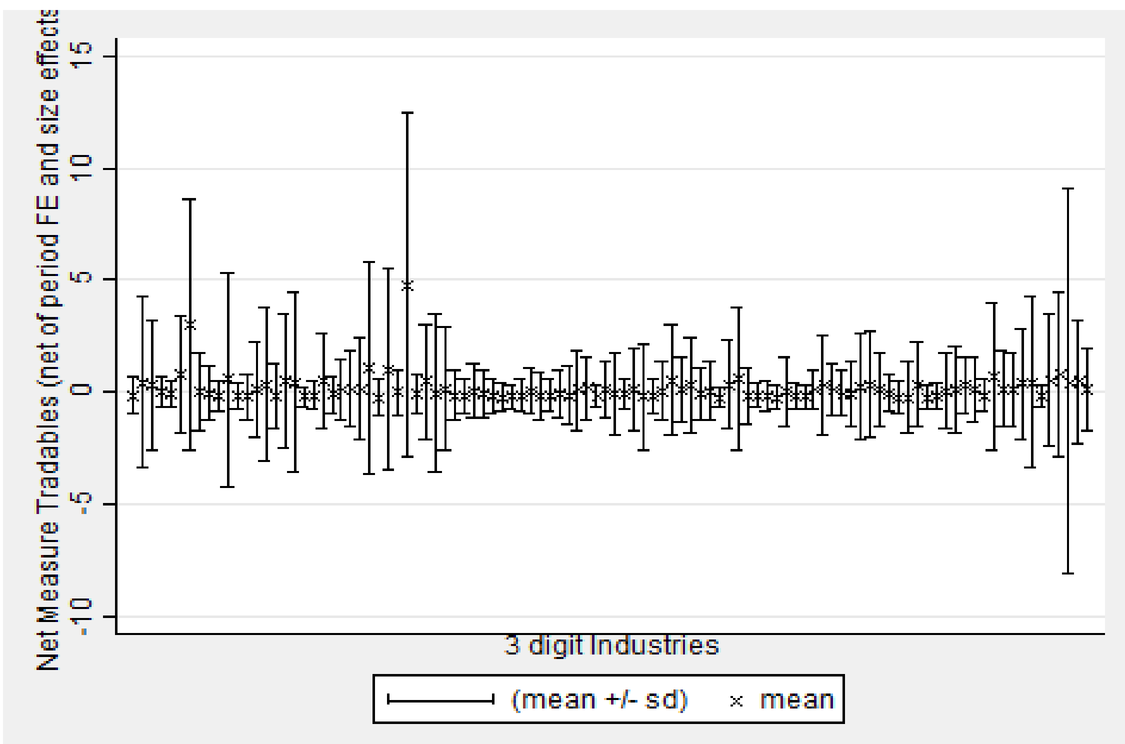
Notes: The table reports estimates of indirect net trade exposure on local industry employment. The estimates are from two stage least squares regressions based on equation (4.3) including federal state x period fixed effects, national industry x period fixed effects and regional and industry level controls. Observations are measured on 3-digit industry x commuting zone level. Panel A investigates whether employment effects of local indirect net trade exposure differ for high vs low technology industries (for definitions see Section 6.2.3). Columns (1) and (4) report results for the whole sample of tradable industries (Column (1) is equivalent to Table 4, Column (4)). Columns (2) and (5) report estimates for high technology industries only, while Columns (3) and (6) report estimates for low technology industries. Panel B investigates whether employment effects of local indirect net trade exposure differ for high vs low skilled industries (for definitions see Section 6.2.3). Columns (1) and (4) report results for the whole sample of tradable industries, while Columns (2) and (5) reports estimates only for high skilled industries and Columns (3) and (6) report results only for low skilled industries. Indirect net trade exposure is measured in per 1 Million EUR per worker (adjusted to 2005 prices). Reported first stage F-statistics are Sanderson-Windmeijer F-Statistics. Standard errors are clustered at the commuting zone level. Significance levels 1%***, 5%**, 10%*.

