HISTORY AND INDUSTRY LOCATION: EVIDENCE FROM GERMAN AIRPORTS

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Abstract—A central prediction of a large class of theoretical models is that industry location is not uniquely determined by fundamentals. Despite the theoretical prominence of this idea, there is little systematic evidence in support of its empirical relevance. This paper exploits the division of Germany after World War II and the reunification of East and West Germany as an exogenous shock to industry location. Focusing on a particular economic activity, an air hub, we develop a body of evidence that the relocation of Germany's air hub from Berlin to Frankfurt in response to division is a shift between multiple steady states.

I. Introduction

A central prediction of a large class of theoretical models is that industry location is not necessarily uniquely determined by fundamentals. While this idea dates back to at least Marshall (1920), it has recently returned to prominence in the theoretical literature on new economic geography that has emerged following Krugman (1991a).[1] These models predict ranges of parameter values where there are several steady state spatial distributions of economic activity. Which of these steady states is selected depends on either initial conditions and the history of shocks or agents' expectations.[2] As a result, in this class of models, small and temporary shocks can have large and permanent effects by shifting the economy from one steady state to another. This contrasts with the view that fundamentals such as institutions and endowments are the primary determinants of location choices. In such a world, there is a unique steady state distribution of economic activity, which the economy gravitates back to after temporary shocks.

[1] See Fujita, Krugman, and Venables (1999) and Baldwin et al. (2003) for syntheses of the theoretical literature and Overman, Redding, and Venables (2003) and Head and Mayer (2004a) for surveys of the empirical literature. Recent contributions to the empirical literature include Amiti and Cameron (2007), Davis and Weinstein (2003), Ellison and Glaeser (1997), Hanson (2004, 2005), Head and Mayer (2004b), Redding and Venables (2004), and Redding and Sturm (2008).

[2] The role of initial conditions and historical accident in selecting between steady states is also referred to as path dependence or hysteresis (see, for example, Arthur 1994; Baldwin & Krugman, 1989; and David, 1985), while the role of expectations in selecting between steady states is sometimes described in terms of coordination failures (see, for example, Cooper & John, 1988; Murphy, Shleifer, & Vishny 1989; Shleifer, 1986). See also Krugman (1991b) and Matsuyama (1991).

Although there is some anecdotal evidence that industry location is not uniquely determined by fundamentals, as discussed, for example, in Krugman (1991c), there is a surprising lack of systematic empirical evidence in favor of multiple steady state distributions of economic activity. On the contrary, in a seminal paper, Davis and Weinstein (2002) examine the Allied bombing of Japanese cities as a large and temporary shock that varied substantially across locations. Surprisingly, they find that city populations recovered very quickly from the wartime shock, and cities returned to their prewar growth path within fewer than twenty years. If even the vast wartime devastation of cities observed in Japan could not move the economy between multiple spatial configurations of economic activity, this appears to suggest an overwhelming role for fundamentals in determining the location of economic activity.

In this paper, we provide new evidence on this question by using the combination of the division of Germany after World War II and the reunification of East and West Germany in 1990 as a source of exogenous variation. This natural experiment has a number of attractive features. German division, which was driven by military and strategic considerations during World War II and its immediate aftermath, provided a large exogenous shock to the relative attractiveness of locations. Division lasted for over forty years and was widely expected to be permanent, which makes it likely that it had a profound influence on location choices. The reunification of East and West Germany in 1990 and the broader opening of the Iron Curtain provided a second shock to the relative attractiveness of locations, which partially reversed the impact of division. We use this combination of shocks to examine whether division resulted in a permanent shift in the location of economic activity from one steady state to another.

We focus on a particular industrial activity, an airport hub, which has a number of advantages. First, there are substantial sunk costs in creating an airport hub. These make the location of the hub particularly likely to be prone to multiple steady states, in the sense that once the sunk costs of creating the hub have been incurred, there is no incentive to relocate. Second, the existence of multiple steady state locations may be reinforced by network externalities, which imply that the profitability of operating a connection to an airport is likely to be increasing in the number of other connections to that airport. Third, a wealth of historical and contemporary data is available on airports and passenger flows.

To guide our empirical work, we develop a simple 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 economic fundamentals is not too large relative to the sunk costs, the model exhibits multiple steady states.

Our basic empirical 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 prewar and division periods. In 1937 Berlin and Frankfurt accounted for 40.8% and 12.6% of the passenger traffic at the ten largest German airports, while in 1988, they accounted for 8.5% and 37.1% of the traffic at these ten airports respectively. Since reunification, Berlin's share of overall passenger traffic has exhibited 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, but there is no statistically significant treatment effect of reunification.

While this evidence is suggestive of multiple steady state locations, an alternative explanation could be that changes in economic fundamentals are responsible for the relocation of Germany's air hub from Berlin to Frankfurt. To strengthen the conclusion that the move of Germany's air hub was indeed a move between multiple steady states, we provide several additional pieces of evidence. We first compare the experience of Germany to that of other European countries. With the exception of Germany, the location of a country's largest airport shows remarkable stability between the period prior to World War II and today. In all European countries but Germany, the largest airport in 1937 is also today's largest airport and is located in the country's largest city. The relocation of Germany's hub is therefore unusual and is not part of a wider pattern of secular changes in air hub locations.

We then examine the reasons for Frankfurt's selection as the new location for Germany's air hub after division. From the remarkable similarity in prewar shares of air traffic between Frankfurt, Cologne, Hamburg, and Munich, it is difficult to predict that Frankfurt rather than one of these other airports would rise to replace Berlin as Germany's leading airport after division. To the extent that differences in fundamentals are reflected in differences in passenger departures, this suggests that Frankfurt did not enjoy superior fundamentals to these other potential locations prior to division. Instead, Frankfurt's postwar rise appears to owe much to a series of relatively small shocks in the immediate postwar period, such as the decision of the U.S. military to use Frankfurt as its main European air transportation terminal.

We next use rich contemporary data to estimate the role of the key economic fundamentals emphasized by the model—proximity to other destinations and local economic activity—and examine their importance in explaining Frankfurt's current dominance of German passenger traffic. To examine the role of proximity to other destinations, we estimate a gravity equation for bilateral passenger departures.

Using a range of different measures of bilateral distance, we find that variation in proximity to destinations across German airports is small and explains little of the variation in departing passengers. To examine the role of local economic activity, we use a decomposition of passenger departures into local passengers originating within 50 kilometers of an airport and several types of transit passengers. We show that while local passenger departures are closely related to local economic activity, Frankfurt's dominance today is entirely accounted for by its role as a transit hub. Furthermore, Frankfurt does not appear to be the most attractive location in terms of local economic activity compared to a number of other locations in the Rhine-Ruhr region of northwest Germany, including Cologne and Dusseldorf.

Finally, although differences in market access and local economic activity across German airports appear to be small relative to differences in total passenger departures, small differences in fundamentals could in principle have a large impact on the relative profitability of alternative locations for the air hub. To rule out this possibility, we use our estimates of the impact of market access and local economic activity to provide a simple quantification of the differences in profitability across alternative potential locations for Germany's air hub. We find that the implied differences in the net present value of profits across locations are small relative to plausible estimates of the sunk costs of creating the hub. Taken together, these results further strengthen the conclusion that Berlin and several other locations in Germany are potential steady state locations for Germany's air hub, in the sense that once the sunk costs of creating the hub have been incurred, there is no incentive to relocate it.

Despite the theoretical prominence of the idea that industry location is not uniquely determined by fundamentals, the empirical literature on this question is relatively small. Following Davis and Weinstein (2002), a number of papers have examined the impact of bombing on the spatial distribution of economic activity. Davis and Weinstein (2008) show that not only the population of Japanese cities but also the location of specific industries quickly returned to their prewar pattern. Brakman, Garretsen, and Schramm (2004) find that the populations of West German cities recovered rapidly from the devastation caused by World War II. Similarly, Miguel and Roland (2011) find that even the extensive bombing campaign in Vietnam did not have a permanent impact on the distribution of population and basic measures of economic development across the regions of Vietnam. Two exceptions are Bosker et al. (2007, 2008), who find some evidence of a permanent change in the distribution of population across West German cities after World War II.

While war-related destruction is an ingenious source for a large and temporary shock, a potential concern is that this shock may not be sufficient to change location decisions, which are forward looking and involve substantial sunk costs. In addition, the continued existence of road networks and partially surviving commercial and residential structures may serve as focal points around which reconstruction occurs.

Institutional constraints such as property rights and land use regulations may provide further reasons that existing concentrations of population and industrial activity reemerge. Finally, even if one observes changes in the location of population, as in Bosker et al. (2007, 2008), it remains unclear whether these are due to secular changes in fundamentals or a move between multiple steady states.

The remainder of the paper is organized as follows. Section II discusses the historical background to German division and reunification. Section III outlines a simple model of air transportation, which is developed in further detail in a Web-based technical appendix available at http://www.mitpressjournals.org/doi/suppl/10.1162/REST_a_0009. Section IV discusses our data and empirical approach. Section V presents our basic finding that division permanently relocated the German air hub from Berlin to Frankfurt, while reunification had no visible effect. Section VI develops a body of evidence that the relocation of the air hub is indeed a movement between multiple steady states. Section VII concludes.

