ECOLOGY, TRADE AND STATES IN PRE-COLONIAL AFRICA

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ABSTRACT. I test Bates' view that trade across ecological divides promoted the development of states in pre-colonial Africa. My main result is that sub-Saharan societies in ecologically diverse environments had more centralized pre-colonial states. I use spatial variation in rainfall to control for possible endogeneity. I construct artificial societies and present narrative evidence to show the results are not due to conquest of trading regions. I also test mechanisms by which trade may have caused states, and find that trade supported class stratification between rulers and ruled.

1. INTRODUCTION

The states that existed in Africa before colonial rule continue to shape its modern development. Pre-colonial state centralization is positively correlated with modern cross-country differences in school attainment, literacy, paved roads and immunizations (Gennaioli and Rainer, 2007). It better predicts nighttime lights today than country-level institutional quality (Michalopoulos and Papaioannou, 2010). The few modern states in Africa that inherited the legitimacy of a pre-colonial predecessor have done better (Englebert, 2000). The parts of French West Africa with more centralized states before colonial rule better resisted French settlement, but these same areas received less investment during the colonial period (Huillery, 2008). These recent empirical findings are in line with those of historians and political scientists, who have argued that alien rulers had to take African systems as given and build upon them during the colonial period (Austin, 2008b; Berry, 1992; Mamdani, 1996). In other contexts, economists have similarly found that the long historical roots of modern states are relevant for modern development (Banerjee and Iyer, 2005; Bockstette et al., 2002; Iyer, 2007). Explaining pre-colonial states, then, is necessary for understanding modern Africa.

In this paper, I test a "Ricardian" view of sub-Saharan states presented by Bates (1983), in his *Essays on the political economy of rural Africa*. He builds on earlier arguments made by Oliver and Fage (1962) and Vansina (1966), among others, who argued that

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TABLE 1. Bates' Evidence

[Table 1 here]

long-distance trade required centralized authorities for administrative purposes, diffused concepts of centralized polities, and stimulated territorial expansion (Bisson, 1982). His model is verbal:

> One of the basic arguments linking political centralization with economic reward rests upon the desire of people to benefit from the gains in welfare which can be reaped from markets. In essence, the argument is Ricardian... the contribution of the state is to provide order and peace and thereby to render production and exchange possible for members of society. The origins of the state, then, lie in the welfare gains that can be reaped through the promotion of markets.

He suggests that gains from trade are greatest where products from one ecological zone can be traded for products from another. It is near ecological divides, then, that we should expect to see states. To support his view, he takes 34 pre-colonial African societies, asks whether they "abut an ecological divide," and classifies them as having a "kinship" political structure, "chiefs," or "central monarchs." I present a condensed version of his results in Table 1. The proportion of societies with central monarchs is greater on an ecological divide.

In this paper, I argue that Bates (1983) is ultimately correct. His argument has been overlooked because his sample size prevents him making a credible econometric argument that this correlation is causal. In this paper, I use ethnographic and geographic data to overcome this limitation. I take data on state centralization for 440 societies in pre-colonial sub-Saharan Africa from Murdock's (1967) *Ethnographic Atlas*. Merging the map of African ethnic groups from Murdock (1959) with information on African ecological zones from White (1983), I am able to compute for each society an index of its "ecological diversity," which I take as a proxy for the gains from trade that existed before colonial rule. I show that this index is strongly related to the presence of pre-colonial states. I use spatial variation in rainfall to control for possible reverse causation, and show that the OLS estimates of the impact of ecological diversity are not overstated. I also use exogenous geographic features to predict raster-level ecological regions, and find that the diversity measured by these predicted points is also related to pre-colonial African states. The relationship between trade and states is robust to several additional controls, removing influential observations, alternative measures of states and trade, and a variety of estimation strategies.

I show that the "Ricardian" view better explains the relationship between states and diverse ecology than six alternative stories. First, while larger territories may require more levels of administration and may be more diverse, area does not explain away the relationship between ecological diversity and states. Second, because panel data are not

available for these ethnic groups, I am not able to conclusively show that societies that independently developed state centralization did not migrate to capture the regions in which the gains from trade were high. In order to argue that this does not explain my results, I construct artificial societies and present narrative evidence on the histories of the most influential observations in the data. By adding similar controls, I am able to show that two other stories – dense population in diverse regions and defense of "islands" of land quality – do not explain away the relationship between trade and states. Fifth, I show that the diversity of grains available for cultivation do not explain away the main results. Sixth, while diverse areas are more ethnically fractionalized, ecology directly impacts states even when this is included in the sample of artificial countries. I test for several mechanisms by which trade may have facilitated state centralization, and find that class stratification is the channel best supported by the data. No one type of trade is shown to be more important than others.

The Ricardian view is only one of many theories of the long-run geographic origins of strong states. It is not my aim, however, to test the Ricardian view against these except insofar as they may also explain the observed link between states and ecological diversity. Diamond (1997) argues that Eurasian endowments of domesticable plants and animals, combined with an East-West orientation that facilitated their diffusion, gave that landmass an early advantage over the Americas and Africa. Jones (2003) makes an argument for Europe that is remarkably similar to the Ricardian view, stating that:

> In Europe's case, the most relevant aspect of the resource endowment was probably the way it was dispersed across a geologically and climatically varied continent, since this provided an inducement to trade (p. xxxii).

Specifically, he suggests that the gains from bulk, low value trade encouraged rulers to gain their revenues through taxation of protected trade, rather than the arbitrary confiscations that would be possible with trade in luxuries (p. 89). Olson (1993), by contrast, suggests that above the level of hunter-gatherers, most societies have some vestige of a state because it is in the interests of "roving" bandits to establish themselves as ruling "stationary" bandits and encourage economic activity that they can tax. In this light, my study highlights a geographic condition that makes this possible through trade. States are only one of many imperfect ways to govern the market (Dixit, 2004), and this study then draws attention to one condition under which they emerge. There are also reasons why we might expect ecological *homogeneity* to facilitate trade and states. Societies that can only produce a narrow range of goods may be compelled to trade. Moav and Mayshar (2011) suggest that the homogeneity of ancient Egypt benefitted that state's centralization, compared with Israel and Babylon. Because all farmers depended on the Nile flood, which could be easily monitored, the state was uniquely able to tax them effectively.

Similarly, this Ricardian view of the origins of pre-colonial African states contrasts with other, though not necessarily rival, theories of African political centralization. Again,

it is not the purpose of this paper to test between these hypotheses unless they are alternative explanations of the relationship between ecological diversity and states. First, the "land-abundance" view (Austin, 2008a; Herbst, 2000) of Africa argues that the relative absence of large states in pre-colonial Africa was the result of sparse population. Unable to tax land, which had little value, African states had to rely on trade taxes for revenue. This is to be understood in contrast with the view of Tilly and Ardant (1975), who argue that it was the need to secure and defend territory that gave rise to modern nation states in Europe. I show in this paper that, even controlling for population density, gains from trade allowed states to exist in Africa. Second, contributions by Nunn (2008) and Robinson (2002) have built on older views, such as those of Rodney (1972), and argued that the slave trade and colonial rule undermined institutional development in Africa, including state centralization. I show that the relationship between states and ecology is robust to measures of access to the transatlantic slave trade.

In the remainder of this paper, I proceed as follows. In section 2, I describe my sources of data, how I measure state centralization, and how I compute ecological diversity for each society. In section 3, I outline the principal econometric specification and the baseline results. In section 4, I demonstrate the robustness of these results to endogeneity, unobserved heterogeneity, influential observations, and alternative measures of trade and states. In section 5, I give evidence that five alternative stories – area necessitates centralization, states migrate to capture gains from trade, states emerge to protect "islands" of land quality in otherwise barren regions, ecological diversity proxies for population density, and ecological diversity produces ethnic diversity – do not explain the results. In section 6, I present suggestive evidence that centralized states emerged from trade because it supported class differentiation, and that no one type of trade mattered most. In section 7, I conclude.

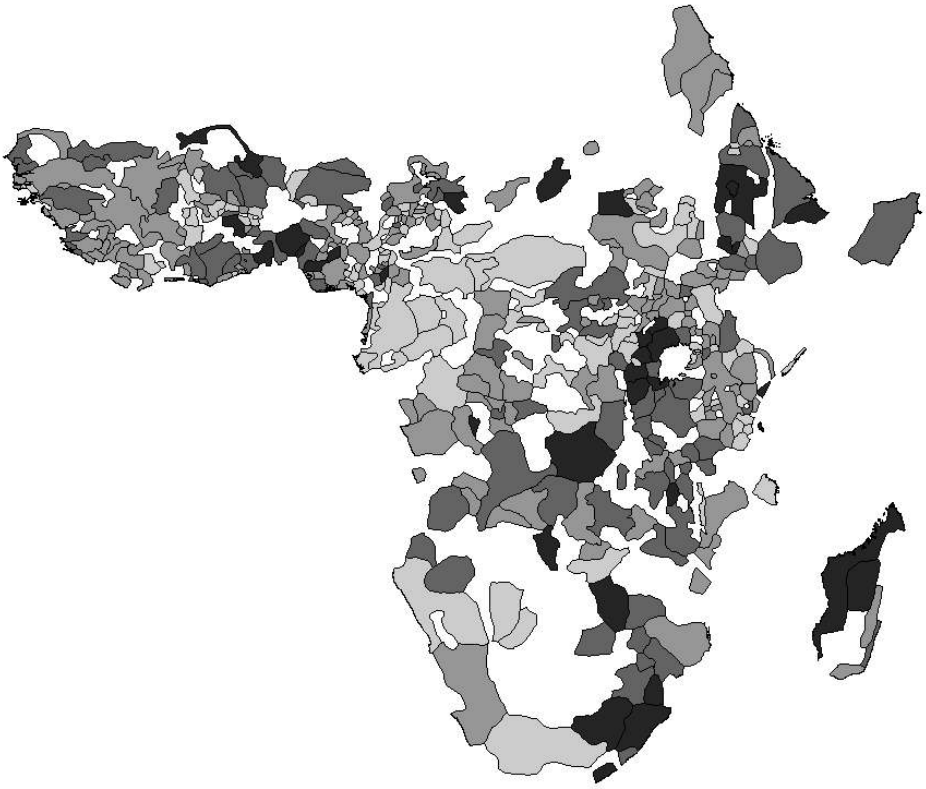
2. DATA

In order to test the Ricardian theory of African states empirically, I need data on three things – African states, the gains from trade, and other variables whose omission could potentially bias the results. In this section I describe my sources of for each.