Figure 1: Total Imports and Exports



Note: The Figure presents the total volume of German trade with China (Panel A) and Eastern Europe (Panel B) in Billion EUR (adjusted to 2005 prices) for the years 1978 to 2008 separately for Imports (solid line) and Exports (dashed line). The figure is equivalent to Figure 1 in Dauth et al. (2014), but derived from own calculations.

Figure 2: Within 3-digit Industry Variation in Net Measure (Tradeables)



Notes: The figure presents for all 3-digit industries in the tradable sector means and standard deviations of indirect net trade exposure to trade shocks of other local tradable industries net of period fixed effects and effects due to differences in tradable and own industry employment share in the region.

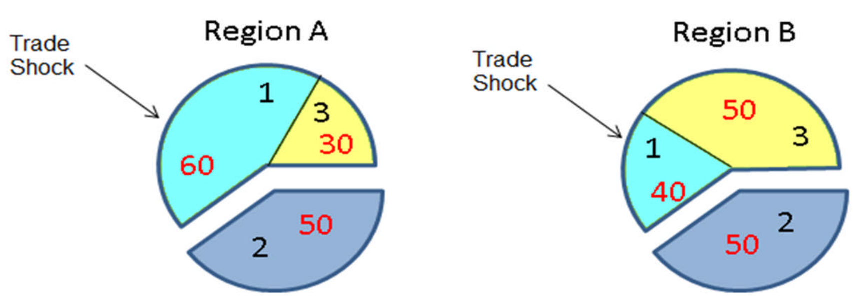
Appendix

A Example and Intuition for the Identification Strategy

Assume there are two regions (A and B) with the same size of the tradable sector, which is represented by the two pies in Figure A1. In each of these two regions 3 tradable industries are present, industry (1), (2) and (3). Assume also, that industry (1) is more prevalent in region A and that industry (2) is the same size in both regions. This implies that the joint size of industry (1) and industry (3) is the same in the two regions and hence industry (3) must be more prevalent in region B. Now, for simplicity, let us assume that only industry (1) is hit by a positive national trade shock from China and Eastern Europe. Let us for now focus on what this implies for labor demand and changes in employment in industry (2).[47] As shown theoretically in Section 3.2, equation (3.8), now two main mechanisms potentially affect employment in industry (2): the reallocation effect (endogenous wage adjustment) and agglomeration spillovers. First, because industry (1) is more prevalent in region A, this implies that industry (1) demands more additional workers in region A compared to region B, which as long as labor is not perfectly mobile, increases wages in region A by more than in region B and hence relatively seen industry (2) should want to reduce employment by more in region A than in region B. However, if at the same time industry (2) benefits from agglomeration spillovers because of the increase in labor market size due to the positive trade shock to industry (1) and hence an increase in the available labor pool potentially leading to better worker-firm matches and the inflow of new human capital into the region potentially increasing knowledge exchange, then these productivity spillovers will also be stronger in region A than in region B, because of the higher prevalence of industry (1) in region A.

The identification strategy exploits exactly this within industry variation in local industry structure of the other tradable industries (keeping the joint relative size of the other tradable industries constant) and hence in indirect exposure to the other local industries' trade shocks. The estimates will be a composite of the reallocation effects and the agglomeration effects. However, as these effects go in different directions, when employment expands more in regions with higher indirect trade exposure, the agglomeration effects outweigh the reallocation effects.

Figure A.1: Example for the Intuition of the Identification Strategy



Notes : The figure corresponds to the example in Appendix A.1 provided to give an intuition of the identification strategy. Black numbers represent industries (industry 1, 2 and 3) and red numbers represent hypothetical employment sizes of these industries. Details of the example are explained in Appendix A.1.

[47] In reality, it is likely that all three of the industries are hit by a trade shock, however in the empirical estimation I will control for the direct trade shock to industry (2) and analyze how the joint indirect trade shocks to the other tradable industries in the region affect local employment of industry (2).

