ITI
8/1/06
1:00 PM

Multiple Equilibria in Industrial Location: Evidence from German Airports*

Stephen J. Redding†
London School of Economics, Princeton and CEPR

Daniel M. Sturm‡
University of Munich and CEPR

Nikolaus Wolf§
Free University of Berlin and CEPR

July 2006

Abstract

Multiple equilibria are a central feature of theoretical work in many fields of economics. Despite their theoretical prominence, there is surprisingly little evidence in support of the empirical relevance of multiple equilibria. This paper exploits the combination of the division of Germany after the Second World War and the reunification of East and West Germany as an exogenous shock to provide evidence for the empirical relevance of multiple equilibria in industrial location. We first establish that division has caused a shift of Germany's air hub from Berlin to Frankfurt and there is no evidence of a return of the air hub to Berlin after reunification. We next develop a body of evidence that the relocation of the air hub is not driven by a change in economic fundamentals but is instead a shift between multiple equilibria.

Keywords: Multiple Equilibria, Economic Geography, German Division, German Reunification

JEL classification: F14, F15, N74

*We would like to thank Tim Besley, Jan Brueckner, Ulrich Müller, Giovanni Peri, Steve Pischke, Esteban Rossi-Hansberg, Joachim Voth and seminar participants at CEPR, Munich, NY Fed, Pompeu Fabra, Second Conference on German Cliometrics and Tokyo BREAD conference for helpful comments. Holger Breinlich, Thomas Eisenbach, Kwok Tong Soo and David Stenzel provided excellent research assistance. We are grateful for financial support from the German Science Foundation (DFG). Redding would like to thank the Department of Economics, Princeton University where some of this paper was written for its hospitality. The views expressed and any errors are the authors' responsibility.

†Department of Economics, London School of Economics, Houghton Street, London. WC2A 2AE, United Kingdom. Tel: +44-20-7955 7483. Fax: +44-20-7831 1840. E-mail: s.j.redding@lse.ac.uk

‡Department of Economics, University of Munich, Ludwigstr. 28 (Vgb), 80539 Munich, Germany. Tel: +49-89-2180 1363. Fax: +49-89-2180 6227. E-mail: daniel.sturm@lmu.de

§Department of Economics, Free University of Berlin, Boltzmannstr. 20, 14195 Berlin, Germany. Tel +49-30-838 52010. Fax: +49-30-838 52140 E-mail: nikolaus.wolf@wiwiss.fu-berlin.de

1. Introduction

The potential for multiple equilibria is a central feature of theoretical work in many fields of economics. A prominent example is multiple equilibria in industrial location which has a long tradition dating back to at least Marshall (1920). More recently these ideas have returned to prominence in the theoretical literature on new economic geography that has emerged following Krugman (1991a). A central prediction of these models is that the location of economic activity is not necessarily uniquely determined by fundamentals. Instead there are ranges of parameter values where several long-run spatial distributions of economic activity may emerge as equilibria, and which of these multiple equilibria is selected depends on either history or expectations (Krugman 1991b and Matsuyama 1991).[1]

Given the theoretical prominence of multiple equilibria, one would expect an extensive empirical literature examining the relevance of this key property of theoretical models of location. However, there is in fact a surprising scarcity of empirical evidence on this question. Furthermore, the most important contribution to the sparse empirical literature by Davis and Weinstein (2002, 2004) finds no evidence whatsoever of multiple equilibria and instead argues that a model with a unique long-run distribution of economic activity best fits the data.

In this paper, we use the combination of the division of Germany after the Second World War and the reunification of East and West Germany in 1990 as a natural experiment to provide evidence in favor of the empirical importance of multiple equilibria. A successful empirical test of multiple equilibria requires an exogenous and temporary shock which is sufficiently large to induce economic activity to relocate. If such a temporary shock resulted in a permanent shift in the location of economic activity, this would be powerful evidence in favor of multiple equilibria. If instead the distribution of economic activity is uniquely determined by fundamentals, the effect of the shock on the location of economic activity would be purely temporary. German division provides a large, exogenous shock to the relative attractiveness of locations. Furthermore, division – while ultimately reversed by reunification – persisted for over 40 years and was widely expected to be permanent. Since location decisions involve sunk costs and are forward-looking decisions, the persistence and apparent permanence of German division make

[1] Models with multiple expectational equilibria have been also described in terms of "co-ordination failures" (see for example Cooper and John 1988), while the role of initial conditions and historical accident in selecting equilibria has been also referred to as "path dependence" or "hysteresis" (see for example David 1985).

it likely that location decisions responded to this shock.

We focus on a single economic activity, an airport hub, which has a number of features that make it likely to be prone to multiple equilibria in location. First, there are substantial sunk costs in creating airport hub facilities. As a result, there may be several locations which will be an equilibrium, in the sense that once the sunk costs have been incurred there is no incentive to re-locate. Second, the existence of multiple equilibria may be reinforced by network externalities which act as a source of cumulative causation. The profitability of operating a connection to an airport is likely to be increasing in the number of other connections to the airport.

To guide our empirical work, we develop a simple general equilibrium model of air transportation. In the model the decision whether to create an air hub depends on the trade-off between the fixed costs of operating direct connections and the longer distances of indirect connections. In addition, there are sunk costs of creating an air hub. The economic fundamentals that determine the attractiveness of a location for the hub are its population and bilateral distances to other locations. If the variation in the economic fundamentals is not too large relative to the sunk costs, the model exhibits multiple equilibria.

Our empirical analysis proceeds in two stages. Our basic finding is that division led to a shift in the German air hub from Berlin to Frankfurt and there is no evidence of a return of the air hub from Frankfurt to Berlin after reunification. The shares of Berlin and Frankfurt in overall passenger traffic are almost exactly reversed between the pre-war and division periods. In 1937 Berlin and Frankfurt accounted for 30.8 and 9.5 per cent of the passenger traffic in pre-war Germany, while in 1988 they accounted for 8.4 and 36.5 per cent of the passenger traffic of West Germany. Since re-unification, Berlin's share of overall passenger traffic exhibits a slight negative trend, while Frankfurt's share has marginally increased. We use simple difference-in-differences estimates to show that the treatment effect of division on the location of the hub is highly statistically significant, while there is no statistically significant treatment effect of reunification.

While this evidence is suggestive of multiple equilibria, the observed relocation of Germany's air hub from Berlin to Frankfurt could also be due to a change in economic fundamentals. To rule out this alternative explanation, we present a number of pieces of evidence. We begin by comparing the experience of Germany to that of other European countries. Data on the location of the largest airport prior to World War II and today show, with the exception of Germany, a remarkable stability over time. Furthermore, again with the exception of Germany, the present-day air hub is located in each country's largest city. This suggests that the relocation of Germany's largest airport is unlikely to have been accidental and that, in the absence of division, the largest airport would have remained in Berlin. This evidence is also suggestive that Berlin, as Germany's largest city, is a potential equilibrium for the location of the air hub.

To further examine whether Berlin is again a viable equilibrium location for the air hub after reunification, as in the pre-war period, we use the structure of the theoretical model to show that Frankfurt's dominance of present-day air travel cannot be explained by economic fundamentals. The model emphasizes two sets of considerations that determine the attractiveness of a location for the hub: remoteness from other locations (market access) and local economic characteristics (in particular population). Using a gravity equation for bilateral passenger departures, we first show that Frankfurt's dominance of Germany's air traffic cannot be accounted for by a superior location relative to destinations worldwide. We next establish that Frankfurt's pre-eminence also cannot be explained by a number of alternative measures of local economic activity, such as the population or GDP of the city and its surrounding area. Instead, Frankfurt's dominance of Germany's air traffic is entirely driven by its role as a hub for transit passengers making indirect connections. This pattern of evidence supports the idea that the relocation of Germany's air hub from Berlin to Frankfurt is explained by a shift between multiple equilibria rather than a change in economic fundamentals.

Since Frankfurt does not have substantially superior market access or local economic characteristics, this raises the question of why it emerged as Germany's leading airport in the years immediately after division rather than other airports such as Cologne, Hamburg and Munich that had similar pre-war shares of passenger traffic. We explore the historical reasons for Frankfurt's rise and relate them to the airport's role as the main European base and transport terminal for the United States military air force in the immediate aftermath of the Second World War. This explanation emphasizes the role of "historical accident" in giving Frankfurt an initial advantage which led to the city's subsequent emergence as the new German air hub.

Finally, while there is no evidence to date of Berlin regaining its pre-war share of passenger traffic, there remains the question of whether Frankfurt will retain its dominance going forward into the future. We examine data on projections of future expansions of airport capacity to show that there are no expectations that Germany's air hub will return to Berlin over the coming decades.

Our findings are related to a number of literatures. A large body of research has examined the theoretical and empirical determinants of location choices. See Fujita *et al.* (1999) and Baldwin *et al.* (2003) for a synthesis of the theoretical literature and Overman *et al.* (2003) and Head and Mayer (2004a) for surveys of the empirical literature. Recent contributions include Amiti and Cameron (2006), Davis and Weinstein (2003), Hanson (1996, 2004, 2005), Head and Mayer (2004b), Overman and Winters (2006), Redding and Venables (2004), and Redding and Sturm (2005).

However, the central theoretical prediction of multiple equilibria in location has only been addressed by a small number of papers. In an influential paper, Davis and Weinstein (2002) propose the Allied bombing of Japanese cities as an exogenous shock which is both large and temporary. The destruction caused by the bombing campaign varied substantially and resulted in very different losses in population across cities. Surprisingly, they find that city populations recovered very quickly from the war-time shock and cities return to their prewar growth path within less than 20 years. In subsequent work Davis and Weinstein (2004) show that not only total population of Japanese cities but also specific industries quickly return to their pre-war pattern. Using the same methodology, Brakman *et al.* (2004) find that the populations of West German cities recover rapidly from the devastation caused by the Second World War. Similarly, Miguel and Roland (2005) find that even the extensive bombing campaign in Vietnam does not seem to have had a permanent impact on the distribution of population and basic measures of economic development across the regions of Vietnam. In contrast Bosker *et al.* (2005) and Bosker *et al.* (2006) find some evidence of a permanent change in the distribution of population across West German cities after the Second World War.

While the use of war-related destruction is an ingenious source for a large and temporary shock, a potential concern is that it may not be sufficient to change location decisions, which are forward-looking and involve substantial sunk costs. The continued existence of road networks and partially-surviving commercial and residential structures may serve as focal points around which reconstruction occurs. Furthermore, institutional constraints such as property rights and land-use regulations may provide additional reasons why existing concentrations of population and industrial activity re-emerge. A further concern is that even if one observes changes in the equilibrium location of population, as in Bosker *et al.* (2005) and Bosker *et al.* (2006), it remains unclear whether these are due to changes in fundamentals or a move between multiple equilibria.

Our approach has a number of attractive features, which enable us to address these concerns. First, division not only makes Berlin an extremely unattractive location, but this shock lasts for over 40 years and is widely expected to be permanent. Therefore, in comparison to war-related destruction this shock is likely to have had a profound impact on location decisions and is more likely to shift economic activity between multiple equilibria. Second, as we focus on a single economic activity, for which a wealth of information is available, we are able to distinguish changes in economic fundamentals from a shift between multiple equilibria.