II.   Historical Background

In the wake of World War II and 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 center of prewar Germany, cutting the country into two areas of roughly equal size.[3] 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 U.S., 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 to its status as the capital of prewar Germany, Berlin was jointly occupied by U.S., 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, comprising the U.S., British, and French sectors, and East Berlin, comprising the Soviet sector (see Sharp, 1975). Although 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 reached only 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.

While division was widely believed to be permanent, the Soviet policies of Glasnost and Perestroika, introduced by Mikhail Gorbachev in 1985, started a process of opening up Eastern Europe.[4] As part of this wider transformation, large-scale demonstrations in East Germany led to the fall of the Berlin Wall on November 9, 1989. In the aftermath of these events, the East German system rapidly began to disintegrate. Only eleven months later, on October 3, 1990, East and West Germany were formally reunified. 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 integration between Eastern and Western Europe has continued with the signing of the Europe Agreements in the early 1990s, which culminated in the recent accession of a group of Eastern European countries to the European Union.

III.   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 Web-based technical appendix.[5] The model formalizes the conditions under which air hubs form and the circumstances under which there are multiple steady state locations of the hub. We use the model to examine the impact of Germany's division and the reunification of East and West Germany on the location of the air hub.

A.   Air Travel and Hub Creation

We consider a model with three locations or cities, which is the simplest geographical structure in which a hub and spoke network can form.[6] If a hub forms, it will have direct connections to the other two cities, and travel between these other two cities will occur through an indirect connection via the hub. A monopoly airline chooses whether to operate

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[3] The areas that became West Germany accounted for about 53% of the area and about 58% of the 1939 population of prewar Germany.

[4] After the signing of the Basic Treaty (Grundlagenvertrag) in December 1972, which recognized "two German states in one German Nation," East and West Germany were accepted as full members of the United Nations. West German opinion polls in the 1980s show that less than 10% of the respondents expected a reunification to occur during their lifetime (Herdegen & Schultz, 1993).

[5] Our model builds on the literature on the airline industry and hub formation in networks more broadly. See, for example, Brueckner (2002, 2004), Campbell (1996), Drezner and Drezner (2001), Hendricks, Piccone, and Tan (1999), and Hojman and Szeidl (2008).

[6] This structure excludes the possibility of multiple air hubs. While the model could be extended to allow for multiple air hubs, we abstract from the additional complications that this would introduce. The empirical evidence we present suggests that the assumption of a single air hub is a reasonable approximation to the current and historical structure of air travel in Germany.

direct connections among all three cities or to create a hub.[7] The airline faces a downward-sloping demand curve for air travel between each pair of cities derived from the demand for consuming nontraded services from other cities. 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 a sunk cost of $H > 0$ units of labor of creating a hub. The hub itself can be located in any one of the three cities.

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, 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

$$\omega_i = F - \left(\pi_{kj}^D - \pi_{kj}^I\right), \qquad (1)$$

where π_{kj}^D and π_{kj}^I 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.[8]

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: $\pi_{kj}^D - \pi_{kj}^I \geq 0$. The reason is the higher marginal costs on indirect connections, together with the reduction in the demand for air travel due to any disutility of changing planes on indirect connections, which reduce the variable profits on indirect connections relative to those on 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: those between populous cities, cities with a central location, and cities whose nontraded 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 is greater.

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 steady state locations of the hub 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:

$$\Omega_i > H \quad \text{and} \quad \Omega_j - \Omega_i < H \quad \text{for all } j \neq i. \qquad (2)$$

In contrast, city i is the unique steady state location of the hub if creating the hub in city i is profitable, and if the hub was located in any other city j, there is an incentive to relocate to city i:

$$\Omega_i > H \quad \text{and} \quad \Omega_i - \Omega_j > H \quad \text{for all } j \neq i. \qquad (3)$$

Therefore, the existence of multiple steady states depends on the variability in cities' profitability as the location for 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 steady state location of the hub except in the knife-edge case when cities are symmetric. However, if the sunk cost of creating the hub is larger than the difference in profitability between alternative possible locations for the hub, there are multiple steady states. When multiple steady states exist, initial conditions determine which is selected. Thus, if both cities A and B satisfy equation (2), city A will be the steady state location if the hub is initially located in city A, and city B will be the steady state location if the hub is initially located in city B.

B. German Division and Reunification

Prior to German division, we suppose that the hub is initially located in city 1, which corresponds in the data to Berlin. The exogenous shock of division will shift the location of the hub between multiple steady states if two conditions are satisfied. First, the negative shock of division to the profitability of Berlin as a location for the hub, denoted S, is sufficiently large that the increase in profits from relocating the hub to city 2 is greater than the sunk cost, where city 2 corresponds in the data to Frankfurt. Given the magnitude of the shock

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[7] While the model assumes for simplicity a single airline, it could be extended to incorporate multiple airlines. The resulting richer model would capture network externalities and competition effects as additional agglomeration and dispersion forces, but multiple steady state locations of the air hub would continue to exist for a range of parameter values.

[8] In the model, we assume that the decision to create the hub is determined by profitability. While German airports are incorporated as private for-profit companies, they are subject to federal and state government regulation (for example, on air and noise pollution and zoning restrictions) and are also partly owned by state and local governments. However, there is no national strategic plan in Germany that dictates the location of the country's air hub, and economic profitability relative to the sunk costs of construction is a major factor in the cost-benefit analysis undertaken for airport construction. We capture this idea in a simple way in the model by supposing that regulations are the same across locations and the monopoly airline decides on air hub location based on a comparison of economic profitability with the sunk costs of construction.

of German division, this first condition is clearly satisfied.[9] Second, reunification sufficiently reverses the negative shock of division to a level S' such that both Berlin and Frankfurt are again possible steady state locations for the hub. These conditions are

$$\Omega_2 - (\Omega_1 - S) > H \quad \text{and} \quad |\Omega_2 - (\Omega_1 - S')| < H. \quad (4)$$

Note that we do not require the profitability of Berlin to completely return to its level prior to division. All we require is that reunification sufficiently increases Berlin's profitability so that both Berlin and Frankfurt are again potential steady state locations for the hub, in the sense that the difference in profitability between the two locations is again small relative to the sunk costs of creating the hub. Finally, while we concentrate on city 1 and city 2 in the discussion above, both cities 2 and 3 could be potential steady state locations for the hub after division.

The two conditions in equation (4) illustrate the difficulties in finding a suitable experiment to provide empirical evidence for multiple steady state distributions of economic activity. On the one hand, large sunk costs increase the range of parameter values for which multiple steady states occur. On the other hand, large sunk costs increase the size of the shock required to shift the economy between multiple steady states.

IV.   Data and Empirical Strategy

A.   Data Description

One of the attractive features of airports is that, in contrast to other economic activities that are likely to be prone to multiple steady state locations, detailed current and historical data are available. Our basic data set is a panel on departing passengers from the ten main German airports during the prewar, division, and reunification periods. For the prewar period, data are available from 1927 to 1938. For the period after World War II, we have data from 1950, the earliest year for which information is available, until 2002.[10]

We combine our basic data set with information from a variety of other sources. To compare the experience of Germany with that of other European countries that 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 examine the determinants of the relative size of airports, we exploit data for 2002 on bilateral departing passengers between German airports and the universe of worldwide destinations flown to from these airports. These data are available for an additional five German airports.[11] The location of all fifteen airports within the boundaries of present-day Germany is shown in figure 1. We combine the bilateral departures data with information on the latitude and longitude coordinates of each airport and worldwide destination, which we use to construct bilateral great circle distances. We also use data on bilateral migration between each German state (*Land*) and other countries to construct a measure of social networks, and we use data on the location of foreign subsidiaries of German companies to construct a measure of business networks.

To explore the importance of local economic activity for the relative attractiveness of different cities as locations for Germany's air hub, we have assembled for 2002 several measures of total population and gross domestic product (GDP) proximate to each airport. Finally, to examine the importance of hub status for the size of airports, we have obtained a breakdown of total passenger departures at the main German airports into local and various types of transit traffic. Detailed references to the data sources are in the data appendix.

B.   Baseline Econometric Specification

Our baseline econometric equation allows changes in trends and intercepts of airport passenger shares for each airport during the prewar, division, and reunification periods,

$$share_{at} = \sum_{a=1}^{A} \eta_{ap} + \sum_{a=1}^{A} \beta_{ap} \text{time}_t + u_{at}, \quad (5)$$

where a indexes airports, t denotes years, and p indicates periods (prewar, 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 changes in mean passenger shares for each airport in the prewar, division, and reunification periods. The coefficients β_{ap} allow trends in passenger shares for each airport to vary by the prewar, division, and reunification periods; u_{at} is a stochastic error.

In equation (5), we allow both mean levels and trend rates of growth of passenger shares to vary across airports and periods because it may take time for a new hub to emerge in response to an exogenous shock. A change in the location of the hub therefore will be visible first in a change in an airport's trend rate of passenger growth before a significant difference in mean passenger levels emerges. This is particularly important for the reunification period, where we have

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[9] The negative shock S captures a number of factors that made Berlin unattractive as a location for West Germany's air hub during division, which include its remote location around 200 kilometers east of the border between East and West Germany, the isolation of West Berlin from East Berlin and its surrounding economic hinterland, Berlin's formal status as an occupied city until 1990, and the prohibition on German airlines flying between West Germany and West Berlin as a result of air travel to West Berlin being restricted to airlines from the occupying powers of Britain, France, and the United States.