B Theoretical Framework - Further Derivations

B.1 Alternative Expressions for Local Industry Labor Demand and the Impact of National Industry Trade Shocks on Local Industry Employment

In this section, I derive an expression for local industry labor demand that depends only on exogenous parameters and using this expression show how national industry trade shocks affect local industry employment. To do so, I start from equation (3.4), the local industry labor demand equation derived in Section 3.2:[48]

$$\begin{aligned} ln\left(L_{jr}\right) = \tfrac{1}{(1-\alpha)(1-\mu)} & \left[ln\left(A_{jr}\right)\right. \\ & + \left(ln\left(A_j\right) + ln\left(p_j\right)\right) \\ & \left. - \left(1-\mu(1-\alpha)\right) ln\left(w_r\right)\right] \\ & + ln\left(\bar{R}_{jr}\right) + C_1 \end{aligned} \tag{B.1}$$

To simplifiy the derivations, I assume in this section that agglomeration economies are constant across industries and hence the local industry specific productivity shifter depends on total regional employment as follows:

$$ln\left(A_{jr}\right) = \lambda ln\left(L_r\right) \tag{B.2}$$

Summing up (the exponential of) equation (B.1) across all industries $j \epsilon J$, plugging in equation (B.2) and solving for $ln\left(L_r\right)$, an expression for total regional labor demand can be derived:

$$\begin{aligned} ln\left(\sum_j L_{jr}\right) = ln\left(L_r\right) = & \frac{(1-\alpha)(1-\mu)}{(1-\alpha)(1-\mu)-\lambda} ln\left(\sum_j \left[\left(p_j A_j\right)^{\frac{1}{(1-\alpha)(1-\mu)}} \bar{R}_{jr}\right]\right) \\ & - \frac{\left(1-\mu(1-\alpha)\right)}{(1-\alpha)(1-\mu)-\lambda} ln\left(w_r\right) \\ & + \frac{(1-\alpha)(1-\mu)}{(1-\alpha)(1-\mu)-\lambda} C_1 \end{aligned} \tag{B.3}$$

Together with assuming a constant elasticity of labor supply (equation (3.5)), equation (B.3) can then be used to derive an expression of local wages depending only on exogenous parameters:

$$ln(w_r) = \frac{\eta}{1+\eta C_3}\left[C_2 ln\left(\sum_j \left[\left(p_j A_j\right)^{\frac{1}{(1-\alpha)(1-\mu)}} \bar{R}_{jr}\right]\right) + C_2 C_1\right] \tag{B.4}$$

The last step is then to plug equations (B.2), (B.3) and (B.4) into equation (B.1) and rearrange

[48] $C_1 = \frac{\mu(1-\alpha)}{(1-\alpha)(1-\mu)} ln\left(\alpha \frac{(1-\alpha)\mu}{i}\right)$, $C_2 = \frac{(1-\alpha)(1-\mu)}{(1-\alpha)(1-\mu)-\lambda}$ and $C_3 = \frac{(1-\mu(1-\alpha))}{(1-\alpha)(1-\mu)-\lambda}$ are constants only determined by exogenous parameters.

such that also local industry labor demand is expressed as a function of exogenous parameters only:

$$\begin{aligned} ln\left(L_{jr}\right) &= \left[\frac{\lambda}{(1-\alpha)(1-\mu)}\left(C_2 - \frac{\eta C_3}{1+\eta C_3}C_2\right) - \frac{\eta C_3}{1+\eta C_3}C_2\right] ln\left(\sum_j \left[(p_j A_j)^{\frac{1}{(1-\alpha)(1-\mu)}}\bar{R}_{jr}\right]\right) \\ &+ \frac{1}{(1-\alpha)(1-\mu)}\left(ln\left(A_j\right) + ln\left(p_j\right)\right) \\ &+ \left[1 - \frac{\eta C_3}{1+\eta C_3}C_2\left(\frac{\lambda}{(1-\alpha)(1-\mu)} + 1\right) + \frac{\lambda}{(1-\alpha)(1-\mu)}C_2\right]C_1 \\ &+ ln\left(\bar{R}_{jr}\right) \end{aligned} \tag{B.5}$$