Finally, our paper is also related to the literature on the airline industry and on hub formation in networks more broadly: see for example Brueckner (2002, 2004), Campbell (1996), Drezner and Drezner (2001), Hendricks *et al.* (1999) and Hojman and Szeidl (2005). More generally, models of multiple equilibria feature throughout economics in fields as diverse as industrial organization (Bresnahan and Reiss 1991, Jovanovic 1989), development economics (Murphy *et al.* 1989), labor economics (Moro 2003) and macroecomomics (Cooper and John 1988, Cooper 2002).

The remainder of the paper is organized as follows. Section 2 discusses the historical background to German division and reunification. Section 3 outlines a simple model of air transportation which is developed in further detail in the appendix. Section 4 presents our basic finding that division permanently relocated the German air hub from Berlin to Frankfurt. Section 5 develops a body of evidence that the relocation of the air hub is indeed a movement between multiple equilibria and is not due to other explanations such as a change in economic fundamentals. Section 6 concludes.

2. Historical Background

In the wake of World War II and with the onset of the cold war, Europe was divided by an Iron Curtain between Western and Eastern spheres of influence. This dividing line ran through the centre of pre-war Germany, cutting the country into two areas of roughly equal size.[2] The origins of Germany's division can be traced back to a wartime protocol that organized the country into zones of military occupation. West Germany was founded in 1949 on the area of the American, British and French zones, while East Germany was founded in the same year on the Soviet zone (see for example Loth 1988).

Berlin was situated approximately 200 kilometers to the East of the border between East and West Germany. Due its status as the capital of pre-war Germany, Berlin was jointly occupied by American, British, French and Soviet armies and for this purpose was divided into four sectors of occupation. With the building of the Berlin Wall in August 1961, the city was firmly divided into West Berlin, which comprised the American, British and French sectors, and East Berlin, which consisted of the Soviet sector (see Sharp 1975). While West Berlin functioned as a de facto part of West Germany, it formally remained under Allied occupation until 1990.

The location of West Berlin as an island surrounded by East German territory raised the problem of access from West Germany to West Berlin. An initial agreement between the Allied and Soviet commanders about access routes broke down in June 1948, when the Soviets blocked rail and road connections to West Berlin. During the ensuing blockade West Berlin was supplied for over a year through the Berlin airlift. A formal agreement on access routes from West Germany was only reached in 1971, with the signing of the Four Power Agreement of September 1971 and the subsequent Transit Agreement ("Transitabkommen") of December 1971. The Transit Agreement designated a small number of road, rail and air corridors and substantially eased East German border controls on road and rail traffic between West Berlin and West Germany.

After forty years of division, the Soviet policies of "Glasnost" and "Perestroika" introduced by Mikhail Gorbachev in 1985 started a process of opening up of Eastern Europe. As part of this wider transformation, large scale demonstrations in East Germany in 1989 led to the fall of the Berlin Wall on 9 November 1989. In the aftermath of these events, the East German system rapidly began to disintegrate. Only eleven months later East and West Germany were formally reunified on 3 October 1990. In June 1991 the German parliament voted to relocate the seat of the parliament and the majority of the federal ministries back to Berlin. The broader process of

[2] The areas that became West Germany accounted for about 53 per cent of the area and about 58 per cent of the 1939 population of pre-war Germany.

integration between Eastern and Western Europe has continued with the signing of the Europe Agreements in the early 1990s, and was further deepened with the accession of eight Eastern European countries to the European Union in 2004.

3. Theoretical Framework

To guide our empirical research, we outline a simple model of air travel and hub creation, which is discussed in further detail in the appendix. The model formalizes the conditions under which air hubs form and the circumstances in which there are multiple equilibria in their location. We assume three locations, which is the simplest geographical structure in which a hub and spoke network can form. If a hub forms, it will have direct connections to the other two locations, while travel between these other two locations will occur through an indirect connection via the hub. We use the model to examine the impact of Germany's division and the reunification of East and West Germany on the equilibrium location of the air hub.

3.1. Air Travel and Hub Creation

We consider a model where there is a downward-sloping demand curve for air travel derived from the demand for consuming non-traded services from other locations (cities). A monopoly airline chooses whether to operate direct connections between cities or to operate indirect connections via a hub.[3] There is a fixed cost of $F > 0$ units of labor of operating each direct connection and then a constant marginal cost in terms of labor for each return passenger journey that depends on the distance flown. In addition, we assume that there is a sunk cost of $H > 0$ units of labor of creating a hub. The airline faces a choice between two modes of serving the three cities: pair-wise direct connections or operating a hub in one city and connecting the other two cities indirectly via the hub. The hub itself can be located in any one of the three cities. To make the airline's choice an interesting one, we assume that direct connections are profitable on all three routes.

The airline is assumed to be able to segment the markets for travel between each pair of cities, and therefore chooses the price on a route to maximize profits subject to the downward sloping demand curve for that route. Equilibrium prices are a mark-up over marginal cost

[3] Introducing multiple air carriers in the model would increase the likelihood of multiple equilibria due to the network externalities that this introduces.

and variable profits are proportional to the revenue derived from a route. Since markets are segmented, evaluating the profitability of operating a hub relative to pair-wise direct connections is straightforward. Whether or not there is a hub, two of the three bilateral routes are always served by direct connections. Therefore, the decision whether to create a hub depends on the relative profitability of a direct and indirect connection on the third bilateral route compared to the sunk costs of creating the hub. The per-period difference in profits from locating the hub in city i and serving all three routes with direct connections, denoted ω^i, equals:

$$\omega^i = F - \left(\pi^D_{kj} - \pi^I_{kj}\right) \tag{1}$$

where π^D_{kj} and π^I_{kj} denote variable profits from a direct and indirect connection between cities k and j, and we denote the present discounted value of the difference in profits by Ω^i.

Condition (1) captures a simple trade-off. On the one hand, creating a hub in city i and operating an indirect connection between cities k and j saves fixed costs F. On the other hand, variable profits between cities k and j are lower if the route is served by an indirect connection rather than a direct connection: $\pi^D_{kj} - \pi^I_{kj} \geq 0$. The reason is the higher marginal costs on indirect connections, together with the reduction in the demand for air travel due to the disutility of changing planes on indirect connections, which reduce variable profits on indirect connections compared to direct connections. The larger the fixed cost and the smaller the difference in variable profits between direct and indirect connections, the more attractive will be a hub relative to pair-wise direct connections.

The three cities will generally differ in terms of their attractiveness as a location for the hub. The airline will prefer to maintain direct connections on routes where there is high demand for air travel, namely those between populous cities, cities with a central location and cities whose non-traded services receive a high weight in consumers' utility. The reason is that the reduction in variable profits from operating an indirect rather than a direct connection is larger when the demand for air travel between a pair of cities increases.

Without loss of generality, we choose to index cities so that lower values of i correspond to more profitable locations for the hub: $\Omega_1 \geq \Omega_2 \geq \Omega_3$. There are multiple equilibria in hub location if there are several cities i where it is profitable to create a hub and, once the city is chosen as the hub, there is no incentive to relocate to another city j:

$$\Omega_i > H \qquad \text{and} \qquad \Omega_j - \Omega_i < H \qquad \text{for all } j \neq i \tag{2}$$

In contrast, there is a unique equilibrium location of the hub in city i if creating the hub in city i is profitable and, if any other city j is chosen as the hub, there is an incentive to relocate to city i:

$$\Omega_i > H \qquad \text{and} \qquad \Omega_i - \Omega_j > H \qquad \text{for all } j \neq i \tag{3}$$

Therefore, the existence of multiple equilibria depends on the variability in cities' profitability as a hub being sufficiently small relative to the value of sunk costs. When the sunk cost of creating the hub is equal to zero, there is a unique equilibrium location of the hub except in the knife-edge case when cities are symmetric. However, if the sunk costs of creating the hub is larger than the difference in profitability between alternative possible locations for the hub, there are multiple equilibria. When multiple equilibria occur, initial conditions determine which equilibrium is selected. Thus, if cities A and B both satisfy equation (2), A will be the equilibrium if the hub is initially located in city A, and B will be the equilibrium if the hub is initially located in city B.

Our framework belongs to a class of models with multiple equilibria where history in the form of initial conditions determines which equilibrium is selected. For a given vector of parameters, the equilibrium of the economy depends on the particular set of initial conditions. This class of models features prominently in the economic geography literature following Krugman (1991a). In the standard core-periphery model where the flow of migrants between regions is determined by the current real wage gap, small initial differences in real wages between regions are reinforced by the forces of cumulative causation. A complementary line of research in the economic geography literature emphasizes the role of expectations in selecting between one of several equilibria. In Krugman (1991b), Matsuyama (1991) and Baldwin (2001), either history or expectations can select between multiple equilibria depending on parameter values and initial conditions.

3.2. German Division and Reunification

The model can be used to examine the implications of German division and the reunification of East and West Germany. Initially the airline will locate the hub in the city with the most attractive location ($i = 1$). In the empirical analysis below, city one will correspond to Berlin. We model German division as an exogenous and unanticipated shock that temporarily reduces the relative attractiveness of city one as a location for the hub.

The model suggests two main reasons why division reduced the relative profitability of locating the hub in Berlin. First, division substantially reduced the size of the local population, which decreases local demand for air travel. West Berlin not only accounted for just 60 percent of the city's 1939 population, but division also isolated West Berlin from its surrounding economic hinterland which was now part of East Germany. Second, the division of Germany and the wider division of Europe as a whole increased the remoteness of Berlin. Since Berlin was located 200 kilometers East of the new border between East and West Germany, West Berlin lost access to nearby locations East of the iron curtain. In addition, access to Berlin from West Germany was limited to designated air corridors and no formal agreement on these access routes was reached until 1971.[4]

The temporary shock of division will permanently shift the equilibrium location of the hub to the next most attractive location ($i = 2$) if two conditions are satisfied. First, the shock is sufficiently large that the increase in profits from relocating the hub is greater than the sunk cost. Second, city two was an equilibrium before the shock so that, once the shock has ended, it is not profitable to relocate the hub back to city one. These conditions are:

$$\Omega_2 - (\Omega_1 - S) > H \qquad \text{and} \qquad \Omega_1 - \Omega_2 < H \tag{4}$$

where S denotes the reduction in the profitability of city one as a location for the hub due to the shock.

The two conditions in equation (4) illustrate the difficulties in finding a suitable experiment to provide empirical evidence for multiple equilibria. On the one hand, large sunk costs make multiple equilibria more likely. On the other hand, large sunk costs increase the size of the shock required to shift the economy between multiple equilibria. Finally, note that in order for division to permanently shift the location of the hub between multiple equilibria, we do not necessarily require the profitability of city one to completely return to its level prior to division (as for simplicity assumed in equation (4)). All we need is that division sufficiently reduces city one's profitability that it is no longer a potential equilibrium, and reunification sufficiently increases city one's profitability that it is again a potential equilibrium.

[4] Although not directly captured by the model, the absence of agreement on West Berlin's legal status until 1990 and the consequent fear that investments in West Berlin would be expropriated may have further reduced the attractiveness of the city as a location for the hub.