To measure African states, I take data from Murdock's (1967) *Ethnographic Atlas*. This was originally published in 29 issues of *Ethnology* between 1962 and 1980. It contains data on 1267 societies from around the world.[1] From this source, I use variable 33, "Jurisdictional Hierarchy Beyond Local Community" to measure state centralization. This gives a discrete categorization between "No Levels" and "Four Levels." This is the same

[1]In particular, I use the revised Atlas posted online by J. Patrick Gray at http://eclectic.ss.uci.edu/~drwhite/worldcul/EthnographicAtlasWCRevisedByWorldCultures.sav.

FIGURE 1. State centralization



Source: (Murdock, 1967). Darker regions have more centralized states.

variable that was used by Michalopoulos and Papaioannou (2010), and originally converted by Gennaioli and Rainer (2007) into a discrete variable to capture the same concept.[2] The sample used for the analysis consists of the 440 sub-Saharan societies, including Madagascar, for which this variable is not missing. I map this measure of state centralization on Murdock's (1959) ethnic map of Africa in Figure 1.[3]

To measure the gains from trade, I follow Bates (1983) in assuming that the ability to trade across ecological zones will be particularly beneficial. To get information on ecology, I use White's (1983) vegetation map of Africa.[4] This classifies African vegetation into 17 major types, which I plot in Figure 2.[5]

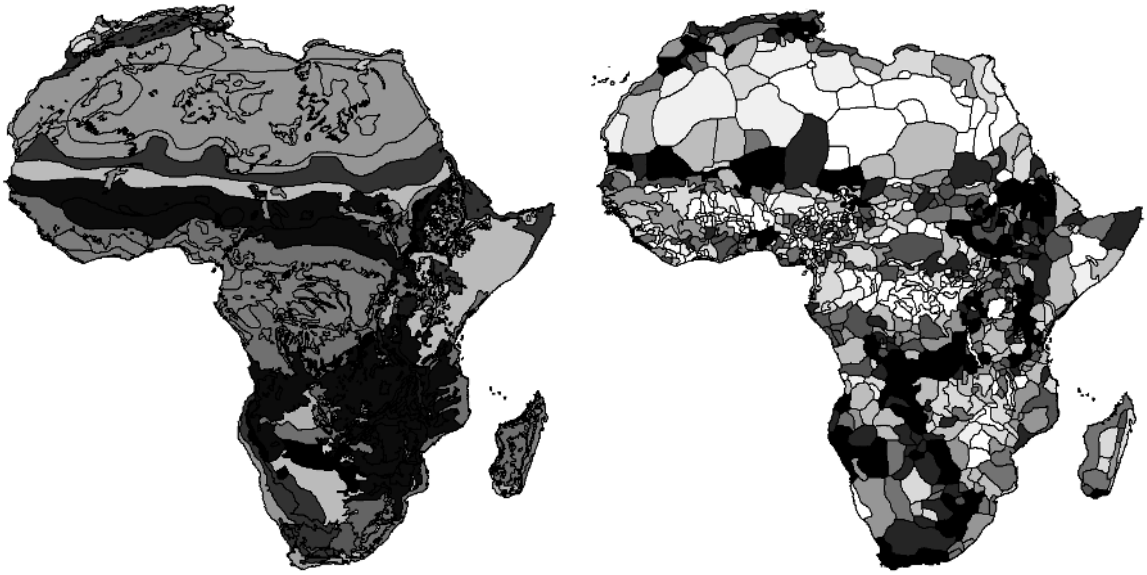
[2]In particular, they took a society as "centralized" if it had at least one level of jurisdiction above the local, and weighted this by each society's share in the national population in 1960 to construct a country-level measure of pre-colonial state centralization in Africa.

[3]This map is available on Nathan Nunn's website.

[4]This is available at http://www.grid.unep.ch/data/download/gnv031.zip.

[5]Altimontaine, anthropic, azonal, bushland and thicket, bushland and thicket mosaic, cape shrubland, desert, edaphic grassland mosaic, forest, forest transition and mosaic, grassland, grassy shrubland, secondary wooded grassland, semi-desert, traditional scrubland, woodland, woodland mosaics and transitions.

FIGURE 2. Vegetation types and ecological diversity



Source: White (1983). In the left-hand map of vegetation types, each shade of grey represents a different one of each of the sixteen major types. In the right-hand side map of ecological diversity, darker regions are more ecologically diverse

To construct a measure of how location relative to these regions could give rise to gains from trade, I calculate the share s_i^t of each society i's area that is occupied by each ecological type t. Then, I use a Herfindahl index to construct a measure of each society's ecological diversity:

$$\text{Ecological diversity}_i = 1 - \sum_{t=1}^{t=17} (s_i^t)^2. \tag{1}$$

The economic analogy for this measure is that, if ethnic groups were markets, vegetation types were firms and these area shares were market shares, this would be an index of the competitiveness of the market. As more ecological zones intersect a society's area, the natural ability to trade increases, and the index rises. I show a map of this variable in Figure 2. Visually comparing Figures 1 and 2, it is apparent that the most centralized African states are clustered along an East-West line between the Sahara desert and West African forest zone, in the diverse microclimates of the Ethiopian highlands, along the barrier between the equatorial rainforest and the East and Central African woodland mosaics, and on the divide between grassland and woodland in the continent's south-eastern corner. In section 4, I show that distance from an ecological divide performs as well as this index at predicting states, as does an alternative index created from FAO data. Summary statistics for the main measures of states and trade, as well as alternatives that will be explained later in the paper, are included in Table 2.

TABLE 2. Summary statistics

[Table 2 here]

It is possible that, even if there is a strong correlation between ecological diversity and state centralization, this is due to omitted variables correlated with the diversity index. I am able to join several other geographic variables to the data on ecology and states using the Murdock (1959) map of Africa. Except where I note otherwise, I take data stored in raster format, and for each society I compute the average value of the points within its territory.[6] In particular, I control for:

Major river: This is a dummy that equals one if the Benue, Blue Nile, Chire, Congo, Lualaba, Lukaga, Niger, Nile, Orange, Ubangi, White Nile, or Zambezi Rivers intersect the ethnic group's territory.

Ag. constraints: This is an index of combined climate, soil and terrain slope constrains on rain-fed agriculture, taken from the FAO-GAEZ project (see Fischer et al. (2001)). I interpret it as an inverse measure of land quality.

Dist. coast: This is average distance from each point in the ethnic group territory to the nearest point on the coast, in decimal degrees, calculated in ArcMap.

Elevation: This is average elevation in meters.

Malaria: This is average climatic suitability for malaria transmission, computed by Adjuik et al. (1998).

Precipitation: This is average annual precipitation (mm). Because some societies are too small for a raster point to fall within their territory, I impute missing data using the nearest raster point.

Ruggedness: This is a measure of terrain ruggedness used by Nunn and Puga (2009). It computes the average absolute difference between an elevation grid cell and its neighbors.

Temperature: This is the accumulated temperature on days with mean daily temperature above 0°C, computed using monthly data from 1961 to 2000 collected by the Climate Research Unit (CRU) of the University of East Anglia. I treat 55537 is as an error code and drop these points. I impute missing values using the nearest raster point.

Dist. L. Victoria: I compute the distance between each ethnic group's centroid and Lake Victoria using the globdist function in Stata.

[6]Raster data taken from the following sources: Ag. Constraints, `http://www.iiasa.ac.at/Research/LUC/SAEZ/index.html`, plate 28; Elevation, `http://epp.eurostat.ec.europa.eu/`; Malaria, `http://www.mara.org.za/lite/download.htm`; Precipitation, `http://www.iiasa.ac.at/Research/LUC/SAEZ/index.html`, plate 1; Temperature, `http://www.iiasa.ac.at/Research/LUC/SAEZ/index.html`, plate 6; Ruggedness, `http://diegopuga.org/data/rugged/`.

TABLE 3. Summary statistics

[Table 3 here]

Date observed: This is the rough date at which the information on the society was recorded, according to the *Ethnographic Atlas*. Dates of observation are missing for the Bomvana and Betsileo. I recode the Bomvana to 1850, to match the date of observation for the other Xhosa. I recode the Betsileo to 1900, the modal date for the other Malagasy societies in the data.

Dist. Atlantic ST: This is the minimum distance between the ethnic group's centroid and the nearest major source of new world demand for slaves (Virginia, Havana, Haiti, Kingston, Dominica, Martinique, Guyana, Salvador, or Rio), computed using the globdist function in Stata. The choice of ports here follows Nunn (2008).

Dist. Indian ST: This is, similarly, the distance to the nearest of Mauritius and Muscat.

Dist Saharan ST: This is the minimum distance to Algiers, Tunis, Tripoli, Benghazi, or Cairo.

Dist Red ST: This is the minimum distance to Mussawa, Suakin, or Djibouti.

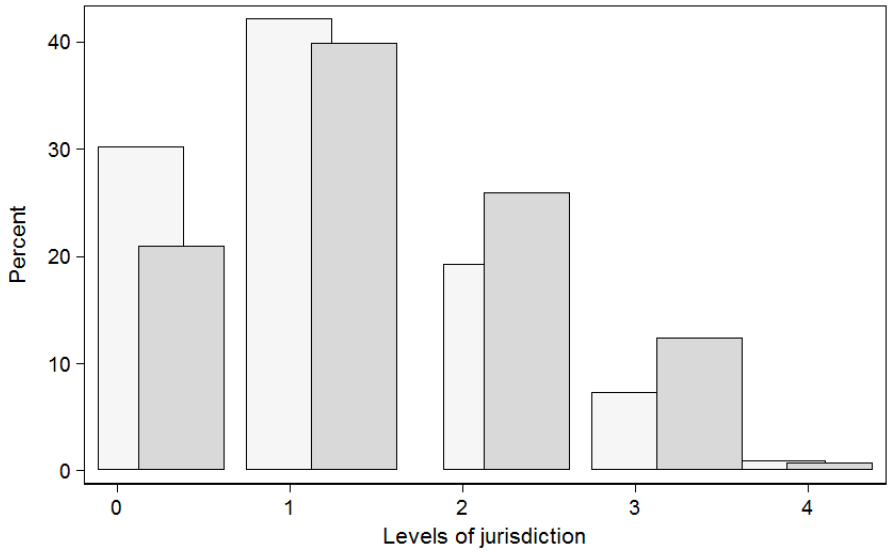
Crop type: I construct dummy variables out of the major crop types recorded in the *Ethnographic Atlas*. I treat these as exogenous characteristics of the natural environment, not as choices.

Summary statistics for these controls and any other variables used in the later analysis are given in Table 3. It is clear that the greatest difficulty with these data are that they are anachronistic – the institutional variables are recorded at an earlier date than the geographic controls and the measure of ecological diversity. Insofar as broad differences across regions in their capacities for rainfed agriculture, terrain ruggedness, ecological regions and similar variables do not change much, this should only add measurement error to the analysis. It is possible, however, that states transform their environments in ways that non-state societies cannot. I use both instrumental variables and non-anthropogenic predictors of ecological types in Section 4 to address this concern.