[10] The ten main German airports are Berlin, Bremen, Cologne, Dusseldorf, Frankfurt, Hamburg, Hanover, Munich, Nuremberg, and Stuttgart. Berlin was served by a single airport (Tempelhof) during the prewar 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.

[11] The five additional airports for which bilateral departures data were available in 2002 are Dresden, Erfurt, Leipzig, Munster, and Saarbrucken.

FIGURE 1.—THE LOCATION OF THE GERMAN AIRPORTS IN OUR SAMPLE
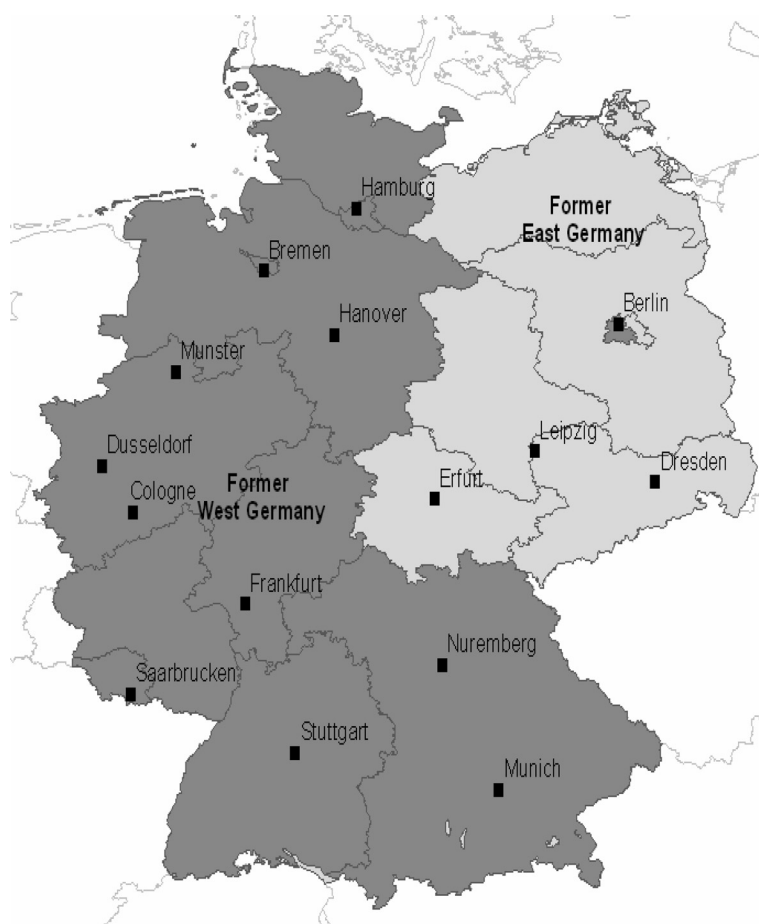
a relatively short period of time over which to observe the impact of the exogenous shock. For this reason, we concentrate on statistical tests based on changes in airports' trend rates of passenger growth.[12]

V.   Basic Empirical Results

A.   Evolution of Airport Passenger Shares

Before we estimate our basic specification, figure 2 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 World War II, Berlin had the largest airport in Germany by a substantial margin and was in fact the largest airport in Europe in 1937 in the historical data used in section VIA. By 1927, when the data shown in figure 2 start, Berlin had more than twice as large a market share as the next largest German airport. From 1931 onward, a period of rapid growth in air traffic at all German airports, Berlin's market share steadily increased and reached a peak of over 40% in 1938. The four

airports ranked after Berlin are Frankfurt, Munich, Hamburg, and Cologne. These airports had very similar market shares, which remained remarkably stable at around 10% throughout the prewar period.

The dominance of Berlin in German air traffic changed dramatically after the division of Germany. While Berlin was still the largest airport in Germany in terms of total departures in 1950, when data became available again, Frankfurt was already the second largest airport, substantially ahead of Hamburg and Munich. Over the next decade, Berlin steadily declined in importance, and by 1960 Frankfurt overtook Berlin as the largest German airport.[13] A further acceleration in the decline of Berlin's share occurred immediately after 1971, when the Transit Agreement between East and West Germany substantially improved road and rail connections between West Berlin and West Germany. By the

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[12] Reestimating equation (5) allowing only changes in intercepts between the prewar, division, and reunification periods yields a similar pattern of results.

[13] The spike in departures in 1953 in Berlin is mainly due to a wave of refugees leaving East Germany via West Berlin after the violent uprisings 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% of total departures in Berlin in this year. Between 1954 and 1960, this stream of East German refugees departing from West Berlin by plane continued at a rate of approximately 95,000 people per year, which accounted for on average 16% of departures in Berlin. It ceased with the building of the Berlin Wall in 1961.

FIGURE 2.—AIRPORT PASSENGER SHARES

DEPARTING PASSENGERS AT THE TEN MAIN GERMAN AIRPORTS
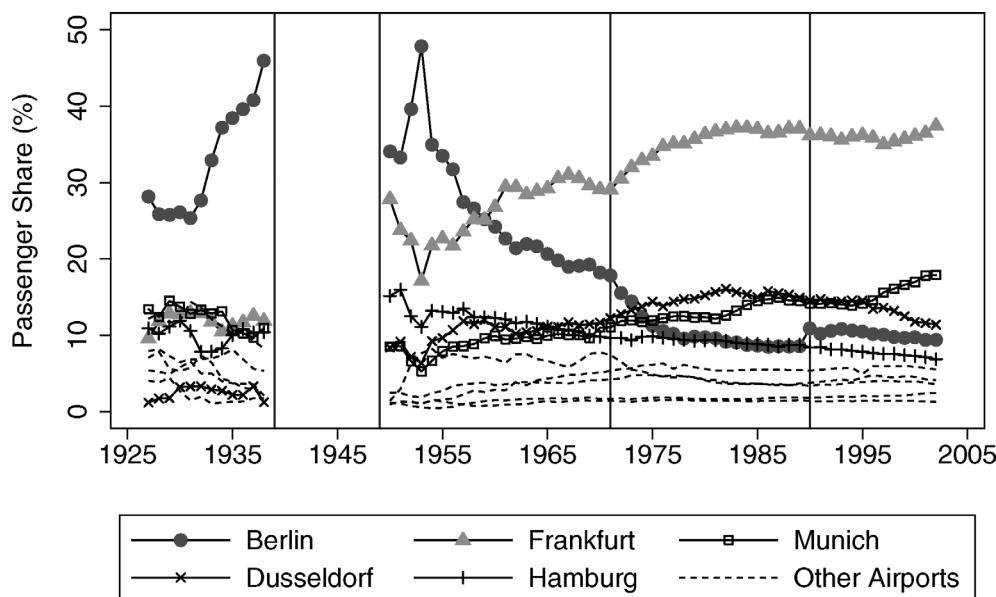
1980s, Frankfurt and Berlin had almost exactly changed roles. Frankfurt in the 1980s had a stable market share between 35% and 40%, while Berlin's market share was just below 10%.

In contrast to the striking change in the pattern of air traffic following division, there was hardly any visible impact of reunification. The small step increase in Berlin's share of passenger traffic in 1990 is due to the fact that we aggregate departures from Tempelhof and Tegel (in West Berlin) and Schoenefeld (in East Berlin) from this year onward. Apart from this small step increase, the trend in Berlin's share of passenger traffic has been slightly negative since reunification. At the same time, Frankfurt clearly remains Germany's leading airport. Its share of passenger traffic has remained virtually flat since reunification, if anything increasing marginally.[14]

Although there is no evidence so far of a return toward prewar patterns of passenger traffic, is there any expectation of a future relocation of Germany's air hub to Berlin? Berlin plans to open a new airport around 2012, which will replace the current system of three airports that together have an annual capacity of about 7.5 million departing passengers. The new airport is designed to have a starting capacity of approximately 10 million departing passengers. Around 2015, Frankfurt airport plans to open a third passenger terminal, which will increase the airport's capacity from its current 28 million departing passengers a year by approximately

another 12.5 million passengers.[15] Therefore, over the coming years, Frankfurt plans to increase its capacity by an even larger amount than Berlin's overall capacity, which illustrates that there is little expectation of a return of Germany's air hub to Berlin.

B. Difference-in-Differences Estimates

To examine the statistical significance of the changes shown in figure 2, table 1 reports results for our baseline specification, equation (5). The coefficients on the time trends in each airport in each period capture mean annual rates of growth of passenger shares. The final column of panel A of table 2 compares the time trends between the prewar and division periods for Berlin and Frankfurt (a difference within airports across periods) and shows that Berlin's mean rate of growth of passenger shares declined by 2.7 percentage points per annum, while Frankfurt's rose by 0.4 percentage points per annum. Both changes are highly statistically significant.[16]

We next consider the statistical significance of the difference in time trends between Berlin and Frankfurt within the prewar 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

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[14] We see a similar pattern in freight departures. Following division, Frankfurt replaced Berlin as Germany's leading airport for freight, and there was again no visible impact of reunification. Berlin's average share in total freight departures fell from 36.5% to 0.7% between the ten years leading up to 1938 and the ten years leading up to 2002. Over the same period, Frankfurt's average share increased from 11.2% to 70.6%.