4. Data and Empirical Strategy

4.1. Data Description

One of the attractive features of airports is that, in contrast to other economic activities which are likely to be prone to multiple equilibria in location, detailed current and historical data are available. Our basic dataset is a panel on departing passengers from the ten main German airports during the pre-war, division and reunification periods. For the pre-war period, data are available from 1927 onwards until 1938. For the period after the Second World War, we have data from 1950, which is the earliest year for which information is available, until 2002.

We combine our basic dataset with information from a variety of other sources. To compare the experience of Germany with that of other European countries which were not subject to division, we have collected data on departing passengers from the largest airports in other European countries in 1937 and 2002. To provide evidence on the relative attractiveness of different cities as locations for Germany's air hub, we have assembled data for 2002 on a variety of city characteristics including total population, employment in industry and Gross Domestic Product (GDP).

Finally, to further examine the determinants of the relative size of airports, we exploit data on bilateral departing passengers between German airports and the universe of worldwide destinations flown to from these airports. We have collected information on the latitude and longitude co-ordinates of each airport and worldwide destination, which are used to construct bilateral great circle distances. Detailed references to the data sources are in the data appendix.

4.2. Baseline Econometric Specification

Our baseline econometric equation is a "difference-in-differences" specification that allows for changes in trends and intercepts of airport passenger shares for each airport during the pre-war, division and reunification periods:

$$share_{at} = \sum_{a=1}^{A} \eta_{ap} + \sum_{a=1}^{A} \beta_{ap} \mathrm{time}_t + u_{at} \tag{5}$$

where a indexes airports, t denotes years, and p indicates periods (pre-war, division and reunification). The dependent variable, $share_{at}$, is the share of an airport in passenger traffic in year t. The parameters η_{ap} are a full set of airport-period fixed effects that allow for changes in mean passenger shares for each airport between the pre-war, division and reunification periods. The coefficients β_{ap} allow trends in passenger shares for each airport to also vary between the pre-war, division and reunification periods; u_{at} is a stochastic error.

The regression specification in equation (5) allows both mean levels and trend rates of growth of passenger shares to vary across airports and periods in order to better detect structural breaks. In particular, it may take time for airport capacity to be constructed and a new hub to emerge in response to an exogenous shock. As a result, a structural break will first be visible in a change in an airport's trend rate of passenger growth before a significant difference in mean passenger levels gradually emerges. This is particularly important for the reunification period where we have a relatively short period of time over which to observe the impact of the exogenous shock. Therefore, we will concentrate below on statistical tests based on changes in airports' trend rates of passenger growth.[5]

Our regression specification enables us to test a number of hypotheses concerning the effect of division and reunification. First, we test the statistical significance of differences in trend rates of growth of passenger shares across airports within periods. This corresponds to a first set of differences across airports. Second, we test the statistical significance of changes in trend rates of growth of passenger shares within airports across periods. This corresponds to a second set of differences across time. Finally, we test whether the change in one airport's trend rate of growth across periods is the same as the change in another airport's trend rate of growth across periods. This corresponds to a "difference-in-differences" estimate of the impact of division or reunification, where we difference both within airports across periods and across airports within periods.

5. Basic Empirical Results

5.1. Evolution of Airport Passenger Shares

Before we estimate our basic specification, Figure 1 displays the share of the ten largest German airports in total departures at these airports over the period 1927 to 2002. This graph reveals a number of striking patterns.

Before the Second World War Berlin has the largest airport in Germany by a substantial

[5] Re-estimating equation (5) only allowing changes in intercepts between the pre-war, division and reunification periods yields a similar pattern of results.

margin and was in fact the largest airport in Europe in 1937. Already in 1927, when our data series starts, Berlin has more than twice as large a market share as the next largest German airport. From 1931 onwards, which is a period of rapid growth in air traffic at all German airports, Berlin's market share steadily increases and reaches a peak of over 40 percent in 1938. The four airports ranked after Berlin are Frankfurt, Munich, Hamburg and Cologne. These airports have very similar market shares, which remain remarkably stable at around 10 percent throughout the pre-war period.

The dominance of Berlin in German air traffic dramatically changes after the division of Germany. While Berlin is still the largest airport in Germany in terms of total departures in 1950, when data become available again, Frankfurt is now already the second largest airport substantially ahead of Hamburg and Munich. Over the next decade Berlin steadily declines in importance and by 1960 Frankfurt overtakes Berlin as the largest German airport.[6] A further acceleration in the decline of Berlin's share occurs immediately after 1971, when the transit agreement between East and West Germany substantially improves road and rail connections between West Berlin and West Germany. By the 1980s Frankfurt and Berlin have almost exactly changed roles. Frankfurt now has a stable market share between 35 and 40 percent, while Berlin's market share has declined to just below 10 percent.

In contrast to the striking change in the pattern of air traffic following division, there is hardly any visible impact of reunification. There is a small step-increase in Berlin's share of passenger traffic. This is due to the re-integration of East and West Berlin, so that total departures from Berlin are now the sum of departures from Tempelhof and Tegel airports in West Berlin and Schoenefeld airport in East Berlin.[7] Apart from this small step-increase, the trend in Berlin's share of passenger traffic is slightly negative after reunification. Frankfurt clearly remains Germany's leading airport. The trend in Frankfurt's share of passenger traffic is virtually flat after reunification, if anything increasing marginally.

[6] The spike in departures in 1953 in Berlin is mainly due to a wave off refugees leaving East Germany via West Berlin in the period around the violent demonstrations in East Germany in June 1953. The Statistical Yearbook of West Germany reports that 257,308 East German refugees left West Berlin by plane in 1953, which accounts for as much as 47 percent of total departures in Berlin in this year. This stream of East German refugees departing from West Berlin by plane continues at a rate of approximately 95,000 people per year, which accounts for on average 16 percent of departures in Berlin during 1954-60, and ceases with the building of the Berlin Wall in 1961.

[7] If departures from Schoenefeld airport in the East are excluded from total departures for Berlin, there is no visible change in Berlin's passenger share in response to reunification.

Compared to the dramatic change in the relative fortunes of the airports in Berlin and Frankfurt other changes in the pattern of German air traffic appear relatively minor. The change in Berlin and Frankfurt's average shares of passenger traffic between the ten years leading up to 1938 and the ten years leading up to 2002 were -25.6 and 23.9 percent. These compare with a change in the average passenger share for Munich, which has risen to become the second largest German airport, of 3.6 per cent over the same period. The airport with the largest change in average passenger shares after Berlin and Frankfurt is Dusseldorf, which experienced a rise of 10.5 percent. However this increase coincides with a decline of 6.9 percent at the airport in Cologne over the same period, which is only 54 kilometers away from the airport in Dusseldorf.[8]

5.2. Difference-in-Differences Estimates

To examine the statistical significance of the changes shown in Figure 1, we now estimate our baseline specification in equation (5). The coefficients on the time trends in each airport in each period capture mean annual rates of growth of passenger shares and are reported in Table 1. We begin by examining the statistical significance of the change in time trends between the pre-war and division periods for Berlin and Frankfurt (a difference within airports across periods). The final column of Panel A of Table 2 shows that Berlin's mean rate of growth of passenger shares declines by 2.7 percentage points per annum, while Frankfurt's rises by 0.4 percentage points per annum. Both these changes are highly statistically significant.[9]

We next consider the statistical significance of the difference in time trends between Berlin and Frankfurt within the pre-war and division periods (a difference within periods across airports). The final row of Panel A of Table 2 shows that within each period the difference in the mean annual rate of growth of passenger shares is in excess of 1 percentage point per annum and is highly statistically significant. Finally, we consider the difference-in-differences, by

[8] We see a similar pattern in freight departures. Following division Frankfurt replaces Berlin as Germany's leading airport for freight and there is again no visible impact of reunification. Berlin's average share in total freight departures falls from 36.5 to 0.7 percent between the ten years leading up to 1938 and the ten years leading up to 2002. Over the same period the average share of Frankfurt increases from 11.2 to 70.6 percent.

[9] As table 1 shows, Frankfurt has the highest mean annual rate of growth during the division period. There are nevertheless two other airports, Cologne and Munich, for which the within-airport change in time trends is more positive than for Frankfurt. This is driven by negative time trends for Cologne and Munich during the pre-war period becoming modestly positive during the post-war period. Furthermore, as is evident from Figure 1, the within-airport change in time trends for Frankfurt understates its rise between the pre-war and division periods, since some of the rise in Frankfurt's post-war share of passenger traffic has already occurred prior to 1950 when data become available (and is therefore captured in Frankfurt's intercept for the division period).

comparing the change in Berlin's time trend between the pre-war and division periods to the change in Frankfurt's time trend between the same two periods. The bottom right-hand cell of Panel A of Table 2 shows that this difference-in-differences in mean annual growth rates is over 3 percentage points per annum and is again highly statistically significant (p-value < 0.001).

We now turn to examine the treatment effect of reunification. Figure 1 suggests that the evolution of airport passenger shares during much of the 1950-89 period is influenced by the treatment effect of division, but by the 1980-89 period passengers shares have completely adjusted to the impact of division. Therefore, we estimate an augmented version of our basic specification (5) where we break out the division period into decades, including fixed effects and time trends for each airport in each decade during the division period. To examine the treatment effect of reunification, we compare the 1992-2002 period to the 1980-89 period immediately preceding reunification.

The final column of Panel B of Table 2 shows that the change in both Berlin and Frankfurt's mean annual rate of growth of passenger shares in the periods immediately before and after reunification is close to zero and far from statistical significance. The final row of Panel B of Table 2 shows that there is a small but nevertheless statistically significant difference in the mean rate of growth of passenger shares between Berlin and Frankfurt that is of the same magnitude within the two periods. The lack of a significant change in the within-airport time trends in the final column of Panel B of Table 2 already suggests that reunification had little impact on passenger shares. The difference-in-differences estimate that compares the change in time trends between the two periods for both airports confirms this impression. As reported in the bottom right-hand cell of Panel B of Table 2, the difference-in-differences estimate is close to zero and entirely statistically insignificant (p-value $= 0.854$).

Therefore, the results of estimating our baseline specification confirm the patterns visible in Figure 1. There is a statistically significant treatment effect of division on the location of Germany's leading airport. In contrast, there is no evidence of a statistically significant treatment effect of reunification.

6. Are There Really Multiple Equilibria?

While the results in the previous section are suggestive that Germany's air hub has shifted between multiple equilibria, an alternative possible explanation is that economic fundamentals have changed so that although Berlin was a potential equilibrium location of the air hub prior to the Second World War, it is no longer a potential equilibrium location after reunification. In this section, we provide several additional pieces of evidence to strengthen the case that there has indeed been a shift between multiple equilibria.

First, we compare the experience of Germany to that of other European countries, to demonstrate how unusual the German pattern of air traffic is and to establish that division was causally responsible for the relocation of Germany's air hub. Second, we derive a prediction for bilateral passenger departures from the theoretical model in order to quantify the role of fundamentals in the form of location relative to destinations (market access) and local economic characteristics (in particular local population) to explaining airports' passenger volumes. We show that Frankfurt's dominance of Germany's passenger traffic cannot be explained by a superior location relative to destinations worldwide or by a greater concentration of local economic activity, and is instead directly related to its status as a transit hub.