3. RESULTS

Before undertaking more sophisticated econometric tests, it is worth investigating whether there is a visible unconditional relationship between the ecological measure of gains from trade and state centralization. Because centralization is a discrete variable, a scatter plot will not present the data clearly. Instead, in Figure 3, I cut the sample into two – societies above and below the median in terms of ecological diversity. For each, I show a histogram of the relative frequencies of states of each level of centralization. It is clear that, below the median (the lighter bars), it is more common for societies to have no levels jurisdiction above the local, or one level. Above the median, there is a greater concentration of societies with two or three levels of jurisdiction. Both above and below

FIGURE 3. State centralization when ecological diversity is above and below the median



The dark bars are for ecological diversity above the median, the light bars for ecological diversity below it. Percentage is on the y axis and levels of jurisdiction on the x axis.

the median, it is quite uncommon for societies to have four such levels. The general pattern is clear; as ecological variation rises, the distribution of state centralization skews to the right.

To test econometrically whether there the gains from trade due to ecological diversity predict the existence of centralized states in pre-colonial Africa, I estimate the following using an ordered probit:

$$\textit{State centralization}_i = \alpha + \beta \textit{Ecological diversity}_i + X_i'\gamma + \epsilon_i. \tag{2}$$

In (2), state centralization is the number of levels of jurisdiction recorded by the *Ethnographic Atlas*. Ecological diversity is the index defined above. The matrix X_i includes the other controls reported listed in section 2, as well as (in some specifications) dummy variables for the thirteen ethnographic regions recorded in the sample.[7] Standard errors are clustered by region.

Table 4 presents the resulting estimates of β. I report the full set of coefficient estimates in Table 19 in the appendix, omitting them in the text for space. In column 1, only the measure of ecological diversity is included. Ecological diversity has a significant

[7]These are: African Hunters, South African Bantu, Central Bantu, Northeast Bantu, Equatorial Bantu, Guinea Coast, Western Sudan, Nigerian Plateau, Eastern Sudan, Upper Nile, Ethiopia/Horn, Moslem Sudan, and Indian Ocean.

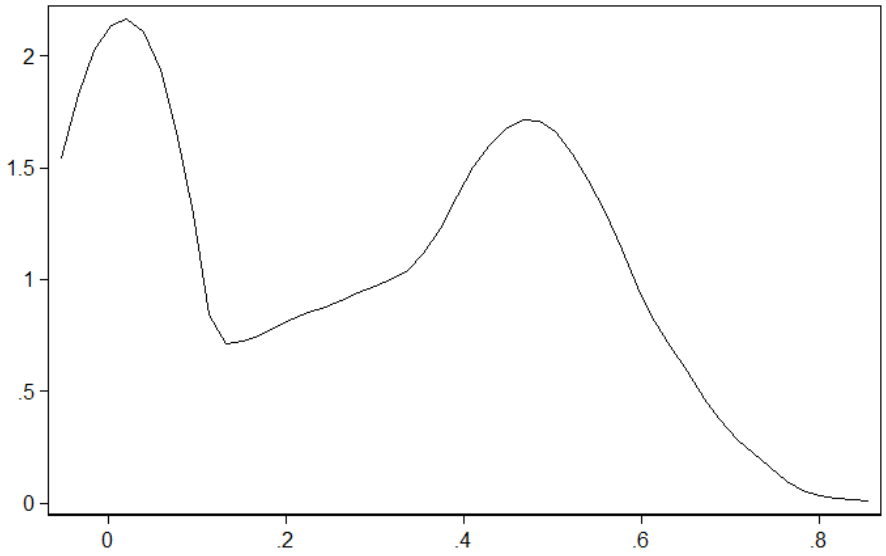
TABLE 4. Main results

[Table 4 here]

and positive correlation with state centralization. This is robust to the inclusion of additional controls in column 2, and the coefficient does not fall by much. While regional dummies do knock away some of the magnitude of the coefficient estimate, it remains significant at the 10% level. Surprisingly, few of the additional controls are statistically significant. The exceptions are elevation (positive in column 3), date of observation (negative in both columns), no major crop (negative in column 2), roots and tubers (positive in columns 2 and 3), major river (positive in columns 2 and 3), and ruggedness (positive in both columns). The positive effect of elevation is likely capturing benefits associated with mountainous regions, such as defensibility, less susceptibility to disease, and soil fertility. The negative effect of the date of observation likely suggests that colonial-era anthropologists chose to first study the least remote and most centralized African societies – the low hanging academic fruit. The negative effect of no major crop suggests that it is difficult to form a state without an agrarian base of any sort. The positive effect of roots and tubers is a surprise, and is likely proxying for unobservable features of forest-zone Bantu societies that better enabled them to create states. Major rivers are associated with trade, and further suggest that the Ricardian view of African states is largely correct. Ruggedness will be related to defensibility. Following Nunn and Puga (2009), it also predicts the ability of African societies to have escaped the worst effects of the slave trades.

Is the effect of ecological diversity large? In Table 4, I report the marginal effects of ecological diversity for each of the three specifications. Across specifications, the marginal effect of a one unit change in ecological diversity is to reduce the probability of having no levels of jurisdiction above the local by roughly 13-26 percentage points; the probabilities of having two or three levels increase to match this, though the effect is slightly stronger for three levels. A one unit change corresponds with a move of roughly four standard deviations in the ecological diversity measure. At a first glance, this would appear to suggest that the effect, while statistically significant, is small. However, ecological diversity has a very clearly bimodal distribution (see Figure 4). A move from one peak at zero to the other peak, at roughly 0.5, better captures the comparison between "diverse" and homogenous societies. This would suggest, then, that were a society to be taken from an ecologically homogenous region and placed in one that was typically diverse, the probability of having some form of state centralization would rise very roughly between 6 and 13 percentage points.

FIGURE 4. Kernel density of ecological diversity



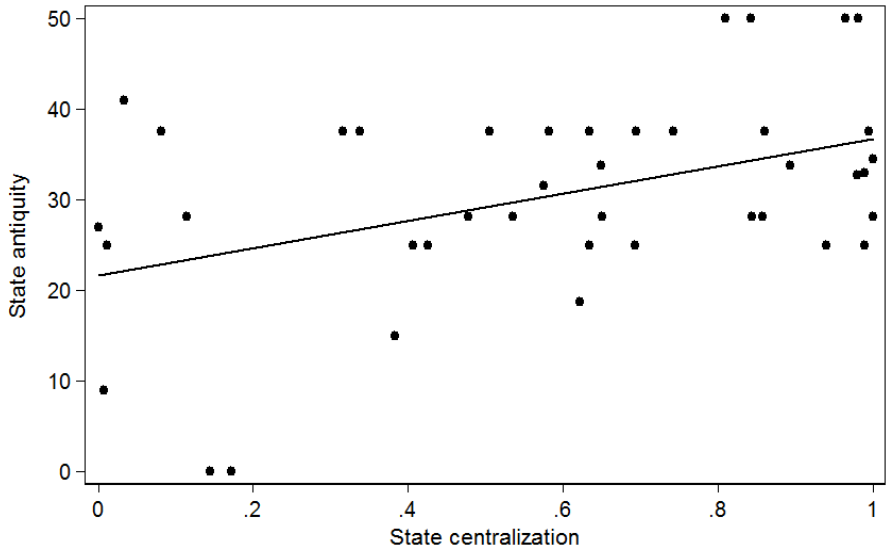
4. ROBUSTNESS

4.1. **Validity of the state centralization measure.** The measure of state centralization I use is far from ideal. One deficiency is that weak but pyramidal states will appear to be centralized in this data. The Bemba, as an example, have two levels of jurisdiction above the local. I would like to replicate these results with alternative measures of state strength. I am not, however, aware of any similar measure available for more than a small sub-sample of the ethnic groups in my data. Instead, I take two other approaches to validate the state centralization measure.

First, I show that it is strongly correlated with other measures of states for which I have data in other samples. Bockstette et al. (2002) and Chanda and Putterman (2007) construct indices of "state antiquity" for modern countries that reflect, in a given fifty year period, a) the existence of a government, b) the proportion of the modern country's territory covered, and c) whether the state was indigenous or externally imposed. I take this measure for the period 1850-1900 as a measure of state strength from roughly the same period as the centralization index. Gennaioli and Rainer (2007) aggregate the state centralization index to the country level using ethnic groups' population shares reported in the *Atlas Narodov Mira*. For 41 countries, I have both of the antiquity and centralization measures. In Figure 5, I show that there is a positive correlation between country-level centralization and state antiquity in the late nineteenth century.

Similarly, the *Standard Cross Cultural Sample* (SCCS) is a sub-sample of 186 societies recorded in the *Ethnographic Atlas* for which much larger number of variables are available. I have not used these in the present study, since only 28 societies in the SCCS

FIGURE 5. State antiquity and state centralization



State centralization is the country-level measure of Gennaioli and Rainer (2007). State antiquity is the variable "aosnew2," covering the period 1851-1900, based on Bockstette et al. (2002), and available on Louis Putterman's website. The regression coefficient is 15.096, and the standard error is 4.970. There are 41 observations.

TABLE 5. Robustness: Regressions of alternative SCCS measures of states on state centralization

[Table 5 here]

TABLE 6. Robustness: Alternative measures of states and diversity

[Table 6 here]

from sub-Saharan Africa. I can, however, show that the centralization measure I use is strongly correlated with the other measures of states coded in the SCCS.[8] For nearly thirty variables from the SCCS that capture ordinal measures of various aspects of state strength, I regress the variable on my measure of state centralization and report the results in Table 5. All of these are significantly related to state centralization, whether they measure the existence of a police force, the presence of taxation, or the capacity of states to enforce their decrees. The measure used in this study, then, is a valid proxy for state strength.

Second, I recode the state centralization measure into a dummy that equals one if the society has any levels of jurisdiction above the local. This may better capture state strength if, for example, it is impossible for a central authority to delegate administrative functions to regional leaders without also losing some control over them. I show in Table 6 that this measure is also positively related to ecological diversity.

[8]The centralization measure is v237 in the SCCS.

TABLE 7. Robustness: Estimation methods

4.2. **Validity of the gains from trade measure.** While ecological variation captures to some degree the presence of gains from trade, it is not clear that it is the best measure available. Bates (1983) divides societies into those that abut a divide, those that are diverse, and those that have no significant variation. As an alternative measure of the gains from trade, I use the White (1983) map to compute the average distance (in decimal degrees) of all points in a group's territory from the nearest boundary between two ecological regions. I present the results in Table 6. The statistical robustness of these results is stronger than the results obtained using ecological diversity. The results are consistent with a one standard deviation increase in the distance from an ecological divide raising the probability of having no levels of jurisdiction above the local by roughly 5 percentage points, with this increase coming from reductions in the probabilities that a society would have two or three levels of jurisdiction. Results using a binary indicator for whether the society is diverse at all (equivalent to whether it is intersected by a divide) are similar. Finally, because some of the ecological types recorded in White's map are similar, potentially leading to over-estimation of ecological diversity, I collapse these classifications into eight "simpler" types.[9] Results are again similar, though the effect of ecological diversity becomes marginally insignificant when regional fixed effects are added. Simplifying the classes in this manner does not do away with the sharply bi-modal distribution of diversity.