Using this version of local industry labor demand, one can now derive a version of equation (3.8) that only depends on exogenous parameters:[49]

$$\frac{dlnL_{jr}}{dlnp_{k'}} = \frac{1}{(1-\alpha)(1-\mu)}\left[\frac{\lambda}{(1-\alpha)(1-\mu)}\left(C_2 - \frac{\eta C_3}{1+\eta C_3}C_2\right) - \frac{\eta C_3}{1+\eta C_3}C_2\right] \tag{B.6}$$

Equation (B.6) shows (equivalent to equation (3.8)) that the effect of changes in the price of the good produced by industry k' depends on the strength of agglomeration forces λ and on the local labor supply elasticity $(\frac{1}{\eta})$. In the absence of agglomeration economies $(\lambda = 0)$, an increase in the price of the good produced by industry k' negatively affects local industry employment in industry j, because industry k' is demanding more labor which puts an upward pressure on wages and hence reduces labor demand of industry j (the reallocation effect). If there are agglomeration economies at play $(\lambda > 0)$, the overall effect is ambiguous and depends on the strength of agglomeration forces λ and the strength of reallocation effects as described in Section 3.2. If $\frac{dlnL_{jr}}{dlnp_{k'}} > 0$ the agglomeration forces outweigh the reallocation effects.

B.2 Alternative Expression for the Agglomeration Elasticity

Using equation (B.6) one can then derive an alternative expression for the calculation of the agglomeration elasticity depending only on the indirect effects of trade shocks and exogenous parameters. As in Section 6.3, I assume that trade shocks do not affect regional wages such that $dlnw_r = 0$ and hence $\eta = 0$ (as $dlnw_r = \eta dlnL_r$). The implied agglomeration elasticity then equals

$$\lambda = \frac{\frac{dlnL_{jr}}{dlnp_{k'}}(1-\alpha)(1-\mu)^2}{1 + \frac{dlnL_{jr}}{dlnp_{k'}}(1-\alpha)(1-\mu)}. \tag{B.7}$$

Using the same parameter values and estimates for the indirect effects as in Section 6.3, this implies an agglomeration elasticity of 0.18, which is virtually identical to the elasticity calculated in Section 6.3.

[49] For simplicity I here assume that initially $p_j = p$, $A_j = A$ and $\bar{R}_{jr} = \bar{R}_r \ \forall j \epsilon J$.

C Supplemental Empirical Results & Tables

C.1 Set of Instrument Countries

Table C1: Set of Instrument Countries

1	Australia
2	Canada
3	Denmark
4	Finland
5	New Zealand
6	Norway
7	Singapore
8	Spain
9	Sweden
10	Switzerland
11	United Kingdom

Notes: The table reports the set of high income countries used to instrument German trade exposure.

C.2 Robustness Analysis

The results presented in the Section 6.2.1 are robust to a number of alternative specifications and alternative choices of instrument countries. Table C2, Panel A presents results of alternative specifications focusing on the effects of spillovers from other tradable industries trade shocks. For comparison, Column (1) presents the baseline results (equivalent to Table 4, Column (4)) estimated using equation (4.3), that is controlling for the tradable industry share in the region, the 3-digit industry share, further regional and industry characteristics, 3-digit industry x period fixed effects and federal state x period fixed effects. In Column (2), the federal state x period fixed effects are replaced by commuting zone x period fixed effects. This specification implicitly controls for endogenous wage changes at the regional level, that is it controls for the part of the reallocation effect that is common to all local industries in the commuting zone.[50] The estimated effect is very similar to the baseline estimate and is in line with the absence of local wage effects estimated in Section 6.1 (see also Table 3, Column (2)). Column (3) instead controls for the change in indirect net exposure to world trade (excluding trade with China and Eastern Europe). This specification is supposed to alleviate concerns about high income countries being affected by common export or import demand shocks, for example because of correlated technological shocks. The results are very similar to the baseline specification indicating that the results are not driven by world demand shocks. A further concern is that local industry employment shares are correlated with future trade shocks, for example because these shares are affected by past trade shocks and trade shocks might be correlated over time. To account for this, in Column (4), instead of using start of period