[15] These numbers are taken from http://www.berlin-airport.de and http://www.ausbau.flughafen-frankfurt.de. While we report capacity as the number of departing passengers, airports often report their capacity as the sum of arriving and departing passengers, which is simply twice the capacity for departing passengers.

[16] As is evident from figure 2, the within-airport change in time trends for Frankfurt understates its rise between the prewar and division periods, since some of the rise in Frankfurt's postwar share of passenger traffic had already occurred prior to 1950 when data become available (and is therefore captured in Frankfurt's intercept for the division period).

TABLE 1.—ESTIMATED TIME TRENDS FOR THE PREWAR, DIVISION, AND REUNIFICATION PERIODS

Period	(1) 1927–1938	(2) 1950–1989	(3) 1990–2002	(4) 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)
Hanover	−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)
Nuremberg	−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^2	0.98	0.98	0.98	0.99

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 (1927–1938, 1950–1989, and 1990–2002). Columns 1–3 report the coefficients on the time trends. Column 4 is based on an augmented specification where the 1950–1989 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 1980–1989. The estimated coefficients on the time trends for 1927–1938 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 ten airports during 1927–1938, 1950–1989 and 1990–2002; the departing passenger data are missing for Cologne in 1950. The standard errors in parentheses are heteroskedasticity robust. Statistical significance: *** 1% level; ** 5% level; * 10% level.

TABLE 2.—ESTIMATED DIFFERENCES IN TIME TRENDS

	(1)	(2)	(3)
	A: Division		
	Period 1927–1938	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)
	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)

The coefficients and standard errors for the estimated time trends for Berlin and Frankfurt are from the regressions reported in table 1. The bottom right cell of each panel contains the difference-in-differences of the estimated time trends. Heteroskedasticity robust standard errors are in parentheses. Statistical significance: *** 1% level; ** 5% level; * 10% level.

rate of growth of passenger shares was in excess of 1 percentage point per annum and was highly statistically significant. Finally, we consider the difference-in-differences by comparing the change in Berlin's time trend between the prewar 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 was over 3 percentage points per annum and was again highly statistically significant (p-value < 0.001).

We now turn to examine the treatment effect of reunification. Figure 2 suggests that the evolution of airport passenger shares during much of the 1950–1989 period was influenced by the treatment effect of division, but by the 1980–1989 period, passengers shares had completely adjusted to the impact of division. Therefore, we estimate an augmented version of our basic specification, equation (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 1980–1989 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 was close to zero and far from statistical significance. The final row of panel B of table 2 shows a small but nevertheless statistically significant difference in the mean rate of growth of passenger shares between Berlin and Frankfurt that was 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 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 2. There is a highly 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.

VI. Is the Relocation of the Hub a Shift between Multiple Steady States?

While the results in section V are suggestive that Germany's air hub shifted between multiple steady states, an alternative potential explanation for our findings is that the relocation of Germany's largest airport was driven by changes in economic fundamentals. In this section, we build a body of additional evidence to strengthen the case that there has indeed been a shift between multiple steady states.

A. International Evidence

Table 3 presents information on the structure of airport traffic in other European countries in 1937 and 2002: the

TABLE 3.—THE LARGEST AIRPORTS OF EUROPEAN COUNTRIES, 1937 AND 2002

	(1) Largest Airport, 1937	(2) Market Share of Largest Airport, 1937	(3) Market Share of Largest Airport, 2002	(4) Rank of Largest Airport 1937 in 2002
Austria	Vienna	94.1	76.5	1
Belgium	Brussels	65.6	89.9	1
Denmark	Copenhagen	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

The countries are the EU 15 countries without Luxembourg (which had no airport prior to World War II and had 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. As in the case of Berlin, we aggregate airports when cities have more than one airport. See the data appendix for detailed references to the sources.

country's largest airport in 1937, the market share of the largest airport in 1937, the market share of the largest airport in 2002, and the rank of the largest 1937 airport in 2002.[17]

Although there are many differences in the technology and structure of air traffic between the prewar and present-day periods, the first striking feature of the table is that Germany is the only country where the leading airport in 1937 was not the leading airport in 2002 (Berlin ranked fourth in 2002). In all other countries, there is a perfect correlation between the past and current 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 current market shares, and we are unable to reject the null hypothesis that the 2002 market shares equal their 1937 values.[18] The remarkable persistence in the location of the leading airport in European countries suggests that there is little secular change in the location of such airports.

Apart from the stability in the identity and market share of a country's leading airport over time, there is also a similarity over time in the shares of direct connections served by a country's leading airport relative to the shares served by other airports. In the case of Germany, Berlin in 1935 served 72% of all destinations served by any other German airport, more than twice Frankfurt's share of 31%. A similar pattern is observed in 2002: Frankfurt served 95% of all destinations served by any other German airport, nearly twice Berlin's share of 55%. Further informal evidence that Frankfurt's current dominance was mirrored in Berlin's prewar

dominance comes from contemporary observers. According to Sefton Brancker, director general for civil aviation within the British Air Ministry, Germany led Europe in terms of the development of civil aviation from the mid-1920s onward (Myerscough, 1985), and Berlin was Europe's prewar aviation hub (Luftkreuz Europas, cited in Weise, 1928).

Finally, a comparison between Germany and other European countries reveals 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 location of the largest airport and the location of the largest city. Taken together, these findings support the idea that in the absence of division, Germany's largest airport would be located today in Berlin and that it is at least not obvious that Berlin, Germany's largest city by a substantial margin, can be excluded as a possible hub location.

B. The Selection of Frankfurt

An important question about the relocation of Germany's air hub after division is why it moved to Frankfurt rather than some other location. As evident from figure 2, there is a remarkable similarity in prewar shares of air traffic among Frankfurt, Cologne, Hamburg, and Munich. From this pattern of prewar passenger departures, it would be difficult to predict that Frankfurt, rather than one of these other airports, would rise to replace Berlin as Germany's leading airport after division. To the extent that differences in fundamentals are reflected in differences in passenger departures, this suggests that Frankfurt did not enjoy superior fundamentals to these other potential locations prior to division.

Instead Frankfurt's rise probably owes much to a number of small historical accidents. In contrast to Cologne and Hamburg, Frankfurt was located in the U.S. occupation zone, and in 1948 it was chosen as the European terminal for the U.S.

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

[18] 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 1 (p-value = 0.162).

Military Air Transport Service, which made the airport the primary airlift and passenger hub for U.S. forces in Europe. As a result of this decision, Frankfurt's airport became the main airport for the Berlin airlift in 1948–1949, which led to a further expansion of its capacity and facilities. Taken together, these relatively small initial shocks helped to propel Frankfurt ahead of Cologne, Hamburg, and Munich.

The patterns visible in Frankfurt's emergence as Germany's air hub have broader implications for the ability of policy interventions to influence location choices. While Frankfurt had a substantially larger passenger share than Cologne, Hamburg, and Munich by 1950, it still took a number of years for it to overtake Berlin. This suggests that dislodging an economic activity from an existing steady state requires large and sufficiently persistent shocks to influence forward-looking location decisions. However, before a steady state has become established, there is likely to be more scope for relatively small shocks to influence location decisions. This is consistent with the choice among Cologne, Frankfurt, Hamburg, and Munich as the new location for Germany's air hub being driven by relatively small shocks, such as the choice of Frankfurt as the primary airlift and passenger hub for U.S. forces in Europe.

C.   The Role of Market Access

The previous two sections have used historical data to argue that the relocation of Germany's air hub is highly unusual in a European context and that the emergence of Frankfurt, rather than some other location, is hard to predict based on prewar data. In the remaining sections of the paper, we use rich contemporary data to estimate the role of the economic fundamentals emphasized by the model and examine their importance in explaining Frankfurt's current dominance of German passenger traffic.

The model suggests two key economic fundamentals that determine the attractiveness of a location for an air hub: proximity to other destinations (market access) and local economic activity. In this section, we examine the role played by market access by estimating a gravity equation using data on bilateral passenger departures. Under the assumptions specified in the Web-based technical appendix, the following standard gravity relationship can be derived from the model,

$$\ln(A_{ij}) = m_i + s_j + \varphi \ln T_{ij} + u_{ij}, \tag{6}$$

which explains bilateral departures from city j to i (A_{ij}) as a function of destination fixed effects (m_i), source airport fixed effects (s_j), bilateral travel costs (T_{ij}), and a stochastic error term u_{ij}.