In addition, the FAO-GAEZ project created its own separate classification of ecological zones that can be used to construct an alternative diversity measure.[10] This source categorizes raster points in Africa into eleven "dominant ecosystem classes."[11] For each ethnic group in the data, I construct a measure analogous to that in (1) using the share of raster points for each ecosystem class, rather than the share of area. Results using this alternative measure of ecological diversity are presented in Table 6. As with the distance from an ecological divide, the coefficient estimates here are more statistically robust than main results.

4.3. **Validity of the estimation.** There are many possible reasons the approach taken to the estimation may be questioned. First, the "parallel regression" assumption of the standard ordered probit model, that the explanatory variables have the same impact on

[9]Mountain if altimontane, other if anthropic, water or azonal, bushland if bushland and thicket or bushland and thicket mosaics, shrub if cape shrubland, transitional scrubland or grassy shrubland, desert if desert or semi-desert, grassland if grassland, secondary wooded grassland or edaphic grassland mosaics, forest if forest or forest transitions and mosaics, and woodland if woodland or woodland mosaics and transitions.

[10]This is plate 55, downloaded from http://www.iiasa.ac.at/Research/LUC/GAEZ/index.htm.

[11]These are Undefined; Grassland; Woodland; Forest; Mosaics including crops; Cropland; Intensive cropland; Wetlands; Desert, bare land; Water and coastal fringes; Ice, cold desert, tundra; and Urban agglomerates.

TABLE 8. Robustness: Influential observations

[Table 8 here]

the latent index at all points, is often violated in real data. In Table 7, I re-estimate the main results using a generalized ordered probit model (Maddala, 1986), in which the coefficients on the latent variables are allowed to vary with the points where the categories of the dependent variable are separated. Convergence could not be achieved with regional fixed effects, so this specification is not reported. As before, ecological diversity predicts greater state centralization. Here, it is clear that this effect is not confined to any single level of centralization. Excepting at four levels, for which few observations exist, the effect is positive throughout.

Another potential concern is that, with only 440 observations in most specifications and thirteen regions, the clusters used for the standard errors may be too small. I have re-defined alternative clusters corresponding roughly to the United Nations' division of Africa into regions – Southern Africa (African Hunters, South African Bantu), Western Africa (Guinea Coast, Western Sudan, Nigerian Plateau, Moslem Sudan), Central Africa (Central Bantu, Equatorial Bantu, Eastern Sudan) and Eastern Africa (Northeast Bantu, Upper Nile, Ethiopia/Horn, Indian Ocean). Re-estimating the main results, I show in Table 7 that the results are now more statistically robust. The coefficient estimate falls less with the addition of these broader fixed effects than with fixed effects added for the regions as defined in the *Ethnographic Atlas*.

Finally, the inclusion of the major river dummy and distances from the coast, Lake Victoria, and slave trade ports may be capturing elements of trade based on features other than ecological diversity. Similarly, while the inclusion of the date of observation is intended to control for both remoteness and the possible impacts of European influence, it may be endogenous to state centralization. I show in Table 7 that excluding these variables barely affects the results.

It is also possible that the results here are driven by outliers. In Table 8, I control for this possibility by dropping influential observations from the sample. I estimate the main results by OLS with the full set of controls and without fixed effects. I then compute the leverage and dfbeta (for ecological diversity) statistics for each observation. In column 1 of Table 8, I drop all observations with leverage greater than $2(df + 2)/N$. In column 2, I remove any observations with absolute dfbeta greater than $2/\sqrt{N}$. The main result survives both of these procedures, though the former is marginally insignificant when fixed effects are included. It is also possible that the results are spuriously identified by variation within a single African region. In columns 3 through 6, I drop each of the "South African bantu," "Ethiopia/horn," 'Moslem sudan" and "Indian Ocean" in turn. These are the regions in which most states are concentrated. The results again are robust to each of these, though some are again marginally insignificant with fixed

TABLE 9. Robustness: Reverse causation

[Table 9 here]

effects. It is not the contrast between a handful of states and their neighbors that is driving the results.

4.4. **Possible reverse causation.** It is also possible that stronger states shape the environment; McCann (1999) describes, for example, the careful regulation of forest resources in Ethiopia before the twentieth century. To control for this possible reverse causation, I employ the standard deviation of temperature within an ethnic group's territory as an instrument for its Ecological diversity. This is intended to capture variation in ecological conditions that are beyond human control, and which give rise to differences in actual vegetation. The disadvantage of this instrument is that it cannot be computed for societies so small that they have only one raster point for temperature, or whose temperature measure was imputed from a nearest neighbor. I present the results in Table 9. In columns 1 through 3, I replicate the main results from Table 4 using OLS, for comparability with the other columns. In columns 4 through 6, I repeat the analysis, but restrict the sample to societies for which the instrument is available. The coefficient estimates are roughly similar, suggesting that selection into non-missing observations of temperature variance will not drive the results. In columns 7 through 9, I present the IV results. I also present the Kleibergen-Paap Lagrange multiplier and F statistics. While these are less statistically robust than the OLS results, the coefficients grow larger. There is no evidence that the ordered probit estimates overstate the effect of ecological diversity on state centralization. This argument is analogous to Frankel and Romer (1999), who instrument for trade openness using using geographical features in a cross-country setting and find that, while their effects are statistically insignificant, there is no evidence that OLS overstates the causal effect of trade on growth.

I am also able to use the FAO classifications to construct an alternative measure of ecological diversity that is not endogenous to human action. For each of the 365,788 raster points in that data, I regress an indicator for each of the eleven ecosystem classes on deciles in latitude, longitude, average precipitation, distance from the coast, accumulated temperatures above five and ten degrees, ruggedness, length of the growing period, and terrain slope, as well as dummies for each type of thermal growing period, frost-free period, and soil class.[12] From each of these linear regressions, I take the linear prediction as the probability that the raster point falls into that ecosystem type. I take the most probable class as the predicted type, and I am able to correctly predict a bit

[12]All of these are downloaded from the FAO-GAEZ website, calculated in ArcMap, or already described above, except for soil type, which is taken from Zobler's grouping of the world's soils into 106 classes such as "Eutric Cambisoils," downloaded from the UNEP website. These often differ from the resolution of the ecosystem raster, and so the nearest raster point in each plate is used.

FIGURE 6. Kernel density of predicted ecological diversity (FAO)

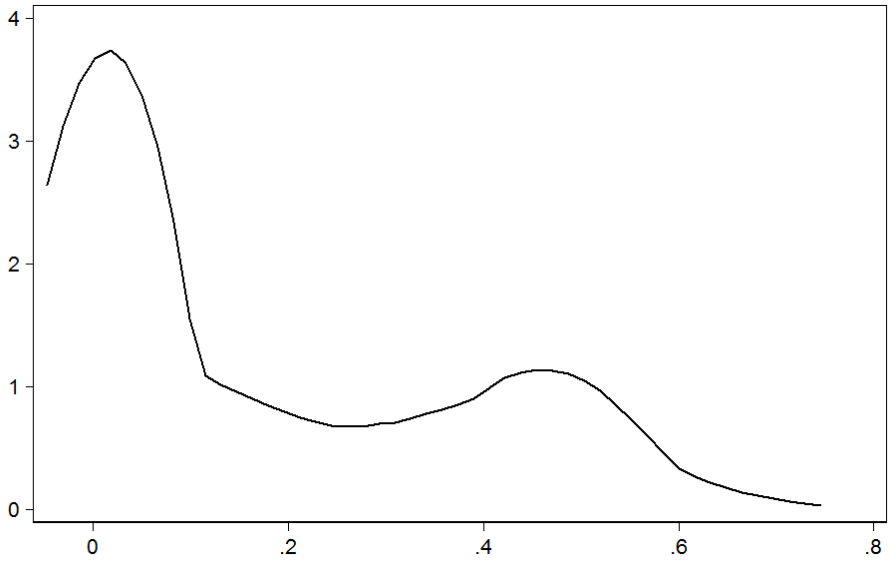


TABLE 10. Robustness: Reverse causation

[Table 10 here]

more than 70% of the raster points by this method. I re-calculate the diversity index using these predicted types. The results using this as a diversity measure are presented in Table 9. I continue to find that this predicts state centralization, except when regional fixed effects are included. This degree of robustness is surprising; because this method is particularly bad at predicting raster points in the less common ecological types, it under-predicts ecological diversity (see the kernel density in Figure 6). This further suggests the results are not due to strong states transforming their landscapes.

4.5. **Possible omitted heterogeneity.** As with any cross-sectional analysis, one of the most pernicious concerns is that the results are driven by unobservables that happen to be correlated with the causal variable of interest – in this case ecological diversity. While I have included an index of ecological diversity constructed from the area shares s_i^t of each ecological type for each ethnic group, I have not generally controlled for these directly. This is primarily for statistical power. These may, however, be significant determinants of states and correlated with ecological diversity. In Table 10 I add these as additional controls. The estimated effect of diversity is now larger, and more statistically robust.

Similarly, the inclusion of regional fixed effects may not fully capture the presence of localized unobservables. In the first panel of Table 10, I include quartics in latitude and longitude, which allow unobservables to vary smoothly across space. The results

are robust to including this, though they become insignificant when region fixed effects are also included. This is not surprising, since this leaves little variation in the data to provide identification.

In Table 10, I also account for omitted heterogeneity by re-estimating the main results using a spatial error model. This replaces the vector of errors in (2) with a spatially-weighted vector $\lambda W\epsilon$, and a vector of iid errors, u. W is a row-normalized spatial weights matrix. I select W so that all societies whose centroids are within ten decimal degrees of each other are given a weight inversely proportionate to their distance from each other. I report the results in Table 10.[13] The effect of ecological diversity remains statistically significant before fixed effects are included, though the estimated coefficients are smaller than in Table 9. Once additional controls are added, I find no evidence that λ is statistically significant. This may be because neighbors' observables fully explain correlations in states across space. In Table 10 I add the observable X of each society's neighbors, weighted by the matrix W. While these are strongly significant – neighbors' characteristics matter – a Moran's I test conducted on the residuals suggests that there is no spatial correlation conditional on these.

In Section 5, I attempt to deal with specific unobservables that are related to alternative interpretations of the data.