[50] In addition, this specification helps to alleviate concerns that the increase in employment following indirect trade shocks is driven by an increase in local amenities attracting more workers to the region rather than agglomeration spillovers.

employment levels to distribute national industry trade flows to the local industries, 1988 levels are used (1981 levels for the instruments) and indirect trade exposure is normalized by 1988 employment of the industry under observation (see equation (4.1)). The results do not change considerably. In Column (5) local industries (within 3-digit category) in the lowest and the highest percentile of indirect net trade exposure are dropped from the sample. This accounts for the fact that industries with the lowest and highest levels of indirect net trade exposure (within 3-digit category) seem to be negatively selected (see Table 2). Excluding these observations increases the coefficient of indirect net trade exposure slightly.

In Panel B of Table C2, I present results using alternative sets of instrument countries. Column (1) presents the baseline results for comparison (equivalent to Table 4, Column (4) in B.1 and to Table 6, Panel B, Column (1) in B.2). Column (2) adds Japan to the set of instrument countries. Column (3) instead adds the US. Column (4) excludes the Eurozone countries Finland and Spain from the set of instrument countries and Column (5) excludes the countries sharing a border with Germany (Switzerland and Denmark). The results in Columns (2) to (5) are largely similar to the baseline results in Column (1).[51] The qualitative conclusions from the baseline results are consequently not driven by a specific choice of the set of instrument countries.

[51]The only larger difference is when including Japan in the set of instrument countries. The lower estimated effect can potentially be explained by the fact that Japanese industries are in high export competition with German industries. Consequently, the correlation in exports to China and Eastern Europe between Germany and Japan is likely to understate the true correlation between the German and Japanese export shocks. This might lead to a downward bias in the effects. Further the Japan coefficient increases to 5.27 percentage points when excluding industries below the 1st or above the 99th percentile of indirect net trade exposure.

Table C2: Agglomeration Spillovers, Robustness

	Panel A: Alternative Specifications				
	Baseline (1)	Adding commuting zone x period FE (2)	Control for World Net Trade Change (3)	start of period instead of 1988 employment (4)	Excluding p1 and p99 (5)
Tradable Sector Measure	7.745***	7.563***	7.127***	7.014***	9.652***
	(1.756)	(1.773)	(2.002)	(1.280)	(3.051)
F-Statistic	27.99	33.79	16.884	30.44	17.413
N	25963	25963	25963	25310	23276

	Panel B: Instrument Countries				
	Baseline (1)	+ Japan (2)	+ USA (3)	Exclude Eurozone (4)	Exclude Neighbours (5)
	B.1 Baseline				
Indirect Net Exposure, Tradables	7.745***	3.006***	6.199***	9.402***	8.419***
	(1.756)	(1.083)	(1.727)	(2.216)	(1.933)
F-Statistic	27.99	39.038	30.899	20.161	25.469
	B.2 High vs Low Skill Exposure				
Indirect Net Exposure, Low Skilled	4.818**	1.322	2.850*	6.675***	4.748**
	(1.891)	(1.213)	(1.542)	(2.511)	(1.871)
Indirect Net Exposure, High Skilled	11.053***	7.135***	8.397***	11.735***	11.730***
	(3.197)	(2.612)	(3.141)	(3.614)	(3.498)
F-Statistic, Low Skilled	20.67	17.951	20.285	17.551	16.114
F-Statistic, High Skilled	30.82	47.806	39.718	21.377	21.581
N	25963	25963	25963	25963	25963