Third, we present estimates of the sunk cost of creating the hub and we examine projections of expansion in airport capacity to show that there is no expectation of Germany's air hub returning to Berlin in the future. Finally, given the absence of superior market access and local economic characteristics in Frankfurt, we discuss explanations as to why it was able to attract Germany's air hub in the years following division rather than other airports with similar pre-war shares of passenger traffic such as Cologne, Hamburg and Munich.

6.1. International Evidence

To demonstrate how unusual the changes in Germany's pattern of air-traffic are, Table 3 presents evidence on the structure of airport traffic in other European countries in 1937 and 2002.[10] Column (1) reports the country's largest airport in 1937; Column (2) lists the market share of the largest airport in 1937; Column (3) shows the market share of the largest airport in 2002; and Column (4) reports the rank of the largest 1937 airport in 2002.

[10] The countries are the EU 15, Norway and Switzerland, but excluding Luxemburg, which did not have an airport prior to Second World War and, due to its size, only has one airport today.

The first striking feature of the table is that Germany is the only country where the leading airport in 1937 is not the leading airport in 2002 (Berlin is ranked fourth in 2002). In all other countries, there is a perfect correlation between past and present locations of the leading airport. The 1937 airport market shares are not only qualitatively but also quantitatively good predictors of the 2002 airport shares. There is a positive and highly statistically significant correlation between the past and present market shares, and we are unable to reject the null hypothesis that the 2002 market shares equal their 1937 values.[11] This persistence in airport market shares in countries which were not subject to the shock of division is consistent with the model, where sunk costs introduce persistence in the location of the air hub over time.

A second striking implication of comparing Germany with other European countries is that Germany is the only country where the largest airport is not currently located in the largest city. In all other European countries, there is a perfect correspondence between the present-day location of the largest airport and the location of the largest city. Taken together these two findings support the idea that, in the absence of division, the German air hub would today be located in Berlin and that it is at least not obvious that Berlin, which is Germany's largest city by a substantial margin, would not be a possible location for the country's air hub.

6.2. Quantifying the Importance of Market Access

We now use the structure of the theoretical model to determine whether Frankfurt's current dominance of German air travel can be explained by superior economic fundamentals or is instead due to its status as a transit hub. The model suggests two sets of economic fundamentals that determine a city's attractiveness as a location for the hub: the city's proximity to other locations (market access) and the local concentration of economic activity (in particular population). To examine the importance of these two sets of considerations, we adopt a two-step procedure. In this section, we estimate a gravity equation which allows us to decompose total passenger departures into the contributions of market access and a source airport fixed effect. In the next section, we relate the source airport fixed effects to local concentrations of economic activity.

The theoretical model implies that the number of return passenger journeys from city j

[11] If the 2002 market shares are regressed on the 1937 market shares excluding the constant, we are unable to reject the null hypothesis that the coefficient on the 1937 market shares is equal to one (p-value=0.162).

to city i is $a_{ij} = \beta_{ij}^{1-\sigma} T_{ij}^{-\sigma} P_j^{\sigma-1} E_j^T$; where E_j^T corresponds to expenditure in the source city which depends on city population and the wage (which is equal to one in equilibrium); P_j is the non-traded price index in the source city; β_{ij} corresponds to the weight of the destination city's non-traded services in the utility of source city residents; $T_{ij} \equiv \left(p_i^x + p_{ij}^a\right)$ captures travel costs and includes the bilateral price of air travel p_{ij}^a and the price of non-traded services in the destination city p_i^x (which is equal to one in equilibrium). Since passenger journeys are round-trips, the total number of departing passengers from city j to city i is the sum of passengers travelling in each direction:

$$A_{ij} = a_{ij} + a_{ji} = \beta_{ij}^{1-\sigma} T_{ij}^{-\sigma} P_j^{\sigma-1} E_j^T + \beta_{ji}^{1-\sigma} T_{ji}^{-\sigma} P_i^{\sigma-1} E_i^T \tag{6}$$

Equation (6) implies that bilateral air travel depends on characteristics of the source city, characteristics of the destination city, and bilateral frictions. We log-linearize this relationship and estimate the following empirical specification for bilateral passenger flows as a function of source city fixed effects (s_i), destination city fixed effects (m_i), and bilateral travel costs which we model using bilateral distance:

$$\ln A_{ij} = s_j + m_i + \varphi \ln\left(dist_{ij}\right) + u_{ij} \tag{7}$$

where u_{ij} is a stochastic error.

We estimate the gravity equation (7) using data on bilateral passenger departures from the 15 German airports for which data were available in 2002 to destinations worldwide.[12] To abstract from substitution from other modes of transport, we focus in our baseline sample on departures to destinations more than 300 kilometers away from any German airport. As a robustness test, we also re-estimate the model using departures to all destinations. Column (1) of Table 4 reports the results of estimating equation (7) using the fixed effects estimator for our baseline sample.[13] The model explains a substantial proportion of the overall variation in bilateral departures with an R^2 of 0.68, and both the source and destination fixed effects are highly statistically significant (p-values < 0.001). Note that the destination fixed effects capture

[12] The five additional airports for which data were available in 2002 are: Dresden, Erfurt, Leipzig, Munster and Saarbrucken. We exploit the additional data where it is available, but all our results are robust to continuing to focus on the ten main German airports.

[13] We add one to the bilateral departures data before taking logarithms. While the linear fixed effects estimator is widely used in the gravity equation literature, we have also re-estimated the model using a Possion fixed effects specification (see Silva and Tenreyro 2006). Again in this specification, we confirm the main finding below that market access contributes little to explaining Frankfurt's dominance of German air travel.

any destination characteristic that is common across all German airports, and so they control for destinations' average distance from German airports. Therefore, the distance coefficient is identified solely from variation in distance induced by airports' differential location within Germany. Nonetheless, we find a negative and highly statistically significant coefficient on distance: a one percent increase in distance travelled is associated with an 1.6% decline in passenger departures, so that doubling distance more than halves bilateral passenger departures.

In the model, hub airports generate much higher levels of passenger departures than would be expected based on their economic fundamentals, because transit passengers changing planes at the hub inflate the total number of departing passengers. As a result, the source airport fixed effect for hub airports will be much larger relative to economic fundamentals than for other airports. Additionally, the existence of a hub could also influence the coefficient on distance that captures bilateral frictions, because the coefficient on distance could differ between a direct connection and the constituent parts of an indirect connection. Therefore, Column (2) re-estimates the model excluding Frankfurt and Munich, which together account for over 95% of transit passengers in Germany. We find a very similar estimated coefficient on distance that is not statistically significantly different from that estimated in Column (1). In a similar spirit, Column (3) re-estimates the model for the sub-sample of destinations beyond 300 kilometers that are served with direct connections from each of the 15 German airports. The estimated coefficient on distance is again close to and statistically indistinguishable from that in Column (1), but the substantially smaller sample means that it is no longer statistically significant at conventional levels (p-value = 0.124). Thus, in practice, there do not appear to be large differences in the estimated coefficient on distance between direct and indirect connections.

The results from the gravity equation estimation can be used to undertake a decomposition of total passenger departures. The destination fixed effects, m_i, capture all relevant characteristics of a destination that influence passenger departures. We use them to construct a measure of each airport's market access, which summarizes the airport's proximity to destinations. Market access is equal to the distance-weighted sum of the destination fixed effects: $MA_j = \sum_i dist_{ij}^{\varphi} M_i$, where M_i is the exponent of m_i.[14] From equation (7), taking exponents and adding up bilateral departures across destinations, predicted departures from each airport can be decomposed into

[14] This measure of market access derived from the gravity equation follows Redding and Venables (2004). See Harris (1954) for an earlier measure of 'market potential.'

the contributions of the source airport fixed effects and market access:

$$\widehat{A}_j = \sum_i \widehat{A}_{ij} = \widehat{S}_j \sum_i dist_{ij}^{\widehat{\varphi}} \widehat{M}_i = \widehat{S}_j \widehat{MA}_j \tag{8}$$

where hats indicate estimated coefficients and predicted values, and where S_j is the exponent of s_j.

Using equation (8), we may decompose percentage differences in predicted departures between airports into the contributions of the source airport fixed effects and market access:

$$\ln\left(\frac{\widehat{A}_j}{A_b}\right) = \ln\left(\frac{\widehat{s}_j}{s_b}\right) + \ln\left(\frac{\widehat{MA}_j}{MA_b}\right) \tag{9}$$

where b indicates the base airport which we choose to be Berlin.[15]

Figure 2 displays the results of undertaking the decomposition in equation (9) for our baseline specification from Column (1) of Table 4. A striking impression from this figure is that, although market access varies across German airports, its contribution to differences in passenger departures is dwarfed by that of the airport fixed effects. This finding is consistent with the fact that, in a comparatively small country such as Germany (which is approximately the size of Montana), airports are sufficiently close together that there is relatively little variation in distance to destinations and hence relatively little variation in market access.

This finding that market access makes a relatively minor contribution to variation in passenger departures is robust across a wide range of specifications. Using the coefficients from the specifications estimated in Columns (2) and (3) of Table 4, we find an extremely similar pattern of results. As an additional robustness test, we re-estimated the model also including departures to destinations less than 300km away from any German airport. This changes the estimated coefficient on distance, since at first increases in distance lead to substitution away from other modes of transport and towards air travel, and so the number of departing passengers is initially increasing in distance. But, also in this specification, we find that market access makes a minor contribution towards explaining variation in passenger departures. Finally, we constructed a simpler measure of market potential based on Harris (1954) using total passenger

[15] The fixed effects in the gravity equation are estimated relative to an excluded category and, therefore, their absolute levels depend on the choice of the excluded category. The normalization relative to a base airport in equation (9) ensures that the results of the decomposition do not depend on the choice of excluded category in the gravity equation estimation. As is clear from equation (9), the choice of base airport does not affect relative comparisons between any pair of airports j and i.

departures from Germany as a whole to each destination more than 300 kilometers away from any German airport. We divide aggregate passenger departures from Germany as a whole to a particular destination by the distance from an airport to that destination. We then calculated the distance-weighted sum of the aggregate passenger departures, which varies across airports due to their different distances from destinations. In this robustness test, the percentage difference in market potential across German airports is again small relative to the percentage difference in airport passenger departures.[16]

Therefore, across a wide range of specifications, the first set of economic fundamentals emphasized by the model - market access - contributes little towards understanding Frankfurt's dominance of German passenger traffic, which is instead driven by differences in the airport fixed effects. In the next section, we examine the extent to which variation in the airport fixed effects is explained by the second set of economic fundamentals emphasized by the model - the local concentration of economic activity.