Finally, I take three more general approaches to deal with unobservables. First, I use the strategy suggested by Wooldridge (2002) for testing robustness to unobserved heterogeneity. I de-mean all of the standard controls included in Table 4, and interact them with my ecological diversity measure. A similar approach is used by Bhalotra and Cochrane (2010), for example. Results are reported in Table 10. I find that, while some of these interactions are significant, they do little to diminish the main result, suggesting that it cannot be explained away by heterogeneous treatment effects once controls are added.

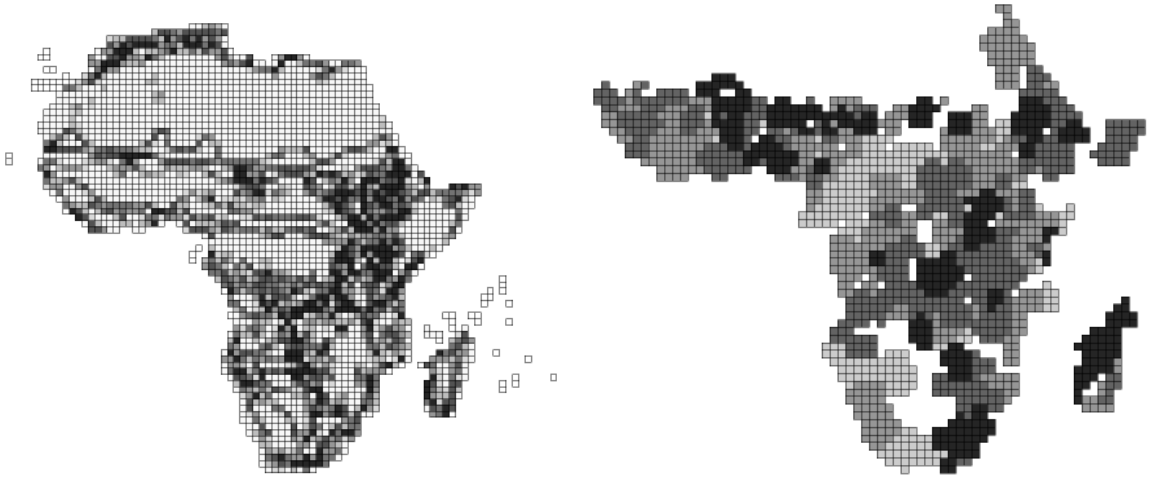
Second, I employ a nearest neighbor matching estimator in order to shift the bulk of identifying variation to those observations that are most similar along their observables.[14] Because these estimators consider a binary "treatment," I divide the sample into observations above and below the median in ecological diversity. Results are given in Table 10. The main results look qualitatively similar using this measure of ecological diversity. If observations are matched using their observable controls (column 4), the difference in state centralization between "treated" and "untreated" societies (the average treatment effect) remains statistically significant and is similar in magnitude to the comparable regression in column 2.

Third, I compute Altonji-Elder-Taber statistics. Replicating the main regression using OLS, I obtain the estimated coefficient on ecological diversity $\hat{\beta}_1$ and the estimated variance of the residuals $\hat{V}_1$. Regressing state centralization on the controls, I obtain

[13] In particular, I use the spatwmat and spatreg commands in Stata.

[14] In particular, I use the nnmatch command in Stata.

FIGURE 7. Ecological diversity and state centralization for artificial countries



Source: Murdock (1967) and White (1983). In the left-hand map of ecological diversity, darker regions are more diverse. In the right-hand map of state centralization, darker regions are more centralized.

the predicted values xb and the estimated variance of the residuals $\hat{V}_2$. Regressing ecological diversity on xb, I obtain the coefficient estimate $\hat{\beta}_2$. Altonji et al. (2005) suggest that if $\frac{\hat{\beta}_1 \hat{V}_2}{\hat{\beta}_2 \hat{V}_1} > 1$, it is unlikely that unobservables will explain away the result of interest. The estimates reported, 4.51 if fixed effects are not included and 3.08 if they are, do not support selection on the unobservables.

5. ALTERNATIVE STORIES

The results presented so far are not, however, completely dispositive. They are consistent with at least five alternative stories of the relationship between ecology, trade and states in pre-colonial Africa. In the remainder of this section, I give evidence that the Ricardian view of African states better fits the data.

5.1. **Larger areas are more diverse and require more centralized administration.** It is possible that, if administering a larger area requires more levels of administration, states that happen to cover greater territories for reasons unrelated to their strength will appear more centralized in the data. Further, larger areas may be mechanically more likely to be ecologically diverse. Conversely, there is the "territorial expansion model" of Spencer (1998, 2010), who argues that the delegation of administrative authority to regional units is a ruler's rational response to territorial expansion. Again, this could create a link between diversity and states that operates through the geographic scope of a society, and not through trade.

I have three strategies for dismissing this alternative explanation of my results. The first is to adopt the "virtual countries" approach of Michalopoulos (2008). I divide the

TABLE 11. Alternative stories: Artificial countries and area groups

[Table 11 here]

African continent into squares 1° by 1° (see Figure 7) and repeat the main analysis. Excepting coastal societies, the units of observation now all have the same area. Because several ethnic groups might intersect a single square, I keep the levels of jurisdiction of the most centralized state as that square's measure of state centralization; that society's crop type, date of observation, and ethnographic region are also kept for the analysis. Results are presented in Table 11. These are even more statistically robust than the main results. Similarly, because the unit of observation for the main analysis is the ethnic group, this approach mitigates the concern that multi-ethnic states will be "double-counted" in the data.

Second, I restrict the sample to societies of similar areas. I compute area quintiles for all ethnic groups. In Table 11, I report the results if the smallest quintile (Q1), largest quintile (Q5) or both are dropped. Results are robust to this sample restriction, and the coefficients on ecological diversity are greatest when both the largest and smallest ethnic groups are removed from the sample. Third, I control for area directly in Table 13 and show that the main effect does not disappear. I discuss this in greater detail below.

5.2. **States conquer trading regions.** The second alternative explanation of the results is that states emerge for reasons unrelated to the gains from trade, and then move to occupy prime trading regions through migration or conquest. My first argument against this alternative story is to appeal to the artificial country results above. That similar results can be achieved using units with regular boundaries suggests that diversity does not result from the irregularly-shaped boundaries of ethnic groups that have conquered their surroundings in ways that overlap with ecology. My second strategy for dismissing this alternative story is to give narrative evidence on the most influential (in terms of dfbeta) societies in the data. The top fourteen of these are listed in Table 12. The central argument of this paper is that trade causes states. If the centralized societies in this list are known to have developed states where they are, rather than migrating to capture them, this supports the Ricardian view. Further, if these states derived their wealth and power from their location relative to geographically-shaped trade routes, it is evidence that profitable trade routes were necessary for states to exist in these locations. I choose six of the most influential centralized states for case study evidence.

It is possible that not all societies are able to take advantage of gains from trade in order to become states. Groups that look different from their neighbors early on may expand in response to new trading opportunities not seized by other societies around them. This need not, on its own, imply rejection of the basic argument that this expansion was based on trade. What is critical is whether the society would have had the resources to become a regional power in the absence of revenues and other benefits coming from this trade. Alternative stories: Six influential states

TABLE 12. Alternative stories: Six influential states

[Table 12 here]

There are six centralized states in Table 9 – the Yoruba, Songhai, Toro, Suku, Luba and Lozi. To test the "Ricardian" view, I ask five questions in each case. First, did these societies participate in trade? Second, was trade a source of wealth for the society? Third, was trade a source of state power? Fourth, did these polities rise and fall with the fortunes of external trade? Fifth, did these states move to capture trading regions after they grew strong? I summarize the answers to these questions in Table 12. While the evidence does not in every case support the view that trade promotes states rather than the reverse (especially the answers to the fourth question), it is broadly consistent with this interpretation.

Yoruba. Morton-Williams (1969) argues that Yoruba Oyo and Akan Ashanti "developed under the stimulus of external trade, owing much from their beginnings to their proximity to the Mande trade routes in the north, and later also to their fortunate positions in the hinterlands during the growth of the maritime markets on the coast." Law (1977) is more guarded, suggesting that three factors together explain the rise of Oyo – the strength of its imported cavalry, its participation in long-distance commerce with the north, and its engagement in the Atlantic slave trade, the latter being followed by Oyo's imperial expansion. It is clear that trade was important in the Oyo economy. Oyo cloth was sold to Dahomey and Porto Novo, and the state imported kola nuts from the forest areas of Yorubaland for consumption and re-export. Salt and camwood were imported, and the latter was re-exported to Nupe. The horses on which the Oyo cavalry depended were also imported from the north, albeit in return for slaves. Critically, Law (1977) shows that the *Alafin* (king) relied heavily on trade taxes for his revenues; even direct taxes were collected in cowries and other currencies that were largely acquired through trade. Further, he and other chiefs engaged in trade personally. Trade upheld the authority of the *Alafin* by permitting him to maintain a superior standard of life, and by enabling him to distribute money and trade goods. The story that emerges from the accounts of Morton-Williams (1969) and Law (1977), then, is of a state that depended on trade across ecological zones for its existence, but was spurred to expand by the rise of the coastal slave trade. Neither author mentions conquest of neighboring regions as a pre-condition for trade.

Songhai. The Songhai Empire, with its capital at Gao, took advantage of a weakened Mali to become free from Malinke control in 1340. Levzion (1975) only links this weakness to trade conditions in a roundabout way, noting that Mali power in Timbuktu was dislodged by first Mossi and later Tuareg raids. Gao was captured by Moroccan forces in 1591, after which the empire fractured. Levzion (1975) attributes Songhai weakness at this point to a divisive civil war, and not to trade factors. It is clear that the empire

depended for its wealth on the trans-Saharan trade. Neumark (1977) attributes the success, not only of Songhay but of the states that preceded it, to "their strategic commercial position on the fringes of the Sahara." Songhay exported principally gold and slaves, as well as ivory, rhinoceros horns, ostrich feathers, skins, ebony, civet, malaguetta pepper, and semi-precious stones. It re-exported cloth and leather goods from Hausaland and kola from the forest zone. It imported salt, linen, silk, cotton cloth, copper utensils and tools, ironwork, paper, books, weapons, cowries, beads, mirrors, dates, figs, sugar, cattle and horses. Leo Africanus noted the empire's prosperity, as abundant food could be produced in the southern savanna and shipped to Timbuktu via the Niger (Levzion, 1975). Lovejoy (1978), similarly, notes that Timbuktu and Gao, Songhay's most important cities "controlled trans-Saharan trade, desert-side exchange, and river traffic on the Niger. Located in the Sahil but with easy access to western and central savanna, they were at the hub of overland and river routes where staples of desert-side trade such as grain and salt could readily be transferred from river boat to camel, and vice versa." Songhay was the first Sudanic empire whose power reached as far as the salt mines of Taghaza (Levzion, 1975). Shillington (1989) notes taxes on trade as a key source of government revenue.