Using the fitted values from this regression relationship, taking exponents, and summing across destinations, equation (6) can be used to decompose variation in total departures from an airport into the contributions of proximity

to destinations (market access, MA_j) and source airport characteristics (source airport fixed effects):

$$\widehat{A}_j = \sum_i \widehat{A}_{ij} = \left[\sum_i T_{ij}^{\widehat{\varphi}} \widehat{M}_i \right] \widehat{S}_j \equiv \widehat{MA}_j \widehat{S}_j, \tag{7}$$

where the hats above variables indicate estimates, $M_i \equiv \exp(m_i)$, and $S_j \equiv \exp(s_i)$. Market access is the travel-cost-weighted sum of the destination fixed effects and summarizes an airport's proximity to destinations worldwide (see Redding & Venables, 2004, for further discussion in the context of international trade). Finally, choosing one airport as the base, percentage differences in total departures can be expressed as the sum of percentage differences in market access and percentage differences in source airport characteristics:

$$\ln \left(\frac{\widehat{A}_j}{\widehat{A}_b} \right) = \ln \left(\frac{\widehat{MA}_j}{\widehat{MA}_b} \right) + \ln \left(\frac{\widehat{S}_j}{\widehat{S}_b} \right), \tag{8}$$

where b indicates the base airport, which we choose to be Berlin.[19]

To estimate the gravity equation in equation (6), we use data on bilateral passenger departures from the fifteen German airports for which data were available in 2002 to destinations worldwide.[20] We begin with a standard baseline specification from the gravity equation literature, in which we add 1 to the bilateral departures data before taking logarithms, and estimate the gravity equation (6) using a linear fixed effects estimator. We discuss the robustness of the results to alternative estimation strategies below.

Our baseline measure of bilateral travel costs, following the large gravity equation literature, is the geographical distance between airports.[21] Following the recent empirical literature in international trade, we also consider measures of social networks based on foreign migration and business networks based on multinational activity (see, in particular, Rauch, 2001, and Combes, Lafourcade, & Mayer, 2005). As a measure of social networks, we use bilateral data on inward and outward foreign migration between each German state and other countries. As a measure of business networks, we use bilateral data on the number of German companies headquartered in each of our airport cities with subsidiaries in each foreign country. For both variables, we also add 1 before taking the logarithm.

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[19] 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 (8) ensures that results of the decomposition do not depend on the choice of excluded category in the gravity equation estimation. As is clear from equation (8), the choice of base airport does not affect relative comparisons between any pair of airports j and i: since $\ln(A_j/A_b) - \ln(A_i/A_b) = \ln(A_j/A_i)$.

[20] We exploit the data on the additional five airports where it is available, but all our results are robust to continuing to focus on the ten main German airports used in figure 2.

[21] To abstract from substitution from other modes of transport, we focus in the baseline specification on departures to destinations more than 300 kilometers away from any German airport.

TABLE 4.—DETERMINANTS OF BILATERAL PASSENGER DEPARTURES

	(1) Logarithm of Bilateral Passenger Departures	(2) Logarithm of Bilateral Passenger Departures	(3) Logarithm of Bilateral Passenger Departures	(4) Logarithm of Bilateral Passenger Departures
Logarithm of distance	−1.652*** (0.543)	−1.313*** (0.490)	−1.556*** (0.489)	−1.286*** (0.465)
Logarithm of foreign migration		0.370*** (0.094)		0.325*** (0.105)
Logarithm of subsidiaries			0.206*** (0.067)	0.145* (0.076)
Source airport fixed effects	Yes	Yes	Yes	Yes
Destination airport fixed effects	Yes	Yes	Yes	Yes
Observations	5,130	5,130	5,130	5,130
R^2	0.680	0.683	0.682	0.684

The dependent variable is the logarithm of 1 plus bilateral passenger departures. Distance is the great circle distance between source and destination airports. Foreign migration is 1 plus the average of inward and outward migration flows between German states and other countries. Subsidiaries is 1 plus the number of foreign subsidiaries of German firms with headquarters in each source city and subsidiaries in each foreign country. The sample includes all worldwide destinations with direct connections from a German airport that are more than 300 kilometers from any German airport. The German airports are Bremen, Berlin, Cologne, Erfurt, Dresden, Dusseldorf, Frankfurt, Hamburg, Hanover, Leipzig, Munich, Munster, Nuremberg, Saarbrucken, and Stuttgart. Standard errors in parentheses are heteroskedasticity robust and clustered on the foreign country in which each destination airport is located. Statistical significance: ***1% level; **5% level; *10% level.

Because our econometric specification includes destination airport fixed effects, these capture any destination characteristic that is common across all German airports, such as average distance from Germany or any dimension of social and business networks that is common to all German airports (for example, whether the country in which the destination airport is located shares a common language with Germany, shares a common currency with Germany, or has policies that restrict travel and commerce with Germany). Therefore, the coefficients on distance and social and business networks are identified solely from the variation in these measures across airports within Germany.

Table 4 reports the results of the gravity equation estimation. In column 1, we report our baseline specification including geographical distance alone. In this baseline specification, we explain a substantial proportion of the overall variation in bilateral departures, with an R^2 of 0.68, and the source and destination fixed effects are both highly statistically significant (p-values < 0.001). We find a negative and highly statistically significant coefficient on geographical distance: a 1% increase in distance traveled is associated with a 1.65% decline in passenger departures, so that doubling distance more than halves bilateral passenger departures. In columns 2 to 4, we augment our baseline specification with our measures of social and business networks. Consistent with results in the international trade literature, we find that both social and business networks are positively related to bilateral passenger departures. The coefficient on geographical distance remains negative and highly statistically significant and is somewhat reduced in magnitude.

We use the specification in column 4 incorporating geographical distance and social and business networks to undertake the decomposition of total departures in equation (8). The results are displayed in figure 3, where the two bars correspond to log differences in market access and the source airport fixed effects from their respective values for Berlin. The sum of the two bars is by construction equal to the log difference of fitted total departures from the value for Berlin. A striking impression from the figure is that although

market access varies across German airports, its contribution to differences in total departures is dwarfed by that of the airport fixed effects. This suggests that in a comparatively small country such as Germany, approximately the size of Montana, airports are sufficiently close together that there is relatively little variation in distance to destinations, and so variation in market access to destinations is unable to explain Frankfurt's current dominance of German air traffic.[22]

This basic finding is robust across a wide variety of alternative specifications. First, we reestimated the baseline specification for departures to all destinations, including those less than 300 kilometers away from any German airport. Second, we reestimated the baseline specification excluding bilateral connections from Frankfurt, since the coefficient on distance could be different for a hub airport. In both cases, we find that market access makes a minor contribution to explaining the variation in total passenger departures. Third, we constructed a simpler measure of market potential, based on Harris (1954), where we use aggregate passenger departures from Germany as a whole to each destination as a proxy for the importance of a destination. For each of our fifteen German airports, we calculate the geographical-distance-weighted sum of aggregate German passenger departures to each destination more than 300 kilometers away from any German airport. The variation in this simpler measure of market potential across German airports is again small relative to the variation in total passenger departures.[23] Finally, although the linear fixed-effects estimator is widely used in the gravity equation literature, we have also reestimated equation (6)

[22] Consistent with this, the difference in geographical distance to individual foreign destinations between Frankfurt and Berlin is relatively small. For example, the great circle distances from Frankfurt and Berlin to New York are 6,184 and 6,364 kilometers, respectively, while those to San Francisco are 9,142 and 9,105 kilometers, respectively, and those to Tokyo are 9,363 and 8,936 kilometers, respectively. The average great circle distances from Frankfurt and Berlin to all destinations in our regression sample are 3,818 and 3,838 kilometers, respectively.

[23] The correlation coefficient between this simpler measure of market potential and our baseline measure of market access from the gravity equation using geographical distance is 0.91, which is statistically significant at the 1% level.

FIGURE 3.—THE ROLE OF MARKET ACCESS
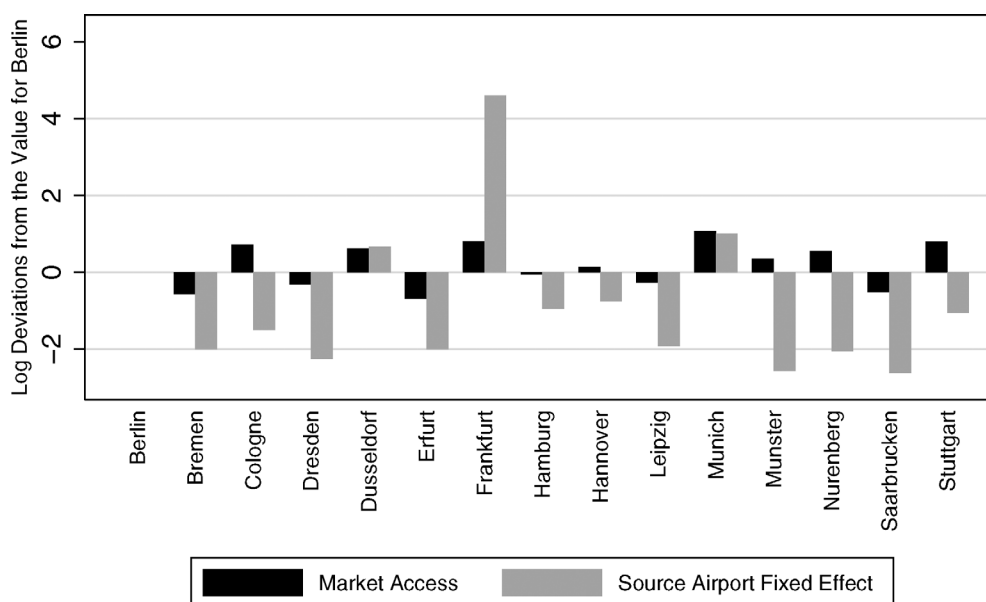
The estimates of market access and the source airport fixed effects are derived from the gravity equation (6) for bilateral passenger departures. The log deviations from Berlin for market access and the source airport fixed effects sum to the log deviation from Berlin for fitted total departures.

using a Poisson fixed-effects specification (see Silva & Tenreyro, 2006). Also in this specification, we find that market access contributes little to explaining Frankfurt's dominance of German air travel.