6.3. The Role of Local Economic Activity

To provide evidence on the local concentration of economic activity, Table 5 reports data on local economic activity in the cities where airports in our sample are located. The data include total population, gross domestic product (GDP) and employment in industry, expressed as indices where Frankfurt is set equal to 100. We report these measures of local economic activity for both the cities themselves and the cities together with counties with which they share a common boundary.[17]

The first striking feature of these data is that Berlin is by far Germany's largest city. In 2002, Berlin's population of over 3.3 million was nearly twice as large as Hamburg's, which is Germany's second largest city, and was more than five times larger than Frankfurt's. Indeed, from Columns (2)-(4), there are several cities with larger population, employment in industry and GDP than Frankfurt. When information on contiguous counties is included in Columns (5)-(7), Frankfurt's population, employment in industry and economic activity remains smaller than the values of several other cities including Berlin. Clearly, these findings do not imply that the economic importance of Berlin relative to other cities in Germany is the same today

[16] The correlation coefficient between this simpler measure of market potential and our baseline measure of market access from the gravity equation estimation is 0.92 and statistically significant at the 1% level.

[17] There are 439 counties in Germany that have an average area of around 800 square kilometres.

as in the period prior to division.[18] However, the data do suggest that it is difficult to explain Frankfurt's vastly greater fixed effect than any other airport in terms of the concentration of local population and economic activity.

An alternative explanation for Frankfurt's vastly greater fixed effect is the airport's status as a transit hub. Table 6 reports data on the concentration of departing passengers and transit passengers across German airports in 2002. Transit passengers are defined as those changing planes at an airport on route to another destination. From Column (3), Frankfurt accounts for more than three-quarters of transit passengers across the German airports. The only other airport with a non-negligible share of transit passengers is Munich, whose share is around 20 percent, and which is Germany's second largest airport. Comparing Columns (2) and (3), transit passengers are much more highly concentrated in Frankfurt than overall passenger departures. Frankfurt's share of transit passengers of 76 percent is more than twice its share of all departing passengers of around 36 percent. From Column (4), transit passengers account for around half of all passenger departures from Frankfurt airport.[19]

To quantify the relative importance of economic fundamentals and other considerations in explaining variation in the source airport fixed effects, Figure 3 graphs the log of the fixed effects against log contiguous population and shows the linear regression relationship between the two variables.[20] The volume of transit passengers at each airport is also displayed in the figure with the size of circle used to indicate the airport. In the absence of a hub, the theoretical model suggests that total departures should be closely related to total population. This prediction is strongly confirmed in the data. We find a close relationship between the estimated value of the fixed effects and city population with two obvious outliers. The largest outlier is Frankfurt, which has a much larger fixed effect than expected based on contiguous population, and which coincides with a much larger volume of transit passengers than any other airport. The second outlier is Munich, which as we saw above is the only other airport with a non-negligible share of transit passengers.[21]

[18] The total population of Berlin declined, for example, from 4.3 million in 1939 to its current 3.3 million.

[19] Our measure of transit passengers is imperfect and provides a lower bound on the true volume of transit passengers, since many passengers travel to Frankfurt over long distances using other modes of transport. In particular, Frankfurt airport is a key station on one of the two North-South high-speed rails links in Germany, which runs from Hamburg through the Ruhr region to Frankfurt airport and then on to Munich.

[20] The coefficient on log continuous population is statistically significant at the 1% level: the estimated coefficient (standard error) are 1.818 (0.371).

[21] The next largest departure from the regression line is Dusseldorf. As discussed in Section 5.1, Dusseldorf

Therefore, while the concentration of local economic activity has a clearly discernible impact on the volume of departing passengers, Frankfurt is a stark outlier from this relationship. Furthermore, Frankfurt's excess volume of departing passengers relative to local economic activity is closely related to the concentration of transit passengers in the airport and their importance as a share of its overall departures.

6.4. Sunk Costs

The existence of multiple equilibria in the model depends on the difference in profitability across alternative possible locations for the hub relative to the value of the sunk costs of creating the hub. While the results so far have shown that there do not appear to be overwhelming differences in market access or the local concentration of economic activity between Frankfurt, Berlin and a number of other locations in Germany, a remaining question is the size of the sunk costs of creating the hub. A lower bound on the likely size of these sunk costs is the construction costs of the infrastructure at Frankfurt airport. A rough estimate of the magnitude of these costs is the construction costs of the two passenger terminals at Frankfurt airport. The first of these passenger terminals was completed in 1972 and at the time cost approximately 1 billion Deutschmark. The second passenger terminal was completed in 1994 and at the time cost approximately 2.5 billion Deutschmark (see Kutscher 1995). The combined cost of these two buildings alone therefore amounts to approximately 2.7 billion Euros in 2002 prices.

6.5. Future Projections

Despite these substantial costs of creating terminal facilities for an air hub, is there any evidence of a future move back to Berlin? Both Berlin and Frankfurt are currently in the process of extending their airport capacities. Berlin plans to open a new airport in 2011 which will replace the current system of three airports. This airport, is designed to have a starting capacity of 20 million passengers (number of departing plus arriving persons per year). The most optimistic passenger forecast of the Berlin airport authorities are 30 million passengers in the year 2030 for this airport, an increase of around 15 million passengers from current levels.

Frankfurt airport is currently seeking planning permission for a third passenger terminal,

airport is only 54 kilometers away from Cologne airport, and taking the two airports together they lie close to the regression line.

which would increase the airport's capacity from its current 56 million passengers a year by another 25 million passengers. Therefore, over the approximately same period, Frankfurt will increase its capacity by an even larger amount then Berlin, which illustrates that there is little expectation of a return of Germany's air hub to Berlin.[22]

6.6. Why Frankfurt?

Since Frankfurt does not have a substantially larger local population or a greatly superior location relative to destinations worldwide, this raises the question of why in the early years of division Frankfurt emerged as Germany's leading airport rather than Cologne, Hamburg and Munich which had similar pre-war passenger shares?

Frankfurt airport was captured by U.S. troops in March 1945, which turned the airport into a military air base and reconstructed the main runway in the following months. From 1948 Frankfurt became the European terminal for the U.S. Military Air Transport Service (MATS) which made the airport the primary airlift and passenger hub for U.S. forces in Europe. As a result, during the Berlin blockade of 1948-9, Frankfurt was the operational centre for the U.S. component of the Berlin airlift, which made by far the largest contribution towards the supply of the city by air.[23]

Already in 1947 Frankfurt was partially opened to civilian passenger traffic and by 1948 ten civilian airlines were flying to the airport. During the Berlin airlift, the airport was closed to civilian traffic, but a second runway was constructed and the airport's facilities were further upgraded (see Kutscher 1995). When the airport was re-opened to civilian traffic after the Berlin airlift, the U.S. presence had conveyed Frankfurt an important initial advantage relative to other airports such as Cologne, Hamburg or Munich. This initial advantage is reflected in Frankfurt's already substantially higher share in departing passengers relative to other West German airports in 1950, when official data become available again.

Therefore, the historical reasons for Frankfurt's rise are related to the airport's role as the main European base and transport terminal for the United States military air force. This explanation emphasizes the role of "historical accident" in giving Frankfurt, rather than the other airports with similar pre-war passenger shares, an initial advantage which led to the city's

[22] These numbers are taken from http://www.berlin-airport.de and http://www.ausbau.flughafen-frankfurt.de.

[23] During the airlift the U.S. supplied 1,783,572.7 tons to Berlin, a total more than three times larger than the British contribution of 541,936.9 tons (see Miller 2000).

subsequent emergence as the new German air hub.

7. Conclusion

While multiple equilibria are a central feature of theoretical work in many fields of economics, and have played a particularly prominent role in theories of industrial location, there is little evidence in support of their empirical relevance. This paper exploits the combination of the division of Germany in the wake of the Second World War and the reunification or East and West Germany, and the wider closing and opening of the Iron Curtain, as a natural experiment to provide empirical evidence in favour of multiple equilibria in location.

Our first finding is that division led to a shift in Germany's leading airport from Berlin to Frankfurt. Berlin and Frankfurt's shares of passenger traffic are almost exactly reversed in response to division, with Berlin's share falling from over 30 percent to under 10 percent and vice versa. In contrast, there is no evidence of a return of the air hub to Berlin in response to reunification. To rule out that this dramatic change in location is not due to a changes in fundamentals, but is indeed a move between multiple equilibria we develop a number of pieces of evidence.

The weight of evidence is consistent with a view that both Frankfurt and Berlin are sufficiently attractive in terms of their fundamentals for them to be potential equilibrium locations for Germany's air hub. There are therefore multiple equilibria in the sense that once the substantial sunk costs of creating an air hub have been incurred in Frankfurt, there is no incentive to relocate to Berlin, but had the sunk costs been incurred in Berlin, there would equally be no incentive to relocate to Frankfurt. Furthermore, the division of Germany - while ultimately temporary - was a sufficiently negative shock to the attractiveness of Berlin as a location for Germany's leading airport to induce a permanent shift in the location of the air hub between these two equilibria.

While our findings provide some of the first evidence that models of multiple equilibria are not only of theoretical interest, there are several potential avenues for future research. An obvious open question is to determine which share of economic activity has the necessary attributes for multiple equilibria in location to be of empirical relevance. A non-negligible share of economic activity seems a priori unlikely to involve sufficiently high sunk costs or agglomeration forces to make it prone to multiple equilibria in location. However, many manufacturing industries and also service sector activities such as, for example, banking, headquarter services or research universities seem to involve sufficiently large sunk costs or agglomeration forces to make multiple equilibria a serious possibility.

The apparent success of the division of Germany in influencing location patterns also has interesting implications for the design of policies which are intended to shift the economy between multiple equilibria. The length and apparent irreversibility of division, which was probably key to its large impact on location patterns, points to the importance of commitment and credibility for policies designed to influence location patterns. In the presence of commitment, however, much less dramatic interventions temporary interventions into the economy than the division of Germany could also have the potential to permanently affect the pattern of economic activity.

A Data Appendix

The data on total departing passengers by airport from 1926-38 are from the Statistical Yearbook of Germany ("Statistisches Jahrbuch für das Deutsche Reich") of the German Statistical Office ("Statistisches Reichsamt"). The data on departing passengers by airport from 1950-89 are from the Statistical Yearbook of the Federal Republic of Germany published by the Federal Statistical Office of Germany ("Statistisches Bundesamt"), as are the data on departing passengers by airport from 1990-2002. Data on transit passengers and on bilateral departing passengers between German airports and over 350 other destinations worldwide are from "Fachserie 8 (Verkehr), Reihe 6.2 (Luftverkehr auf allen Flugplätzen)" of the Federal Statistical Office which is available at http://www.destatis.de/.

The data on the concentration of departing passengers in other European countries in 2002 is reported in "Worldwide Airport Traffic Report 2002" of the Airports Council International (ACI). The comparable data for 1937 were taken from the 1938 issue of the "Revue Aeronautique Internationale". Data on population, employment in industry and GDP in each German county ("Kreis") are from the publication "Bruttoinlandsprodukt, Bruttowertschöpfung in den kreisfreien Städten und Landkreisen Deutschlands 1992 und 1994 bis 2003 (Reihe 2 - Kreisergebnisse, Band 1)" of the "Arbeitskreises Volkswirtschaftliche Gesamtrechrechnungen der Länder", which is available at: http://www.statistik.baden-wuerttemberg.de/Arbeitskreis_VGR/

The ten main German airports included in our sample are: Berlin, Bremen, Cologne, Dusseldorf, Frankfurt, Hamburg, Hannover, Munich, Nurenberg, and Stuttgart. The five additional airports for which data were available in 2002 are: Dresden, Erfurt, Leipzig, Munster and Saarbrucken. Berlin was served by a single airport (Tempelhof) during the pre-war period, and there were two airports in West Berlin (Tempelhof and Tegel) and one airport in East Berlin (Schoenefeld) during division. We aggregate Tempelhof and Tegel during division, and aggregate all three Berlin airports during reunification. The three-letter airport codes are: BLN: Berlin; BRE: Bremen; CGN: Cologne; DUS: Dusseldorf; DRS: Dresden; ERF: Erfurt; FRA: Frankfurt; HAM: Hamburg; HAJ: Hannover; LEJ: Leipzig; FMO: Munster; MUC: Munich; NUE: Nurenburg; SCN: Saarbrucken; STR: Stuttgart.