It is true that, after its establishment, Songhay did expand – Bovill (1995) writes that Songhay moved into the Hausa states to capture their quality land and into Air to drive out Tuareg raiders. Levzion (1975) adds that these conquests were largely along the Niger river, because of Songhay's dependence on its Sorko fleet for its military power. This is not necessarily counter to the Ricardian view. In the case of Air, this was a movement to protect existing trade interests, not to secure new routes. The strength of Songhay, like many of the states that came before it, had already been based on its favorable location for trade before it began its expansion.

Toro. One of Uganda's four traditional kingdoms, Toro broke free of Bunyoro in 1830, was reconquered in 1876, and became independent once again with Lugard's help in 1891. The base of economic production in Toro was hoe-cultivation of finger-millet, plantains, sweet potatoes and beans, though a cattle-keeping class existed (Taylor, 1962). Under Bunyoro control, the territory produced iron goods and salt for sale within the interlacustrine region (Ingham, 1975). This shaped the revenues of subordinate states; the Babito chief of Kisaka introduced agents to collect tax from both salt producers and traders, a portion of which was sent to Bunyoro (Ingham, 1975). Trade was a source of revenue to the state, both through tribute collection and direct control. Taylor (1962) states that the king, chiefs and lords of Toro maintained control over land, cattle, lakes, salt lakes, medicinal springs, canoe services, and "certain commodities having exchange or prestige value," such as tusks and lion skins. They collected many of these same goods as tribute, as well as labor and military service, and reallocated them to relatives, chiefs, officials and others. He further suggests that the "distribution of goods and services" was mainly through kinship and feudal systems, though barter was also present.

Ingham (1975) describes the Toro region as one of relative prosperity. The Toro kings sold slaves, ivory and cows to Arab traders in return for guns and cloth (Taylor, 1962). Independent Toro was also an exporter of salt; Good (1972) notes that, until 1923, the *okukama* or *Mukama* (king) of Toro held personal ownership over the trade in salt from Lake Katwe and other lake deposits near Kasenyi. This was sold for regional consumption in Bunyoro, ocassionally as far east as Lake Victoria, in Rwanda and Tanzania, and into the Congo perhaps fifty miles beyond the present border (Good, 1972). This was, however, an example of a state expanding to take advantage of a tradable resource. Lake Katwe was in Busongora, which had also seceded from Bunyoro, and which was an early conquest by independent Toro (Good, 1972). Bunyoro recaptured the territory during the 1880s.

Suku. The Suku are a petty state in the Congolese savanna, part of the Central African "matrilineal belt." They appear to have become independent from the Lunda empire during the early nineteenth century by moving into vacant land east of the Kwango valley (Kopytoff, 1965). This was precipitated by the collapse of Lunda rule over the region as a whole (Kopytoff, 1964). Kopytoff (1965) writes that Suku participation in the rubber trades of the nineteenth century and Second World War was "marginal," and that these periods were "the only ones when the Suku had any cash crops to sell. At present, the region is both too poor and too far from the centers to export a commercially feasible product of any kind." Similarly, the Suku lacked a developed system of market places and itinerant trade was "not at all developed" (Kopytoff, 1967). The Suku did, however, participate as middlemen in the long-distance trade between the raffia and palm-oil producers north and east of them and southern groups who traded directly with the Portuguese (Kopytoff, 1967). They also purchased raw raffia for weaving into cloth, which was exported to the southeast along with palm oil in return for shell money and European goods, some of which were exported (Kopytoff, 1967). The Suku were known for their wealth in shell money. The Suku *MeniKongo* (king) actively ruled over some twenty or thirty villages around the capital, and administered the remainder of his kingdom through regional chiefs. Kopytoff (1964) tells us that shell money was legal tender in rendering tribute to chiefs, so the same logic as used by Law (1977) implies that direct taxes were, indirectly, taxes on trade.

Given that much of the Suku kingship terminology is Lunda, Kopytoff (1965) supposes that Suku political organization (like that of the neighboring Yaka) is also Lunda in origin. Lunda dominated the upper Kasai basin from c. 1700 (Birmingham, 1976). Within the empire's territory lay both copper mines and salt, which were sources of both trade and tribute (Birmingham, 1976). Slaves for export were collected through both war and the tributary system of tax collection, and this revenue allowed the royal court to judiciously distribute the trade goods over which it held a virtual monopoly (Birmingham, 1976). The Suku inherited state forms from their trading predecessor, and prospered from their position as middlemen.

Luba. The separate Luba states were not unified until the eighteenth century (Birmingham, 1976). Before this period, separate Luba states such as Kikonja or Songye had control of localized dired fish, salt, oil palm, raffia cloth, and copper-working industries (Birmingham, 1976). Trade was largely "vertical," collected by chiefs as tribute, and no class of "horizontal" traders exchanging goods between producers emerged before the growth of the Luba empire. In the late eighteenth century, Luba Lomami responded most vigorously to the new long distance trade in ivory and slaves (Birmingham, 1976). Bisa traders exchanged cloth, beads and cattle for tusks that were sold subject to taxation and supervision by either the royal household or by chiefs (Birmingham, 1976). This trade was preceeded by "pioneering chiefs," who advanced into new lands and arranged for the purchase of ivory while at the same time creating "a more or less permanent Luba political superstructure" behind which the Bisa traders followed (Birmingham, 1976).

After 1780, the Luba expanded, first into the space between the Lualaba and Lake Tanganyika, and later into the fishing and palm oil areas of the Lalaba lakes, the copper production portions of the Samba, and the ivory-producing province of Manyema (Birmingham, 1976). At its peak in the mid-nineteenth century, the empire presided over "a wide-ranging and international trade" in oil, salt, poisons, drums, slaves, copper, palm cloth, baskets, iron, skins and fish. Wilson (1972) argues that long-distance trade was the cause of this expansion. The slave trade pushed Lunda to establish Kazembe as a tributary kingdom. Sub-regional specializations, such as Sanga production of copper crosses, was stimulated by the influx of trade goods. Luba-Lomami itself began as a producer of salt and hoes, sold in neighboring regions. New trades developed in response to trade goods; for example, the traditional trade with the Holoholo was supplemented with beads and ivory. Birmingham (1976) argues that the decline of the Luba kingdom followed that of the ivory trade. Their Yeke-Nyamwezi trading partners began to focus on copper, conquering production centers belonging to Mpande and Katanga. Swahili-Arab traders began to trade directly into the forest, cutting out the Luba. With ivory becoming scarce and the price of slaves declining, the Luba were unable to purchase the guns needed to secure their power without exporting large numbers of internally captured slaves. The kingdom disintegrated into warring factions and became dominated by its neighbors.

Lozi. The pastoral Lozi (or Barotse) have occupied the Barotse floodplain of the Zambezi river since roughly 1600 (Gluckman, 1941), and have had a centralized king since at least as early as the start of the nineteenth century (Birmingham, 1976). There was considerable trade within Lozi territory in the specialized products of each region – bulrush millet and cassava meal, wood products and iron were brought in from the bush areas, and the Zambezi facilitated transport (Gluckman, 1941). He further suggests that Lozi domination of its surroundings was facilitated by the society's internal cohesion, stemming from the inequality made possible by royal control of the most productive farming

mounds within the floodplain, as well as a need to protect cattle in outlying areas during the flood season. The result was that the Lozi traded with its neighbors as they did not trade among themselves. Further, the king and princess chief both collected tribute in the form of specialized production of the "tribes" under his command, including canoes, weapons, iron tools, meat, fish, fruit, salt, honey, maize and manioc (Birmingham, 1976).

The Lozi were ruled between 1840 and 1864 by the Sotho-speaking Kololo who invaded from the south. The Lozi spurned Lovale traders before the emergence of the trade in slaves and ivory in southern Kololo around 1850. Before this, they had sent traders to the Lunda areas of the upper Zambezi, trading only indirectly with the Portuguese (Flint, 1970). Flint (1970) suggests that the major change was the rise of the ivory trade relative to the slave trade by 1853. He argues that the Kololo used Livingstone as a 'prestigious outsider,' helping them negotiate with the peoples through whose territory the Lozi traded. By 1860, long distance trade had become of major importance to the Barotse. The Kololo obtained ivory either as tribute from the Barotse or by selling iron hoes to the Tonga, and then sold this ivory either to middlemen or directly to the coast. The Lozi also exported cattle and forest products in return for trade goods during this period (Gluckman, 1941). Trade gave the Kololo king an independent power base, strengthening him against other chiefs who depended on cattle raiding for revenue. He worked to establish a new set of 'caravan chiefs' (Flint, 1970).

Flint (1970) suggests that the more trade-oriented Barotse of the floodplain came into conflict with the southern Kololo, whose raids on their neighbors disrupted trade, and who refused to move the capital into the floodplain where it would be better situated relative to trade routes. Further, the king received profits from ivory and distributed within his court, shutting out the Barotse. Though the details are not clear, Birmingham (1976) ties the restoration of Lozi independence to this trade. He argues that traders operated independently of the state, and the second Kololo king was followed by an interregnum before a Lozi king was restored in the 1870s. He suggests that the western ivory trade "may have facilitated" this restoration. Gluckman (1941) suggests that the restored Lozi king traded cattle, ivory and slaves on his own account for trade goods that he distributed, both among his own people and among subject tribes.

Overall, these are consistent with the Ricardian view that opportunities for trade give rise to states. While Songhai and Oyo expanded to capture more territory, they did so after having arisen in a location favorable to trade across ecological zones. The Luba too expanded after 1780, but did so based on power already acquired through proximity to the Bisa ivory trade. When that trade declined, the kingdom collapsed. The pre-Kololo Lozi dominance over surrounding peoples, while stemming in part from the cohesion deriving from their environment, also depended on the ability to trade and collect tribute in the diverse products of their neighbors. That the Suku participated in long-distance trade while possessing only limited internal markets further supports that

TABLE 13. Alternative stories: Additional controls and ethnic competition

[Table 13 here]

it is the ability to trade the products of different macro-ecological regions that matters most. In every case, rulers relied heavily on taxing trade. The exception is Toro, which emerged in a region with an existing trade in salt and iron, but conquered Busongora in part to capture the most important source of salt in the region. Toro, however, inherited its political structure from Bunyoro, which had previously grown strong in part due to its sale of metal goods and control of the Kibiro salt industry.

My third strategy for dismissing this alternative explanation is to control directly for area. This is not done in the main analysis, because it is potentially endogenous. States that independently develop strong states might have larger areas, biasing the coefficient on both area and potentially on the other coefficients. With that caveat in mind, if it is only through expansion that states become correlated with ecological diversity, there should be no correlation conditional on area. I include it, then, as an additional regressor in Table 13. The impact of area is negligible, and the coefficient remains significant, positive, and of a similar magnitude.