Notes: The table reports estimates of indirect net trade exposure on local industry employment. All estimates are from two stage least squares regressions based on equation 4.3 including federal state x period fixed effects, national industry x period fixed effects and regional and industry level controls. Observations are measured on 3-digit industry x commuting zone level. Panel A, Column (1) shows the baseline specification results from Table 4, Column (4). In Column (2) federal state x period fixed effects are replaced by commuting zone x period fixed effects. Column (3) controls for the change in net world trade (total German net trade minus net trade with China and Eastern Europe). Column (4) uses 1988 employment instead of start of period employment for both accruing national trade flows to local industries and the normalization of the indirect trade exposure measure and weights regressions by 1988 employment. Column (5) exludes the industries with the lowest and the highest percentile of indirect net trade shocks. In Panel B the baseline specification is estimated with varying sets of instrument countries. Column (1) repeats the baseline specifications. Column (2) adds Japan to the baseline set of instrument countries, Column (3) instead adds the USA. Column (4) excludes the Eurozone countries from the baseline set of instrument countries (i.e. Finland and Spain) and Column (5) excludes countries sharing a border with Germany (i.e. Switzerland and Denmark). Indirect net trade exposure measures are measured in per 1 Million EUR per worker (adjusted to 2005 prices). Reported first stage F-statistics are Sanderson-Windmeijer F-Statistics. Standard errors are clustered at the commuting zone level. Significance levels 1%***, 5%**, 10%*.

C.3 US Input-Output Tables (3-digit level)

Table C3 investigates the impact of economic proximity on the strength of spillovers, by using US input-output tables at the 3-digit industry level as a proxy for the German input-output relations to be able to analyse the effects on vertically linked industries on a finer level than between 2-digit industries. I use the input-output tables from the 1997 Benchmark Input-Output Accounts published by the Bureau of Economic Analysis (BEA). The correlation between the upstream measures of indirect trade exposure at the 2-digit and the 3-digit industry level is 0.5 and the correlation between the two downstream measures of indirect trade exposure is 0.46. The estimated results are very similar to the results in Table 5.

Table C3: Agglomeration Spillovers, Mechanisms (US Input-Output Tables (3-digit))

	Only Worker Transition Measure (1)	Only Upstream Measure (2)	Only Downstream Measure (3)	All Mechanisms (4)
Indirect Net Exposure Worker Transitions	7.818**			8.949**
	(3.425)			(3.497)
Indirect Net Exposure Upstream		-0.381		-1.103
		(0.619)		(0.748)
Indirect Net Exposure Downstream			-0.597	-1.416**
			(0.582)	(0.570)
Indirect Net Exposure	-2.213	3.145***	3.197***	-1.966
	(1.995)	(0.650)	(0.820)	(1.914)
F-Statistic Worker Transitions	23.36			32.644
F-Statistic Upstream		26.55		33.106
F-Statistic Downstream			17.91	20.567
F-Statistic Indirect Net Exposure	26.568	19.717	35.264	26.477
N	25963	25963	25963	25963

Notes: The table investigates whether employment effects of local indirect net trade exposure vary by economic proximity. Estimates are from two stage least squares regressions based on equation (4.3) including federal state x period fixed effects, national industry x period fixed effects and regional and industry level controls. The indirect net trade exposure is reweighted according to 3 measures of economic proximity (see equation 6.1): The maximum of the share of workers leaving industry j and moving to industry k and the share of workers leaving industry k and moving to industry j over a 5- year window from t-5 to t (Column (1), equivalent to Table 4, Column (1)), the share of goods produced in industry k that is sold to industry j (Column (2)), the share of goods produced in industry j that is sold to industry k (Column (3)). These measures are calculated using US input-output tables at the 3-digit industry level. In Column (4), the 3 reweighted indirect net trade exposure measures are jointly included into the regression. All measures (including the baseline measure) are normalized to have mean 0 and standard deviation 1. Indirect net trade exposure is measured in per 1 Million EUR per worker (adjusted to 2005 prices). Reported first stage F-statistics are the Sanderson-Windmeijer F-Statistics. Standard errors are clustered at the commuting zone level. Significance levels 1%***, 5%**, 10%*.