B Theoretical Appendix

This appendix develops in further detail the general equilibrium structure which underlies the simple model of air travel and hub creation outlined in the main text.

B1. Endowments and Preferences

We assume that each location (or city) supplies a differentiated non-traded service that can only be consumed at the point of production. To focus on the demand for air travel, we assume that air travel is the only means of consuming non-traded services in other cities. For a resident of a city to consume one unit of the non-traded service produced by another city requires one return flight. Consumers also derive utility from a homogeneous numeraire good which is assumed to be freely traded between cities.[24]

The representative consumer's preferences are Cobb-Douglas in a consumption index of non-traded services and in the homogeneous numeraire good. The modelling of the demand for non-traded services follows Anderson and van Wincoop (2003). The non-traded services consumption index is assumed to take the standard Constant Elasticity of Substitution (CES) form so that:

$$U_j = \left(\sum_{i=1}^{N} \beta_{ij}^{\frac{1-\sigma}{\sigma}} c_{ij}^{\frac{\sigma-1}{\sigma}} \right)^{\left(\frac{\sigma}{\sigma-1}\right)\alpha} (q_j)^{1-\alpha}, \qquad 0 < \alpha < 1, \ \sigma > 1 \tag{10}$$

[24] This formulation sweeps all economic activity that is traded through routes other than air travel into the homogeneous numeraire good, and allows us to focus on the demand for and supply of air travel.

where $N = 3$ denotes the number of cities; α is the share of expenditure on non-traded services; σ is the elasticity of substitution between the varieties of non-traded services; β_{ij} is an inverse measure of the utility derived by consumers in city j from the non-traded services produced in city i; c_{ij} denotes the consumption of non-traded services produced in city i by residents of city j; q_j indicates the consumption of the homogeneous numeraire good.[25]

Cities are populated with a mass of L_i consumers who have identical preferences, have a fixed city of residence from which they may travel to consume non-traded services, and are endowed with one unit of labor that is supplied inelastically with zero disutility.

B2. Technology and Market Structure

The numeraire good is produced under conditions of perfect competition and according to a constant returns to scale technology: $y_i = l_i^y$, where y_i and l_i^y denote output and labor used in production of the numeraire. We choose units in which to measure the numeraire good so that the unit labor requirement is equal to one. Since the numeraire good is freely traded, its price is equal to one in all cities: $p_i^y = p^y = 1$. In addition, we focus on parameter values for which all cities produce the numeraire good, which pins down the equilibrium wage as equal to one: $w_i = w = 1$.[26]

Non-traded services are produced under conditions of perfect competition and according to a constant returns to scale technology:[27]

$$x_i \equiv \sum_{j=1}^{N} x_{ij} = l_i^x \tag{11}$$

where x_i corresponds to total production of non-traded services in city i, x_{ij} is the quantity of non-traded services produced in city i and sold to residents of city j, and l_i^x denotes total employment of labor in non-traded services in city i. We also choose units in which to measure non-traded services so that the unit labor requirement for this sector is equal to one.

[25] Throughout the analysis, the first subscript corresponds to the point of production and the second subscript to the point of consumption. We use i to indicate the city of production and j to indicate the city of residence of consumers.

[26] Incomplete specialization can be ensured by an appropriate choice of values for the preference parameters β_{ij} and labor endowments for each city.

[27] Therefore, non-traded services are differentiated by city of production (as in Armington 1969) but are homogeneous within cities. Allowing for differentiated varieties of non-traded services within cities is straightforward, but merely complicates the analysis without adding any additional insight.

The differentiation of non-traded services by city of origin ensures that all cities produce non-traded services. With the equilibrium wage equal to one, perfect competition and the production technology (11) imply that the equilibrium price of non-traded services is equal to one: $p_i^x = p^x = 1$. Since consuming one unit of a non-traded service from another city requires one return flight, the number of passenger journeys (a_{ij}) equals demand for non-traded services (c_{ij}), that is $a_{ij} = c_{ij}$ for $i \neq j$. As the source and destination cities are not necessarily symmetric, the total number of return flights between cities j and i is equal to $a_{ij} + a_{ji}$.

We consider a monopoly airline that has the choice whether to operate direct connections between cities or to operate indirect connections via a hub.[28] We assume that there is a fixed cost of $F > 0$ units of labor of operating each direct connection and then a marginal cost in terms of labor for each return passenger. In addition, we assume that there is a sunk cost of $H > 0$ units of labor of creating a hub. Since we focus on equilibria where specialization is incomplete, and so the wage in all cities is equal to one, the airline is indifferent as to where to source labor. The marginal cost is a function of the distance flown d_{ij}, $\psi(d_{ij})$, where distance flown depends on whether a direct or indirect connection is operated between cities j and i. With a direct connection, the airline flies the shortest feasible distance between cities i and j, δ_{ij}, and so $d_{ij} = \delta_{ij}$. With an indirect connection, the airline flies the shortest feasible distance from city i to the hub in city k plus the shortest feasible distance from city k to city j, and so $d_{ij} = \delta_{ik} + \delta_{kj} \geq \delta_{ij}$. The total labor required for a_{ij} passenger journeys from city i to city j is therefore:

$$l_{ij}^a = \begin{cases} a_{ij}\psi(\delta_{ij}) + F & \text{if the connection is direct} \\ \\ a_{ij}\psi(\delta_{ik} + \delta_{kj}) & \text{if the connection is indirect} \end{cases} \tag{12}$$

B3. Airline Equilibrium Prices and Profits

Consumers are price-takers and take into account the full cost of consuming non-traded services, which equals their price at the point of production plus the cost of air-travel. Expenditure minimization yields the standard CES demand for non-traded services. Therefore city j residents' demand for the non-traded services produced in city i, and hence city j residents'

[28] Introducing multiple air carriers in the model would increase the likelihood of multiple equilibria due to the network externalities that this introduces.

demand for air travel to city i, is:

$$c_{ij} = a_{ij} = \beta_{ij}^{1-\sigma} T_{ij}^{-\sigma} P_j^{\sigma-1} E_j^T \tag{13}$$

where β_{ij} is the inverse measure of the utility derived by consumers in city j from the non-traded services produced in city i; in order to capture the disutility of changing planes on indirect connections, we assume that β_{ij} is higher if a route is served by an indirect rather than a direct connection; $T_{ij} = p_i^x + p_{ij}^a$ is the composite cost of purchasing one unit of non-traded services at price p_i^x and one return air journey at price p_{ij}^a; $E_j^T = \alpha E_j = \alpha w L_j$ is expenditure on the composite good of non-traded services and air travel which equals a constant share of total expenditure which equals income; P_j is the CES price index summarizing the full cost of consuming non-traded services for residents in city j:

$$P_j = \left[\sum_{i=1}^{N} \left(\beta_{ij} T_{ij} \right)^{1-\sigma} \right]^{\frac{1}{1-\sigma}} \tag{14}$$

We assume that the airline is able to segment markets for travel between each pair of cities. Combined with our assumption of constant marginal cost, this implies that pricing is independent on travel between each pair of cities. Profit maximization yields the standard result that the equilibrium price of a return trip between two cities is proportional to marginal cost:

$$p_{ij}^a = \begin{cases} \left(\frac{\varepsilon(a_{ij})}{\varepsilon(a_{ij})-1} \right) \psi\left(\delta_{ij}\right) & \text{if the connection is direct} \\ \\ \left(\frac{\varepsilon(a_{ij})}{\varepsilon(a_{ij})-1} \right) \psi\left(\delta_{ik} + \delta_{kj}\right) & \text{if the connection is indirect} \end{cases} \tag{15}$$

where $\varepsilon\left(a_{ij}\right)$ denotes the elasticity of demand.

From the equilibrium pricing rule, variable profits from passenger journeys from city j to city i equal revenue divided by the elasticity of demand: $\rho_{ij} = \left(p_{ij}^a a_{ij} \right) / \varepsilon\left(a_{ij}\right)$. Variable profits for the route as a whole equal the sum of variable profits on passenger journeys in each direction: $\pi_{ij} = \rho_{ij} + \rho_{ji}$. Variable profits will be lower if a route is served by an indirect rather than a direct connection for two reasons. First, marginal cost is higher if a route is served by an indirect connections, which increases prices. Since demand is elastic, the higher prices decrease revenues and so diminish variable profits. Second, the disutility of changing planes on indirect connections (higher β_{ij}) reduces the demand for air travel, which decreases revenues and so again diminishes variable profits.[29]

[29] All our analysis requires is that variable profits are lower if a route in served by an indirect rather than a direct connection. This can be generated in a variety of ways. While we focus on the simplest possible framework

References

Amiti, Mary and Lisa Cameron (2006) "Economic Geography and Wages," *Review of Economics and Statistics*, forthcoming.

Anderson, James and Eric van Wincoop (2003) "Gravity with Gravitas: A Solution to the Border Puzzle," *American Economic Review*, 93(1), 170-192.

Armington, Paul S. (1969) "A Theory of Demand for Products Distinguished by Place of Production," *IMF Staff Papers*, 16, 170-201.

Baldwin, Richard E. (2001) "The Core-Periphery Model with Forward-Looking Expectations," *Regional Science and Urban Economics*, 31(1), 21-49.

Baldwin, Richard, Rikard Forslid, Philippe Martin, Gianmarco Ottaviano and Frederic Robert-Nicoud (2003) *Economic Geography and Public Policy*, Princeton: Princeton University Press.

Bosker, Maarten, Steven Brakman, Harry Garretsen and Marc Schramm (2005) "Looking for Multiple Equilibria when Geography Matters: German City Growth and the WWII Shock," University of Groningen, mimeograph.

Bosker, Maarten, Steven Brakman, Harry Garretsen and Marc Schramm (2006) "A Century of Shocks: The evolution of the German City Size Distribution 1925-1999," University of Groningen, mimeograph.

Brakman, Steven, Harry Garretsen and Marc Schramm (2004) "The Strategic Bombing of German Cities during WWII and its Impact on City Growth," *Journal of Economic Geography*, 4(2), 201-218.

Bresnahan, Timothy and Peter Reiss (1991) "Empirical Models of Discrete Games," *Journal of Econometrics*, 64, 57-81.

Brueckner, Jan (2002) "Airport Congestion When Carriers Have Market Power," *American Economic Review*, 92, 1357-1375.

to generate this result, a richer model would also be able to explain the empirically observed lower prices for indirect connections. While this would complicate the analysis, it would not change the basic property of the model that variable profits are lower if a route is served by an indirect rather than a direct connection.