5.3. **Islands of quality.** The third alternative story is that states emerge to protect "islands" of particular quality. This competition is fiercest when these islands are very different from neighboring areas, and areas with diverse land qualities will similarly have diverse ecologies. Jones (2003, p. 105-106), similarly, argues that the European patchwork of nation states (as opposed to China's unifying empire) was based on the prevalence of fertile islands separated by natural boundaries. This is also similar to Allen's (1997) view that the Egyptian state benefitted from the fact that its citizens were confined to a fertile valley surrounded by desert. Carneiro (1970), likewise, has noted that the Nile, Tigrus-Euphrates, and Indus valleys as well as the Valley of Mexico and the mountain and coastal valleys of Peru were all areas of circumscribed agricultural land. In columns 3 and 4 I control for the range of agricultural constraints – the difference in land quality between the best and worst points in a society's territory. This does diminish the effect of ecological diversity, though it remains significant when regional fixed effects are not included. That the range of agricultural constraints is not significant, however, suggests it should not be included in the best specification. Results are also robust to including the presence of bovines as a control (not reported).

5.4. **Population density.** Fourth, it is possible that ecological diversity is correlated with population density, which alone explains the centralization of pre-colonial African states. I add population density in 1960, published by the United Nations Environment Programme, as a proxy for historical population density.[15] This is reported in columns 5 and 6 of Table 13, and the effect of ecological diversity remains intact.

[15]Raster data taken from `http://na.unep.net/datasets/datalist.php`.

TABLE 14. Mechanisms: Other institutional outcomes

[Table 14 here]

5.5. **Ethnic competition.** Fifth, it is possible, combining the stories of Michalopoulos (2008) and Tilly and Ardant (1975), that ecology-specific human capital gives rise to a greater number of ethnic groups in regions of diverse ecology, and that competition between these groups leads to greater state centralization. To show that this is not driving my results, I return to my sample of artificial countries. For each square, I count the number of ethnic groups that intersect it in Murdock's map, and include this as an additional control in Table 13. In column 1, there is a positive but insignificant correlation between diversity and the number of ethnic groups in an "artificial country." This is an artefact of the specification chosen – if I take the full sample of artificial countries (rather than only those for which information on states are available) the correlation is strong and positive, confirming the Michalopoulos (2008) result with a different measure of geographic heterogeneity. If I include the number of ethnic groups as an additional control, this does not diminish the direct effect of ecological diversity on states, suggesting that this and the gains-from-trade explanation of states are not mutually exclusive.

6. MECHANISMS

6.1. **How does trade cause states?** There are many reasons centralized states might arise due to gains from trade. In Table 14, I test whether the *Ethnographic Atlas* supports any of these. The first possible mechanism is to take over the authority of other smaller states in its vicinity. The atlas contains a variable (V32) that records the number of "levels of local jurisdiction." Following Bolt and Smits (2010), I take this as a crude measure of the strength of local states, and use it as an outcome in place of state centralization in (2). While there is a suggestive negative correlation between ecological diversity and local states when no other controls are added, this is not robust to the inclusion of other variables or to region fixed effects. Similarly, V72 records the rules for succession to the office of the local headman. I construct a "headman is appointed" dummy if this rule is "appointment by higher authority." There appears to be no correlation in the data. I am not able to conclusively test for the spread of Islam as a mechanism. The data only state whether high gods are "supportive of human morality", which is only positive for a handful of societies outside of the Moslem Sudan, Western Sudan and Ethiopia. This is only for a sample roughly half the size of the main sample, and does not appear to be related to ecological diversity, though its collinearity with the region fixed effects make it impossible to test whether it this is the case within regions.

Another possible mechanism for the rise of states is the ability of kings to amass wealth through taxation, letting them gain prestige and control the flow of tribute. To

TABLE 15. Mechanisms: Other sources of trade

[Table 15 here]

test for this mechanism, I use V66, "class stratification among freemen," which is divided into five levels. In order, these are "absence among freemen," "wealth distinctions," "elite," "dual," and "complex." Here there is a strong relationship between gains from trade and inequality. Results (not reported) are similar if a binary class stratification measure is used. Similarly, I test whether there is a relationship between gains from trade and one particular form of inequality – slavery. V70 codes slavery into four levels. These are "absence or near absence," "incipient or nonhereditary," "reported but type not identified," and "hereditary and socially significant." While there is a positive correlation of ecological diversity and slavery conditional on other controls, this is not apparent in the unconditional correlation, nor when regional fixed effects are added. Many of these results are statistically weak, but they do suggest strong links between trade and class stratification.

It is also interesting to note that the ecological diversity variable does predict modern economic activity, though not robustly. I use the same $\ln(1 + \text{Avg. light density})$ normalization of 2009 nighttime lights as Michalopoulos and Papaioannou (2010) to test this. The ecological diversity measure predicts conditional, though not unconditional, differences in modern light densities. This effect disappears, however, when standard errors are clustered by ethnographic regions.

6.2. **What sort of trade matters?** While the ecological diversity measure serves as a proxy for the capacity to trade products from different ecological zones, it will not capture other forms of trade. In Table 15, I test whether three other sources of trade – fishing, iron, and gold – give similar rise to states. A society's percentage dependance on fishing is V3 in the *Ethnographic Atlas*. I find no correlation between this and states. While it is possible that the impact of fishing is being hidden by the impacts of other controls (notably coastal distance and major rivers), regressing states on the fishing variable similarly does not yield a significant result (not reported). To test the importance of minerals, I take data from the US Geological Service's Mineral Resources Program.[16] These records contain data on both metallic and nonmetallic mineral resources at specific sites, with their latitudes and longitudes. "Iron" is the number of deposits of iron found within an ethnic group's territory, and "gold" is analogously defined. If there is likely to be any endogeneity bias from using modern data, it will be positive, since states that have inherited the strength of their pre-colonial predecessors will likely be better able to exploit their countries' resources. Despite this, I find no evidence that iron matters. Gold enters significantly having either mineral within an ethnic group's

[16]The data are available at `http://mrdata.usgs.gov/`

TABLE 16. Mechanisms: Regressions of SCCS measures of trade on state centralization

[Table 16 here]

TABLE 17. Mechanisms: Local or long distance trade?

[Table 17 here]

TABLE 18. Mechanisms: Is Africa different?

[Table 18 here]

territory when no controls are added, though the effect of gold is marginally insignificant with controls. "Salt" is the number of salt-producing cites listed by Sundstr
"om (1974) within an ethnic group's territory.[17]

While the sample of African societies in the SCCS is too small to use for comparing that source's data on trade with the main sample here, I can test whether state centralization is correlated with any particular form of trade in the SCCS's global sample of ethnic groups. In Table 16, I present the results of regressing several of these indicators on the state centralization measure and a constant. The presentation here is similar to Table 5. I find that societies with states are more likely to trade for food, through more levels of intermediation, and that this trade is more important to their subsistence. Political power is more likely to depend on commerce in more centralized states, trade and markets are more likely to exist, and exchange is more important both within and beyond the community, though this latter correlation is not significant at conventional levels.

Interestingly, Tables 16 and 15 suggest that it is more mundane, intra-community trade in products such as food, rather than long distance trade in products such as gold and ivory, that matters for the formation of states. The main data sources here do not allow for these two types of trade to be conclusively tested against each other. However, the "ecological diversity" measure is more intuitively related to trade that is possible within an ethnic group's borders, while the "distance from an ecological divide" variable is more suggestive of long distance trade. In Table 17, I test whether the estimated effect of either one disappears when both are included as regressors. They are, however, strongly correlated (see column 1), which limits the power of this test. With controls, both coefficients fall relatively 40% relative to their values in Tables 4 and Table 6. The distance from a divide remains more statistically robust, especially once regional fixed effects are added. It is not, then, possible to rule out the importance of either long distance or local trade.

[17]Of 271 sites he lists, I match 84 to ethnic groups in the data and 157 to specific geographic locations, such as Cape Lopez. For 30 I could not find a match.

6.3. **Is Africa different?** In other work, I have assembled an analogous data-set for all 1,267 societies of the *Ethnographic Atlas*.[18] While some of the controls used here are either not available or computed somewhat differently in that data, I am able to expand the present analysis to the whole world. Results in Table 18 suggest that Africa is not different: in a sample of more than 1,000 societies from around the world, ecological diversity continues to predict the existence of states.

7. CONCLUSION

I have used this paper to provide empirical support for Bates's (1983) Ricardian view of pre-colonial African states. The gains from trade stemming from ecological diversity predict the presence of state centralization across sub-Saharan societies recorded in the *Ethnographic Atlas*. Moving from a homogenous zone to one that is ecologically diverse predicts that the chance a society is centralized rises between 6 and 13 percentage points. Distance from an ecological divide serves as well in predicting states. There is no evidence this is overstated due to endogeneity or the influence of outliers or specific ethnographic regions. The histories of African societies are consistent with this interpretation of the data, rather than one in which states emerge and then migrate. Similarly, area, defense of fertile islands, correlation with dense population, and ethnic competition do not explain the results. Michalopoulos and Papaioannou (2010) show that the strength of pre-colonial African states does more to predict modern development, using night-time lights as a measure, than country-level institutions. These states are rooted in the intersection of ecology and trade.

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[18]For more details, see Fenske (2011).

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TABLE 19. Full results

[Table 19 here]

Table 1. Bates' evidence

	Abuts ecological divide	Diversified area	No ecological variation
		Political structure	
Kinship	12%	17%	40%
Chiefs	38%	50%	20%
Central monarch	50%	33%	40%
N	8	6	20
		Central bureaucracy	
Absent	25%	40%	67%
Present	75%	60%	33%
N	8	5	18
		National army	
Absent	38%	40%	50%
Present	62%	60%	50%
N	8	5	20
		Army commanded at	
Local level	62%	40%	50%
Regional level	0%	20%	10%
National level	38%	40%	40%
N	8	5	20

Notes: Adapted from Bates (1983), p. 43.