D. Local Economic Activity and Local Departures

Having shown that market access makes a relatively small contribution toward explaining differences in passenger departures across airports, we now examine the model's other key determinant of the attractiveness of an airport as a hub: local economic activity. To do so, we begin by decomposing total passenger departures from each airport into local departures that originate in the vicinity of the airport and various forms of transit traffic. Using this decomposition, we then examine the relationship between local departures and local economic activity, as well as the variation in local economic activity across alternative potential locations for Germany's air hub.

We decompose total passenger departures from each German airport into four components: (a) international air transit passengers, who are changing planes at the airport en route from a foreign source to a foreign destination; (b) domestic air transit passengers, who are changing planes at the airport and have either a source or final destination within Germany; (c) ground transit passengers, who arrived at the airport using ground transportation and who traveled more than 50 kilometers to reach the airport; and (d) local passengers, who arrived at the airport using ground transportation and who traveled less than 50 kilometers to reach the airport.

To undertake this decomposition, we combine data on air transit passengers collected by the German Federal Statistical Office with information from a harmonized survey of departing passengers at all major German airports in 2003

coordinated by the German Airports Association (Arbeitsgemeinschaft Deutscher Verkehrsflughäfen). Although the disaggregated results of the survey of departing passengers are proprietary data, Wilken, Berster, and Gelhausen (2007) construct and report a number of summary results. These include the share of all departing passengers from each German airport whose journey began within 50 kilometers of the airport, which ranges from 85% in Berlin to 37% in Frankfurt, with an average of 59% across the fifteen airports.

Figure 4 breaks out total departures at the German airports in 2002 into the contributions of these four categories of passengers. The panels display total departures, total departures minus international air transit passengers, total departures minus all air transit passengers, and total departures minus all air and ground transit passengers (i.e., local departures). Total departures (top left panel) vary substantially across airports: from 0.2 million in Saarbrucken to nearly 24.0 million in Frankfurt. Simply subtracting international air transit passengers from total departures (top right panel) substantially reduces the extent of variation: from 0.2 million in Saarbrucken to 16.4 million in Frankfurt.

Since international air transit passengers are en route from a foreign source to a foreign destination and are merely changing planes within Germany, this category of passengers seems most closely connected with an airport's hub status. International air transit passengers alone account for around 32% of Frankfurt's total departures, and Frankfurt accounts for around 82% of international air transit passengers in Germany.[24] Therefore, Frankfurt's hub status clearly plays

[24] The only other airport with a nonnegligible share of international air transit passengers is Munich, which has developed over the past two decades into a much smaller secondary hub. International air transit passengers account for 14% of Munich's total departures, and Munich's share of this category of passengers in Germany is 17%.

FIGURE 4.—TRANSIT AND LOCAL PASSENGER DEPARTURES, 2002
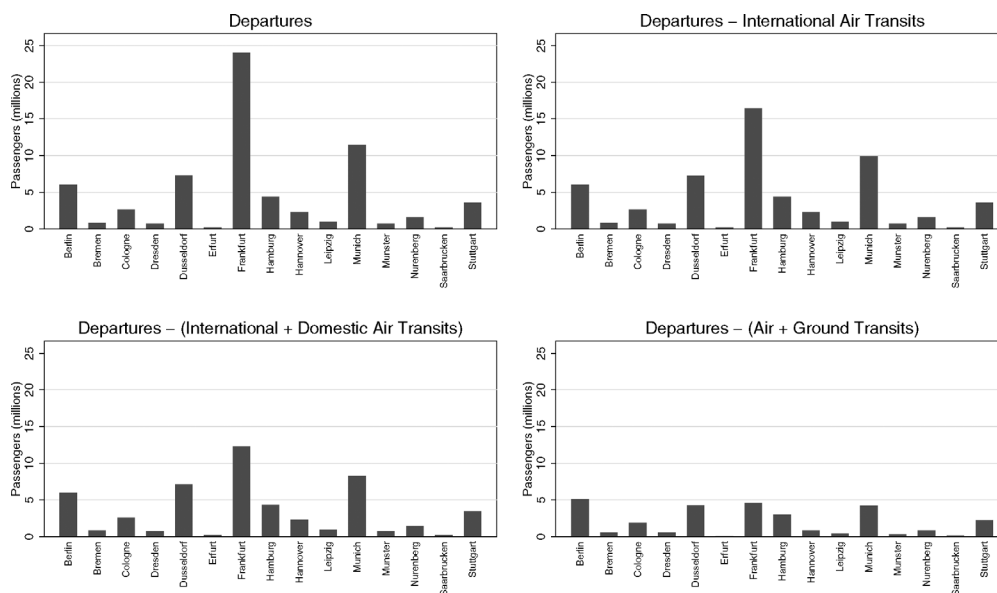
International air transit passengers are those changing planes at an airport en route from a foreign source to a foreign destination. Domestic air transit passengers are those changing planes at an airport with either a source or destination within Germany. Ground transit passengers are those who traveled more than 50 kilometers to an airport using ground transporation. See the data appendix for further discussion of the data sources.

a major role in understanding its dominance of German passenger traffic. This conclusion is strengthened by subtracting both international and domestic air transit passengers from total departures (bottom left panel). Together the two categories of air transit passengers account for 49% of Frankfurt's total passenger departures, and Frankfurt accounts for 75% of all air transit passengers in Germany.[25]

Moving to local departures in the bottom right panel (subtracting both air and ground transit passengers from total departures) entirely eliminates Frankfurt's dominance of German air travel: 4.55 million passengers originated from within 50 kilometers of Frankfurt airport, compared to 4.23 million for Munich, 4.28 for Dusseldorf, and 5.07 million for Berlin. This decomposition suggests that Frankfurt's much higher volume of passenger traffic than Berlin, Munich, or Dusseldorf is due to its larger volume of transit traffic and not a larger volume of passenger traffic originating from within the immediate vicinity of the airport.

While variation in local departures cannot explain Frankfurt's dominance of German air travel, figure 5 shows that this category of passengers is closely related to local economic activity, as suggested by the theoretical model. The figure plots the logarithm of the number of passengers originating within 50 kilometers of each airport against the logarithm of GDP within 50 kilometers of each airport, as well as the linear regression relationship between the two variables.[26]

The figure shows a tight relationship between local passenger volumes and local GDP. Over 80% of the variation in local departures is explained by the regression, and the coefficient on local GDP is highly statistically significant.[27]

One notable feature of figure 5 is that Cologne and Dusseldorf have greater concentrations of local economic activity than Frankfurt, and the difference in local economic activity between Frankfurt and Berlin is in fact around the same magnitude as between Frankfurt and Dusseldorf. This finding parallels our discussion in section VIB, where we noted that several other German airports had similar levels of prewar passenger traffic to Frankfurt. From the concentrations of local economic activity shown in figure 4, it also seems difficult to conclude that Frankfurt is the only possible location for Germany's air hub. A similar picture also emerges from the headquarters data that we used in section VIC for our gravity estimation. In these data, Frankfurt is ranked fourth in terms of the number of headquarters, after Hamburg, Berlin, and Munich.

To further reinforce the point that Frankfurt is not necessarily the most attractive location for Germany's air hub, figure 6 places our fifteen airports in the context of the distribution of GDP within 50 kilometers of every German city with more than 50,000 inhabitants in 2002.[28] The figure displays the log rank – log size relationship for this distribution and labels the cities in which the fifteen German airports are

[25] The corresponding numbers for Munich are 28% of the airport's total departures and 20% of all air transit passengers in Germany.

[26] GDP within 50 kilometers of an airport is calculated from the population of all municipalities (*Gemeinden*) within 50 kilometers of the airport and the GDP per capita of the counties (*Kreise*) in which the municipalities are located. See the data appendix for further discussion.

[27] The estimated coefficient (standard error) on local GDP is 1.592 (0.237). Regressing local passenger departures on population (instead of GDP) within 50 kilometers of an airport yields a similar pattern of results.

[28] As discussed above, GDP within 50 kilometers is calculated from the population of all municipalities within 50 kilometers of a city and the GDP per capita of the counties in which those municipalities are located.