Brueckner, Jan (2004) "Network Structure and Airline Scheduling," *Journal of Industrial Economics*, 52, 291-312.

Campbell, James F. (1996) "Special Issue on Hub Location," *Location Science*, 4, 125-212.

Cooper, Russell and Andrew John (1988) "Coordinating Coordination Failures in Keynesian Models," *Quarterly Journal of Economics*, 103(3), 441-463.

Cooper, Russell (2002) "Estimation and Identification of Structural Parameters in the Presence of Multiple Equilibira," NBER Working Paper No. 8941.

David, Paul A. (1985) "Clio and the Economics of QWERTY," *American Economic Review*, 75(2), 332-337.

Davis, Donald and David Weinstein (2002) "Bones, Bombs, and Break Points: The Geography of Economic Activity," *American Economic Review*, 92(5), 1269-1289.

Davis, Donald and David Weinstein (2003) "Market Access, Economic Geography and Comparative Advantage: An Empirical Assessment," *Journal of International Economics*, 59(1), 1-23.

Davis, Donald and David Weinstein (2004) "A Search for Multiple Equilibria in Urban Industrial Structure," NBER Working Paper No. 10252.

Drezner, Tammy and Drezner, Zvi (2001) "A Note on Applying the Gravity Rule to the Airline Hub Problem," *Journal of Regional Science*, 41(1), 67-73.

Fujita, Masahisa, Paul Krugman and Anthony Venables (1999) *The Spatial Economy: Cities, Regions and International Trade*, Cambridge: MIT Press.

Hanson, Gordon H. (1996) "Localization Economies, Vertical Organization, and Trade," *American Economic Review*, 86(5), 1266-1278.

Hanson, Gordon H. (2004) "The Home Market Effect and Bilateral Trade Patterns," *American Economic Review*, 94, 1108-1129.

Hanson, Gordon H. (2005) "Market Potential, Increasing Returns, and Geographic Concentration," *Journal of International Economics*, 67, 1-24.

Harris, Chauncy D. (1954) "The Market as a Factor in the Localization of Industry in the United States," *Annals of the Association of American Geographers*, 44(4), 315-348.

Head, Keith and Mayer, Thierry (2004a) "Empirics of Agglomeration and Trade," in Vernon Henderson and Jacques-François Thisse (eds.), *Handbook of Regional and Urban Economics*, Amsterdam: NorthHolland.

Head, Keith and Mayer, Thierry (2004b) "Market Potential and the Location of Japanese Investment in Europe," *Review of Economics and Statistics*, 86(4), 959-972.

Hendricks, Ken, Michele Piccone and Guofo Tan (1999) "Equilibria in Networks," *Econometrica*, 67(6), 1407-1434.

Hojman, Daniel and Szeidl, Adam (2005) "Core and Periphery in Endogenous Networks," University of California Berkeley, mimeograph.

Jovanovic, Boyan (1989) "Observable Implications of Models with Multiple Equilibria," *Econometrica*, 57(6), 1431-1437.

Krugman, Paul (1991a) "Increasing Returns and Economic Geography," *Journal of Political Economy*, 99(3), 483-499.

Krugman, Paul (1991b) "History Versus Expectations," *Quarterly Journal of Economics*, 106(2), 651-667.

Kutscher, Markus (1995) *Geschichte der Luftfahrt in Frankfurt am Main*, Frankfurt am Main: Umschau Buchverlag.

Loth, Wilfried (1988) *The Division of the World, 1941-1955*, London: Routledge.

Marshall, Alfred (1920) *Principles of Economics*, London: Macmillan.

Matsuyama, Kiminori (1991) "Increasing Returns, Industrialization, and Indeterminacy of Equilibrium," *Quarterly Journal of Economics*, 106, 617-650.

Miguel, Edward and Gérard Roland (2005) "The Long Run Impact of Bombing Vietnam," University of California Berkeley, mimeograph.

Miller, Roger E. (2000) *To Save a City: The Berlin Airlift, 1948-1949*, College Station (TX): Texas A&M University Press.

Moro, Andrea (2003) "The Effect of Statistical Discrimination on Black-White Wage Inequality: Estimating a Model with Multiple Equilibria," *International Economic Review*, 44(2), 467-500.

Murphy, Kevin M., Andrei Shleifer and Robert W. Vishny (1989) "Industrialization and the Big Push," *Journal of Political Economy*, 97(5), 1003-1026.

Overman, Henry G., Stephen Redding and Anthony Venables (2003) "The Economic Geography of Trade, Production and Income: A Survey of Empirics," in James Harrigan and E. Kwan Choi (eds.), *Handbook of International Trade*, Oxford: Blackwell.

Overman, Henry G. and Alan L. Winters (2006) "Trade Shocks and Industrial Location: The Impact of EEC accession on the UK," CEPR Discussion Paper No. 5574.

Redding, Stephen and Sturm, Daniel (2005) "The Costs of Remoteness: Evidence from German Division and Reunification," CEPR Discussion Paper No. 5015.

Redding, Stephen and Anthony Venables (2004) "Economic Geography and International Inequality," *Journal of International Economics*, 62(1), 53-82.

Sharp, Tony (1975) *The Wartime Alliance and the Zonal Division of Germany*, Oxford: Clarendon Press.

Silva, Santos J. M. C. and Silvana Tenreyro (2006) "The Log of Gravity," *Review of Economics and Statistics*, forthcoming.

Statistisches Bundesamt, "Statistisches Jahrbuch für die Bundesrepublik Deutschland," Wiesbaden, various years.

Statistisches Reichsamt, "Statistisches Jahrbuch des Deutschen Reiches," Berlin: Verlag für Sozialpolitik, Wirtschaft und Statistik, various years.

TABLE 1

Estimated Time Trends for Pre-war, Division and Reunification Periods

	1927-1938	1950-1989	1990-2002	1980-1989
Berlin	1.851***	-0.814***	-0.123***	-0.139***
	(0.267)	(0.067)	(0.018)	(0.024)
Bremen	-0.259***	0.022***	-0.001	0.004
	(0.062)	(0.003)	(0.004)	(0.005)
Cologne	-0.360***	0.064***	0.044**	-0.043**
	(0.086)	(0.013)	(0.021)	(0.020)
Dusseldorf	0.036	0.203***	-0.300***	-0.050
	(0.080)	(0.015)	(0.032)	(0.038)
Frankfurt	0.029	0.436***	0.037	0.034
	(0.098)	(0.036)	(0.048)	(0.031)
Hamburg	-0.078	-0.145***	-0.125***	-0.084***
	(0.068)	(0.014)	(0.006)	(0.017)
Hannover	-0.453***	-0.082***	0.031*	-0.071***
	(0.056)	(0.028)	(0.017)	(0.015)
Munich	-0.337***	0.195***	0.360***	0.320***
	(0.081)	(0.013)	(0.043)	(0.053)
Nurenberg	-0.274***	0.017***	0.048***	0.028***
	(0.058)	(0.002)	(0.005)	(0.005)
Stuttgart	-0.156***	0.096***	0.030**	0.001
	(0.056)	(0.009)	(0.014)	(0.010)
Airport-period intercepts	YES	YES	YES	YES
R-squard	0.98	0.98	0.98	0.99

Notes: Columns (1)-(3) report results from a single regression of airport departing passenger shares on separate intercepts and time trends for each airport and time period (1927-38, 1950-89 and 1992-2002). Columns (1)-(3) report the coefficients on the time trends. Column (4) is based on an augmented specification where the 1950-89 period is broken out into decades and separate intercepts and time trends are included for each airport in each decade. Column (4) reports the estimated coefficients on the time trends for 1980-89. The estimated coefficients on the time trends for 1927-38 and 1990-2002 in the augmented specification are the same as in Columns (1) and (3), but the standard errors are larger as a result of the increase in the number of parameters estimated. The sample includes 649 observations on 10 airports during 1927-38, 1950-89 and 1990-2002; the departing passenger data are missing for Cologne in 1950. The standard errors in parentheses are heteroscedasticity robust. Statistical significance: *** 1% level; ** 5% level; * 10% level.

TABLE 2

Estimated Differences in Time Trends

	(1)	(2)	(3)
Panel A: Division			
	Period 1926-1938	Period 1950-1989	Between-Period Difference
Berlin	1.851***	-0.814***	2.665***
	(0.267)	(0.067)	(0.275)
Frankfurt	0.029	0.436***	-0.407***
	(0.098)	(0.036)	(0.104)
Within-Period Difference	1.823***	-1.250***	**3.072*****
	(0.284)	(0.075)	**(0.294)**
Panel B: Reunification			
	Period 1980 - 1989	Period 1990-2002	Between-Period Difference
Berlin	-0.139***	-0.123***	-0.016
	(0.024)	(0.018)	(0.031)
Frankfurt	0.034	0.037	-0.003
	(0.031)	(0.050)	(0.059)
Within-Period Difference	-0.172***	-0.160***	**-0.012**
	(0.039)	(0.053)	**(0.066)**

Notes: Regressions include separate intercepts and time trends for each airport and time period. The bottom right cell of each panel contains the difference-in-differences estimate. Robust standard errors in parenthesis.

TABLE 3

The Largest Airports of European Countries in 1937 and 2002

	(1) Largest Airport in 1937	(2) Market share of largest airport in 1937	(3) Market share of largest airport in 2002	(4) Rank of largest airport 1937 in 2002
Austria	Vienna	94.1	76.5	1
Belgium	Brussels	65.6	89.9	1
Denmark	Kopenhagen	96.2	91.7	1
Finland	Helsinki	80.3	73.7	1
France	Paris	70.2	61.4	1
Germany	Berlin	30.8	35.0	4
Greece	Athens	43.9	34.7	1
Ireland	Dublin	100.0	78.1	1
Italy	Rome	35.7	34.5	1
Netherlands	Amsterdam	62.3	96.4	1
Norway	Oslo	75.6	45.8	1
Portugal	Lisbon	100.0	46.3	1
Spain	Madrid	43.5	26.8	1
Sweden	Stockholm	56.9	61.9	1
Switzerland	Zurich	55.7	62.0	1
United Kingdom	London	52.7	65.6	1

Notes: The countries are the EU 15 countries without Luxembourg (which had no airport prior to the Second World War and has only one airport in 2002) and Norway and Switzerland. The prewar data for Austria refer to the year 1938. The prewar data for Spain are the average over 1931 to 1933. See the data appendix for detailed references to the sources.

TABLE 4

Determinants of Bilateral Passenger Departures

	(1) log Bilateral Passenger Departures	(2) log Bilateral Passenger Departures	(3) log Bilateral Passenger Departures
log Distance	-1.651*** (0.343)	-1.706*** (0.351)	-1.728 (1.120)
Source Airport Fixed Effects	YES	YES	YES
Destination Fixed Effects	YES	YES	YES
Sample	Destinations >300km	Destinations > 300 km, excld. Frankfurt & Munich	Destinations > 300 km, served by all airports
Observations	5130	4446	330
R-squared	0.680	0.670	0.719

Notes: left-hand side variable is one plus bilateral passenger departures. Baseline sample in Column (1) comprises foreign destinations that are more than 300 kilometres away from any German airport. The German airports are: Bremen, Berlin, Cologne, Erfurt, Dresden, Dusseldorf, Frankfurt, Hamburg, Hannover, Leipzig, Munich, Munster, Nurenburg, Saarbrucken and Stuttgart. Estimation using Ordinary Least Squares. Standard errors in parentheses are heteroscedasticity robust. *** denotes statistical significance at the 1 percent level.