FIGURE 5.—LOCAL DEPARTURES AND LOCAL GDP
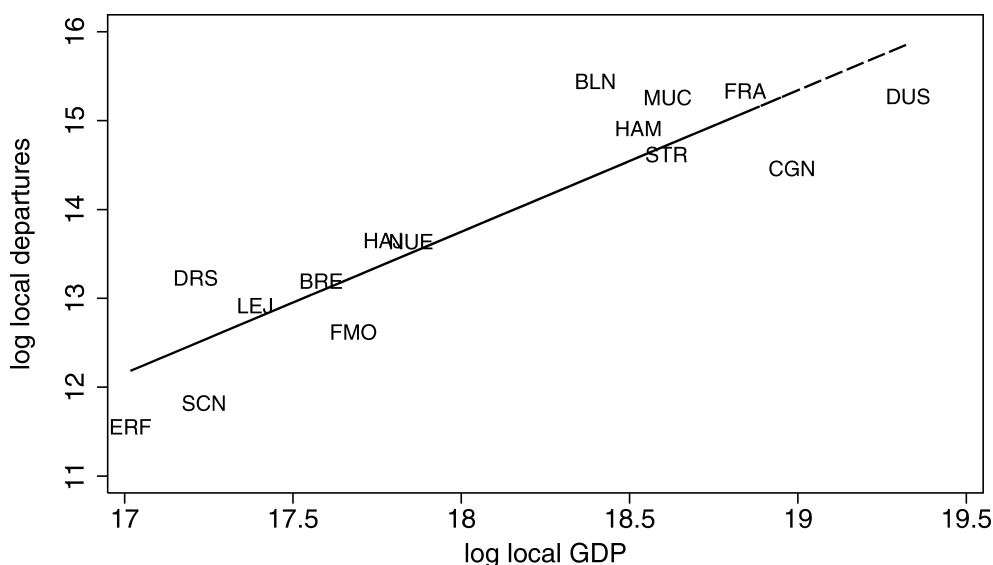
Local departures are those who traveled less than 50 kilometers to an airport. Local GDP is calculated from the population of all municipalities within 50 kilometers of an airport and the GDP per capita of the counties in which the municipalities are located. The three-letter codes are: BLN: Berlin; BRE: Bremen; CGN: Cologne, DUS: Dusseldorf; DRS: Dresden; ERF: Erfurt; FRA: Frankfurt; HAM: Hamburg: HAJ: Hanover; LEJ: Leipzig; FMO: Munster; MUC: Munich; NUE: Nuremberg; SCN: Saarbrucken; STR: Stuttgart.

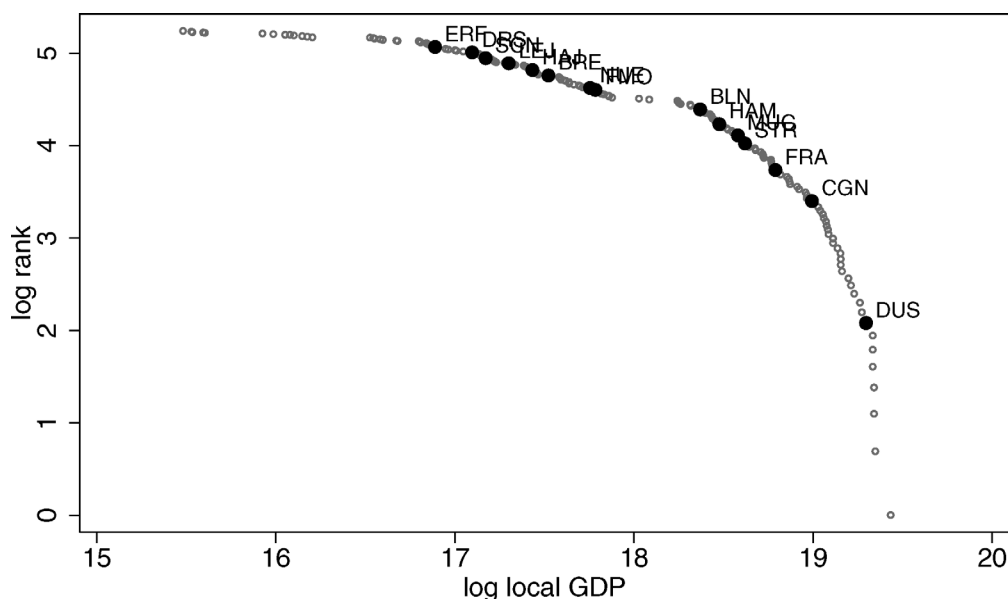FIGURE 6.—LOCAL GDP FOR GERMAN CITIES, 2002

Figure displays German cities with a population greater than 50,000. Local GDP is the sum of GDP in all municipalities whose centroids lie within 50 kilometers of the centroid of a city. Municipality GDP is constructed using municipality population and GDP per capita in the county where the municipality is located. Rank is defined so that the city with the largest local GDP has a rank of 1. See the note to figure 5 for the list of three-letter codes.

located.[29] As apparent from the figure, the fifteen airports are not necessarily located in the cities with the greatest local concentrations of economic activity. Furthermore, the thirty cities with the greatest concentrations of local economic activity within 50 kilometers are all located in the Rhine-Ruhr region of northwest Germany, which includes Cologne and Dusseldorf. Frankfurt, located to the south in the Rhine-Main region of western Germany, is ranked 42.[30]

E. Quantifying Differences in Profitability across Locations

While the previous two sections have shown that differences in market access and local economic activity across our fifteen airports appear to be small relative to differences

[29] As in the literature concerned with population-size distributions (see, for example, Rossi-Hansberg & Wright, 2007), we find departures from the linear relationship between log rank and log size implied by a Pareto distribution. The concave relationship shown in the figure implies thinner tails than a Pareto distribution.

[30] We find a similar pattern of results for population within 50 kilometers.

in total passenger departures, and Frankfurt is not necessarily the most attractive location, even small differences in fundamentals could in principle have a large impact on the relative profitability of alternative locations for the air hub. Therefore, in this section, we combine our estimates of the impact of market access and local economic activity to provide a simple quantification of the differences in profitability across alternative potential locations for Germany's air hub.

To quantify these differences in profitability, we first construct an estimate of the impact of the relocation of the hub on the total number of departing passengers across the 15 German airports as a whole. We then combine the change in total passenger departures with an estimate of net profits per passenger. Finally, we compare the implied change in the net present value of profits with plausible values of the sunk costs of creating the hub.[31] Consistent with our results above, we find that differences in the net present value of profits are small relative to plausible estimates of the sunk costs of creating the hub, and therefore several airports within Germany are potential steady state locations for Germany's air hub.

To evaluate the impact of the relocation of Germany's air hub on total passenger departures, we use our decomposition of total departures into transit traffic and local departures from the previous section. While the relocation of Germany's air hub would affect passenger departures on each bilateral connection because of general equilibrium changes in price indices, the first-order impact of a change in the location of the hub is likely to be that the transit passengers currently traveling via Frankfurt would have to instead travel via the new location of the hub. To evaluate the magnitude of this impact, we consider each category of transit passengers separately.[32]

For domestic and international air transit passengers, we calculate the difference in distance traveled if the hub is in another German city instead of Frankfurt.[33] We then use the coefficient on distance from the estimation of the gravity equation (6) in column 4 of table 4 to infer how the volume of passengers would change in response to the change in distance traveled. Column 1 of table 5 reports the estimated change in the number of air transit passengers in response to a relocation of the hub to Berlin, Dusseldorf, Hamburg,

and Munich, respectively. Consistent with our earlier findings that market access plays a relatively minor role, the estimated changes in the number of air transit passengers as a result of the relocation of the hub are small compared to total passenger departures across the 15 German airports.

We next estimate the impact of relocating ground transit passengers from Frankfurt to another airport. Two key determinants of ground transit passengers for an airport are likely to be the surrounding concentration of economic activity and whether an airport is a hub because of the larger number of direct connections offered by a hub. To estimate the relationship between ground transit departures and the surrounding concentration of economic activity, we regress the log number of ground transit passengers departing from an airport on the log of distance-weighted GDP for the airport, where the latter is calculated as the distance-weighted sum of GDP in all German counties. To isolate the contribution of the surrounding concentration of economic activity and to abstract from the role of hub status, we exclude Frankfurt and also Munich from the regression.[34]

The estimated coefficient on distance-weighted GDP is positive and statistically significant at the 1% level, with this variable alone explaining around 60% of the cross-section variation in ground transit passengers; the estimated coefficient (standard error) is 2.986 (0.624). We use this estimated coefficient to calculate the predicted change in the number of ground transit passengers at the hub as a result of the difference between distance-weighted GDP at the alternative location of the hub and that at Frankfurt. Column 2 of table 5 reports the predicted changes in the volume of ground transit traffic at the hub as a result of the change in the hub's proximity to surrounding economic activity. The estimated changes in ground transit passengers are somewhat larger than those in air transit passengers, but are small relative to total departures at Frankfurt and across the 15 German airports.

Column 3 of table 5 reports the implied change in total passenger departures across the 15 German airports as a result of the hypothetical relocation of the hub. Column 4 reports this change as a percentage of total passenger departures across the 15 German airports. For each of the alternative locations of the hub, the change in total passenger departures is small relative to both current passenger departures at Frankfurt and total passenger departures across the 15 German airports. As a point of comparison, the average annual growth in the number of departing passengers at these 15 airports over the period 1992 to 2002 was 4.5%. To convert the implied change in total passenger departures into a change in profits, we assume a value for airport profits of 10 euros per passenger.[35] Assuming a discount rate of 3% per annum, the net present value of

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[31] This exercise therefore implicitly evaluates the profitability of relocating the hub for the system of airports as a whole. In reality, airports are incorporated separately from one another (and also from airlines). As a result, it is likely to be substantially more difficult for a new entrant to displace an existing hub because the sunk costs of creating a hub are large relative to its operating costs.

[32] Data are available on the total number of transit passengers at each airport and bilateral passenger departures between airports. To estimate the number of air and ground transit passengers traveling on bilateral connections with Frankfurt, we assume the share of each type of transit passenger in bilateral connections with Frankfurt is the same as for total passenger departures at Frankfurt.

[33] In the data, there is a flow of domestic air transit passengers to the current location of the hub in Frankfurt from each of the other airports. If the hub were relocated to one of these other airports, there would instead be a flow of domestic air transit passengers from Frankfurt to the new hub airport. To capture this change in the structure of air travel, we assume that the current flow of domestic air transit passengers from an airport to Frankfurt is a good proxy for the flow that would travel from Frankfurt to the new hub airport.

[34] Results change only marginally if Frankfurt and Munich are included in this regression.

[35] The figure of 10 euros per passenger is likely to be an overestimate. According to the German Association of Airports (Arbeitsgemeinschaft Deutscher Verkehrsflughäfen), average after-tax profits per passenger for the largest German airports in 2005 were 2.53 euros per passenger, while according to the 2006 *Annual Report of Lufthansa*, average operating profits on passenger business during 2005 and 2006 were 5.14 euros per passenger.

TABLE 5.—ESTIMATED IMPACT OF RELOCATING THE AIR HUB FROM FRANKFURT ON TOTAL PASSENGER DEPARTURES ACROSS THE 15 GERMAN AIRPORTS

Alternative Location of the Air Hub	(1) Estimated Change in Air Transit Passengers	(2) Estimated Change in Ground Transit Passengers	(3) Estimated Change in Total Passenger Departures	(4) Estimated Percentage Change in Total Passenger Departures
Berlin	−407,498	−1,862,056	−2,232,380	−3.38
Dusseldorf	148,590	− 18,331	125,759	0.19
Hamburg	−332,672	−1,644,620	−1,852,323	−2.80
Munich	566,039	− 865,146	− 422,204	−0.64

The table reports the estimated change in passenger departures across the 15 German airports as a result of the hypothetical relocation of the air hub from Frankfurt to each of the alternative locations. All air transit passengers who currently change planes at Frankfurt are assumed to instead fly via the alternative airport, and the coefficient on distance from column 4 of table 4 is used to infer the change in the number of air transit passengers as a result of the change in distance traveled caused by the relocation of the hub. The logarithm of ground transit departures is regressed on the logarithm of the distance-weighted sum of GDP in all German counties, and the estimated coefficient is used to infer how the number of ground departures currently observed in Frankfurt would change if it instead had the distance-weighted GDP of the alternative location of the hub. See the main text for further discussion. Total bilateral departures for the 15 German airports in 2002 were 66,134,047. Total bilateral departures from Frankfurt airport in 2002 were 23,782,604.

a change in total passengers by 2.5 million (which is larger than any of the changes in table 5) would be 0.86 billion euros. In comparison, the construction costs of the new terminal facilities in Berlin, which are at best one-third of the size necessary to replace Frankfurt, are projected to be around 2 billion euros.[36]

Our analysis of the impact of relocating the hub from Frankfurt to another German airport clearly makes a number of simplifying assumptions and assumes that apart from the relocation of transit traffic from Frankfurt to an alternative airport, the structure of German air traffic remains unchanged. Despite these caveats, the stark difference between the implied change in the net present value of profits and plausible estimates for the sunk costs of creating the hub suggests that it is unlikely the difference in profitability across alternative locations for the air hub in Germany outweighs the large sunk costs of creating the hub. This reinforces the conclusion that several other locations apart from Frankfurt, including Berlin, are potential steady state locations for Germany's air hub.

VII. Conclusion

While a central prediction of a large class of theoretical models is that industry location is not uniquely determined by fundamentals, there is a surprising scarcity of empirical evidence on this question. In this paper, we exploit the combination of the division of Germany in the wake of World War II and the reunification of East and West Germany in 1990 as a natural experiment to provide empirical evidence for multiple steady states in industry location. We find that division results in a relocation of Germany's leading airport from Berlin to Frankfurt, but there is no evidence of a return of the leading airport to Berlin in response to reunification.

To provide evidence that this change in location is indeed a shift between multiple steady states, we compare Germany with other European countries, use data on prewar passenger shares, examine the determinants of bilateral departures from German airports to destinations worldwide, and exploit information on the origin of passengers departing from each German airport. We show that Frankfurt's rise to become Germany's postwar air hub is difficult to predict based on

either prewar passenger shares or current economic fundamentals. We quantify the impact of differences in economic fundamentals on both transit activity and local departures and show that the predicted changes in the net present values of profits across alternative potential locations for Germany's air hub are small relative to the sunk costs of creating the hub. All of the available evidence therefore suggests that the location of an air hub is not uniquely determined by fundamentals and that there is instead a range of possible steady state locations for the hub for which differences in economic fundamentals are dominated by the substantial sunk costs of creating the hub.

While the main focus of our research has been to find a natural experiment for which we can provide compelling evidence in support of multiple steady states in industry location, our findings also have broader implications for the ability of public policy and other interventions to influence location choices. The sheer magnitude of German division and the length of time that it took for Frankfurt and Berlin to exchange places as Germany's air hub suggest that the type of intervention required to dislodge an established steady state needs to be not only large but also sufficiently persistent to influence forward-looking location decisions. This offers support for those who are pessimistic about the ability of realistic interventions to dislodge an economic activity from an existing steady state. However, the similarity of prewar passenger shares and also current economic fundamentals between Frankfurt and several other locations within Germany suggest that Frankfurt's subsequent rise to become Germany's air hub was by no means a forgone conclusion. Therefore, there may be substantially more scope for relatively small interventions, such as the U.S. military's decision to make Frankfurt their main postwar European air transport base, to influence location decisions before a new steady state has become established.

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[36] This estimate is taken from http://www.berlin-airport.de/DE/BBI/.

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DATA APPENDIX

Total departing passengers at the ten main airports: The data for 1927 to 1938 are from the *Statistical Yearbook of Germany* (*Statistisches Jahrbuch für das Deutsche Reich*) of the German Statistical Office (Statistisches Reichsamt). The data for 1950 to 1989 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 to 2002.

Bilateral departures: Data on bilateral departures between the 15 largest German airports in 2002 and destinations worldwide are taken from Statistisches Bundesamt (2003).

Transit passengers and local departures: Information on the number of air transit passengers, who are passengers changing planes at an airport en route to another destination, is reported for 2002 in Statistisches Bundesamt (2003). Wilken et al. (2007) report summary results from a harmonized passenger survey in 2003, including the percentage of all passengers commencing their air journey at each German airport who traveled to that airport from a location less than 50 kilometers away. We use these percentages to divide non–air transit passenger departures in 2002 into two groups: ground transit passengers, who traveled more than 50 kilometers to the airport using ground transportation, and local departures, who traveled less than 50 kilometers to the airport.

Departing passengers in other European countries: Data on the concentration of departing passengers in other European countries in 2002 are reported in "Worldwide Airport Traffic Report 2002" (Airports Council International, 2002). The comparable data for 1937 were taken from the 1938 issue of the *Revue Aeronautique Internationale*.

Distances between locations: Data on the longitude and latitude of each airport were extracted from http://worldaerodata.com, which is based on the data from the DAFIF database originally compiled by the U.S. National

Geospatial-Intelligence Agency. Data on the longitude and latitude of the administrative capital of each German county (*Kreis*) and the geographical centroid of each German municipality were constructed using the 2002 version of the GN250 GIS database supplied by the German Federal Agency for Cartography and Geodesy (Bundesamt für Kartographie und Geodäsie). The latitude and longitude data were used to compute great circle distances between locations.

Population and GDP data: Data on population and GDP in each German county in 2002 are taken from Arbeitskreis Volkswirtschaftliche Gesamtrechnung der Länder (2005). Data on the population in all municipalities within 50 kilometers of each German city with more than 50,000 inhabitants were constructed using the GN250 GIS database referenced above. We combine these two data sources to estimate GDP within 50 kilometers of each German city. We identify the county in which each municipality is located, multiply its population with the GDP per capita of the county in which it is located, and then sum over all municipalities within 50 kilometers of each German city.

Foreign migration: Data on bilateral migration between the German states (Länder) and other countries for 2002 are from the Federal Statistical Office. The data report the flow of inward and outward migration to and from foreign countries for each German state.

Foreign subsidiaries: Data on the location of the foreign subsidiaries and headquarters of German companies are from Bureau Van Dijk's Orbis database. The data report for each company the location of its headquarters and the location of each of its foreign subsidiaries. Using these data, we construct a bilateral measure of the total number of subsidiaries in each foreign country that have headquarters in each of the German cities where airports are located.