TABLE 5

The Economic Characteristics of the Locations of Germany's Major Airports in 2002

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Population	Population (Frankfurt=100)	Employment in Industry (Frankfurt=100)	Gross Domestic Product (Frankfurt=100)	Contiguous Population (Frankfurt=100)	Contiguous Employment in Industry (Frankfurt=100)	Contiguous Gross Domestic Product (Frankfurt=100)
Berlin	3,390,290	527.5	321.5	165.5	197.8	137.3	104.6
Hamburg	1,727,445	268.8	221.5	163.0	124.1	104.2	107.0
Munich	1,231,916	191.7	233.6	140.3	74.3	86.5	96.5
Cologne	968,775	150.7	133.6	85.0	148.3	138.3	111.8
Frankfurt	642,680	100.0	100.0	100.0	100.0	100.0	100.0
Stuttgart	588,030	91.5	150.1	69.8	95.2	156.1	86.0
Dusseldorf	571,473	88.9	94.7	77.5	90.9	98.5	81.8
Bremen	541,955	84.3	99.3	42.9	46.8	48.2	32.8
Hannover	517,310	80.5	81.6	43.5	100.0	86.8	58.7
Leipzig	493,627	76.8	59.3	23.6	36.2	31.2	17.3
Nurenberg	492,356	76.6	101.0	44.0	51.2	68.1	41.8
Dresden	479,073	74.5	72.6	26.9	42.1	45.7	21.4
Saarbrucken	349,497	54.4	62.5	22.3	34.5	43.4	21.9
Munster	267,872	41.7	33.7	20.9	69.0	74.4	41.1
Erfurt	199,952	31.1	31.1	11.8	28.0	29.6	13.6

Notes: population, employment in industry and gross domestic product are for the cities ("Stadtkreise") where German airports are located. Contiguous population, employment in industry and gross domestic product include the city's own data and the data from all counties ("Kreise") that share a border with the city. There are 439 German counties that have an average area of around 800 square kilometres in 2002. See the data appendix for detailed references to the sources.

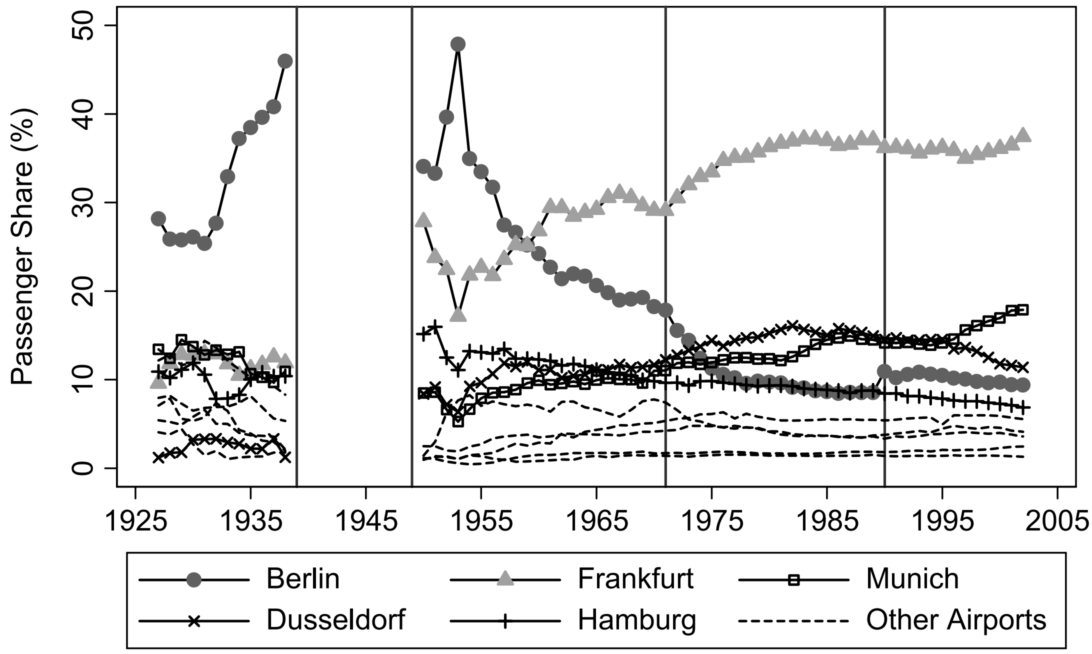
TABLE 6

Total Departing Passengers and Transit Passengers in 2002

	(1) Total Departing Passengers (Thousands)	(2) Airport Share in Departing Passengers (%)	(3) Airport Share in Transit Passengers (%)	(5) Transit Share of Departing Passengers (%)
Berlin	6,016.4	9.0	0.4	0.9
Hamburg	4,402.7	6.6	0.5	1.9
Munich	11,462.0	17.2	20.5	27.7
Cologne	2,640.3	4.0	0.2	1.3
Frankfurt	23,984.2	35.9	75.5	48.8
Stuttgart	3,552.6	5.3	0.5	2.1
Dusseldorf	7,300.6	10.9	1.1	2.3
Bremen	829.5	1.2	0.0	0.6
Hannover	2,298.0	3.4	0.1	0.5
Leipzig	933.0	1.4	0.1	1.0
Nurenberg	1,574.0	2.4	1.2	11.5
Dresden	729.1	1.1	0.1	1.1
Saarbrucken	203.0	0.3	0.0	0.2
Munster	704.0	1.1	0.0	0.3
Erfurt	208.4	0.3	0.0	0.1

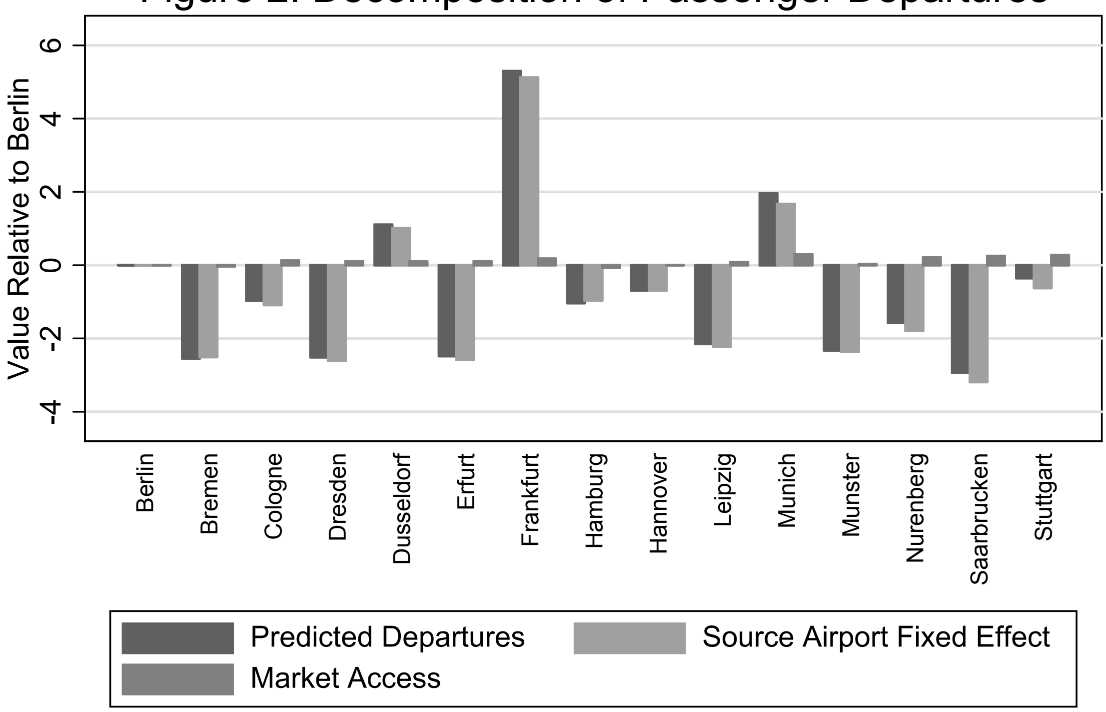
Notes: See the data appendix for detailed references to the sources.

Figure 1: Airport Passenger Shares



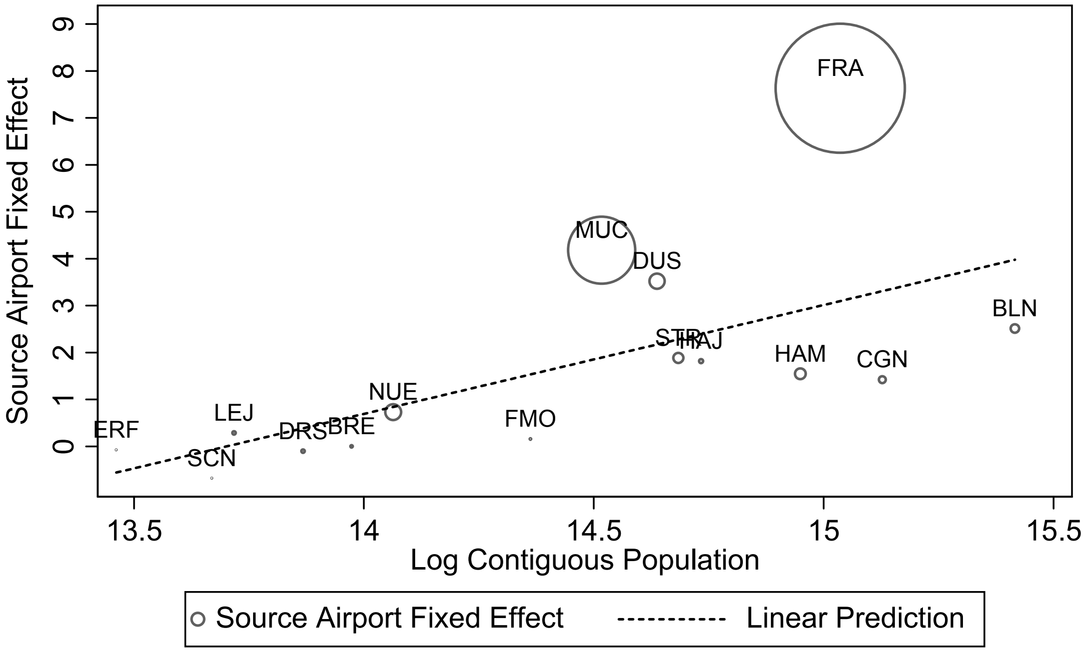
Note: share of airports in departing passengers at the ten main German airports

Figure 2: Decomposition of Passenger Departures



Note: values relative to Berlin. The first bar equals the sum of the second and third bars.

Figure 3: Airport Fixed Effects, Population and Transits



Note: see appendix for airport codes; size of circle proportional to number of transit passengers.