Table 2. Summary Statistics

	Mean	s.d.	Min	Max	N
			Outcomes		
State centralization	1.15	0.93	0	4	440
Any centralization	0.73	0.44	0	1	440
Local state	2.91	0.68	2	4	439
Class stratification	1.25	1.41	0	4	364
Slavery	1.83	1.03	0	3	383
Headman appointed	0.066	0.25	0	1	320
Light density	1.50	0.18	1.15	3.34	440
			Gains from trade		
Ecological diversity	0.30	0.23	0	0.80	440
Eco. Div. (FAO)	0.47	0.23	0	0.80	440
Predicted Eco. Div. (FAO)	0.20	0.21	0	0.70	440
Dist. ecological divide	0.45	0.53	0.019	2.95	440
Any diversity	0.78	0.42	0	1	440
Salt	0.42	0.88	0	6	440
Gold production	0.34	1.86	0	24	440
Iron production	0.12	0.33	0	1	440
% dep. on fishing	8.32	10.9	0	70	440

Table 3. Summary Statistics

	Mean	s.d.	Min	Max	N
			Controls		
Major river	0.23	0.42	0	1	440
Ag. constraints	5.41	1.06	2.94	8.92	440
Dist. coast	5.54	3.76	0	14.9	440
Elevation	728	520	-7.41	2,308	440
Malaria	0.83	0.27	0	1	440
Precipitation	1,194	528	32.4	2,954	440
Ruggedness	71,792	70,413	0	421,381	440
Temperature	8,882	1,112	5,295	10,699	440
Dist. L. Victoria	2,198	1,438	131	5,708	440
Date observed	1,919	21.6	1,830	1,960	440
Dist. Atlantic ST	6,688	1,515	3,671	9,949	440
Dist. Indian ST	4,546	1,589	1,028	7,953	440
Dist. Saharan ST	3,333	975	806	6,999	440
Dist. Red ST	2,887	1,360	107	5,773	440
Crop: Missing	0	0	0	0	440
Crop: None	0.025	0.16	0	1	440
Crop: Trees	0.084	0.28	0	1	440
Crop: Roots/tubers	0.19	0.39	0	1	440
			Other variables used		
Temperature s.d.	294	292	0	1,635	370
Area	2.43	3.64	8.2e-06	27.0	440
Pop. density	22.2	28.5	0	311	440
Ag. Constraints Range	4.66	1.95	0	9	440
Grain endemicity	0.35	0.25	0	0.76	425

Table 4. Main Results

	(1)	(2)	(3)
	State centralization		
Ecological diversity	0.794***	0.703***	0.437**
	(0.266)	(0.234)	(0.219)
Other controls	No	Yes	Yes
Region F.E.	No	No	Yes
	Marginal effects		
0 levels	-0.259***	-0.220***	-0.132**
	(0.087)	(0.069)	(0.064)
1 level	-0.022	-0.024	-0.016*
	(0.038)	(0.029)	(0.009)
2 levels	0.152***	0.149***	0.098**
	(0.052)	(0.050)	(0.048)
3 levels	0.118***	0.091***	0.048**
	(0.044)	(0.034)	(0.024)
4 levels	0.010	0.004	0.001
	(0.008)	(0.004)	(0.002)
Observations	440	440	440

*** p<0.01, ** p<0.05, * p<0.1. Regressions estimated by ordered probit. Standard errors in parentheses clustered by region. Other controls are those listed as "controls" in the table of summary statistics.

Table 5. Regressions of alternative SCCS measures of states on state centralization

Dependent variable	Coef	s.e.	N
v81: Political autonomy	0.485	0.082	182
v82: Trend in political autonomy	0.395	0.069	182
v84: Higher political organization	0.400	0.071	181
v85: Executive	0.801	0.086	181
v89: Judiciary	0.261	0.022	181
v90: Police	0.889	0.080	178
v91: Administrative hierarchy	0.943	0.071	181
v700: State punishes crimes against persons	0.185	0.033	91
v701: Full-time bureaucrats	0.242	0.026	91
v702: Part of kingdom	0.136	0.029	86
v756: Political role specialization	1.220	0.167	89
v759: Leaders' perceived power	0.432	0.069	89
v760: Leaders' perceived capriciousness	0.240	0.097	66
v761: Leaders' unchecked power	0.385	0.076	85
v762: Inability to remove leaders	0.420	0.100	77
v763: Leaders' independence	0.426	0.070	86
v764: Leaders' control of decisions	0.584	0.136	87
v776: Formal sanctions and enforcement	0.412	0.068	89
v777: Enforcement specialists	0.461	0.076	88
v779: Loyalty to the wider society	0.228	0.104	83
v784: Taxation	0.536	0.069	84
v785: Rareness of political fission	0.154	0.102	64
v1132: Political integration	1.185	0.070	118
v1134: Despotism in dispute resolution	0.132	0.023	104
v1135: Jurisdictional perquisites	0.172	0.067	34
v1736: Tribute, Taxation, Expropriation	0.961	0.152	77
v1740: Levels of political hierarchy	1.600	0.196	100
v1741: Overarching jurisdiction	0.331	0.070	94
v1742: Selection of lower officials	0.524	0.061	95

Each row reports the estimated coefficient and standard error when the listed variable in the SCCS is regressed on state centralization and a constant (not reported). All results are significant at conventional levels. I have reversed the signs for variables 756, 759, 760, 761, 762, 763, 764, 765, 776, 777, 779, and 784, so that higher values correspond to greater state strength. I have re-labeled these variables to capture the positive re-coding, and have re-labeled some other variables so that their meaning is clearer. I have removed the missing values 0 and 8 from variable 1132, and converted variable 89 into a binary ``judiciary present'' measure, since the categories of judiciary were not clearly ordered.

Table 6. Robustness: Alternative measures of states and diversity

	(1)	(2)	(3)
	Any centralization		
Ecological diversity	0.252**	0.280**	0.207*
	(0.128)	(0.128)	(0.118)
	State centralization		
Dist. ecological divide	-0.326***	-0.301***	-0.267***
	(0.078)	(0.071)	(0.073)
	State centralization		
Any diversity	0.480***	0.359**	0.225*
	(0.155)	(0.142)	(0.126)
	State centralization		
Ecological diversity (Simpler classes)	0.907***	0.793**	0.557
	(0.335)	(0.311)	(0.356)
	State centralization		
Eco. Div. (FAO)	0.967***	0.999***	0.540**
	(0.198)	(0.282)	(0.275)
Other controls	No	Yes	Yes
Region F.E.	No	No	Yes
Observations	440	440	440

*** p<0.01, ** p<0.05, * p<0.1. Robust standard errors in parentheses. Regressions estimated by ordered probit with coefficients reported, except with "any centralization" as the outcome, in which case probit is used with marginal effects reported. Standard errors in parentheses clustered by region. Other controls are those listed as "controls" in the table of summary statistics.

Table 7. Robustness: Estimation methods

	(1)	(2)	(3)
	State centralization: Generalized ordered probit		
Equation 1	0.778*	0.976**	
	(0.408)	(0.455)	
Equation 2	0.916***	0.848***	
	(0.282)	(0.268)	
Equation 3	0.777**	0.865**	
	(0.359)	(0.420)	
Equation 4	-1.249*	-19.310***	
	(0.691)	(1.282)	
	State centralization: Alternative regions		
Ecological diversity	0.794***	0.703**	0.661*
	(0.212)	(0.343)	(0.373)
	State centralization: No "trade" controls		
Ecological diversity	0.794***	0.506**	0.415*
	(0.266)	(0.257)	(0.222)
	State centralization: No date control		
Ecological diversity	0.794***	0.693***	0.423*
	(0.266)	(0.238)	(0.221)
Other controls	No	Yes	Yes
Region F.E.	No	No	Yes
Observations	440	440	440

*** p<0.01, ** p<0.05, * p<0.1. Robust standard errors in parentheses. Regressions estimated by ordered probit. Standard errors in parentheses clustered by region. Other controls are those listed as "controls" in the table of summary statistics.

Table 8. Robustness Influential observations

Dropped	*High leverage*	*High dfbeta*	*South African Bantu*	*Ethiopia and Horn*	*Moslem Sudan*	*Indian Ocean*
			State centralization			
Ecological diversity	0.642**	0.958***	0.735***	0.752***	0.611**	0.768***
	(0.286)	(0.289)	(0.228)	(0.233)	(0.238)	(0.226)
Other controls	Yes	Yes	Yes	Yes	Yes	Yes
Region F.E.	No	No	No	No	No	No
Observations	406	411	421	400	417	435
			State centralization			
Ecological diversity	0.236	0.682**	0.484**	0.412*	0.369	0.496**
	(0.334)	(0.285)	(0.205)	(0.234)	(0.229)	(0.215)
Other controls	Yes	Yes	Yes	Yes	Yes	Yes
Region F.E.	Yes	Yes	Yes	Yes	Yes	Yes
Observations	406	411	421	400	417	435

*** p<0.01, ** p<0.05, * p<0.1. Robust standard errors in parentheses. Regressions estimated by ordered probit. Standard errors in parentheses clustered by region. Other controls are those listed as "controls" in the table of summary statistics.

Table 9. Robustness: Reverse causation

	(1)	(2)	(3)	(4)	(5)	(6)
	State centralization					
	OLS			*OLS: Temp. s.d. nonmissing*		
Ecological diversity	0.678***	0.542***	0.327**	0.699**	0.612***	0.387**
	(0.219)	(0.163)	(0.150)	(0.275)	(0.190)	(0.191)
Other controls	No	Yes	Yes	No	Yes	Yes
Region F.E.	No	No	Yes	No	No	Yes
Observations	440	440	440	370	370	370
	State centralization					
	IV			*Ordered probit*		
Ecological diversity	1.597**	1.023	1.335			
	(0.716)	(2.711)	(2.366)			
Predicted Eco. Div. (FAO)				0.494***	0.284*	0.037
				(0.181)	(0.151)	(0.179)
Other controls	No	Yes	Yes	No	Yes	Yes
Region F.E.	No	No	Yes	No	No	Yes
Observations	370	370	370	440	440	440

*** p<0.01, ** p<0.05, * p<0.1. Robust standard errors in parentheses. Standard errors in parentheses clustered by region. Other controls are those listed as "controls" in the table of summary statistics.

Table 10. Robustness: Heterogeneity

	(1)	(2)	(3)
	State centralization: Including area shares		
Ecological diversity	1.080***	0.943***	0.479**
	(0.291)	(0.262)	(0.229)
	State centralization: Latitude/longitude quartic		
Ecological diversity	0.676***	0.597***	0.304
	(0.233)	(0.211)	(0.214)
	State centralization: Spatially correlated errors		
Ecological diversity	0.492**	0.491**	0.326
	(0.228)	(0.244)	(0.228)
Wald test (λ=0)	33.71	1.187	7.22e-06
	State centralization: Including neighbors' X		
Ecological diversity	0.697***	0.512***	0.304
	(0.201)	(0.192)	(0.196)
WX p	0	0.000	0.000
Moran p	0.278	0.426	0.186
	State centralization: Interactions with de-meaned controls		
Ecological diversity	0.583	0.730***	0.449*
	(0.420)	(0.259)	(0.244)
	Nearest Neighbor Matching		
Above Median Diversity SATE		0.202**	
		(0.096)	
	Altonji-Elder-Taber Statistics		
		4.51	3.08
Other controls	No	Yes	Yes
Region F.E.	No	No	Yes
Observations	440	440	440

*** p<0.01, ** p<0.05, * p<0.1. Robust standard errors in parentheses. Regressions estimated by ordered probit with coefficients reported, except with spatially correlated errors, described in the text. Standard errors in parentheses clustered by region, except with spatially correlated errors. Other controls are those listed as "controls" in the table of summary statistics.

Table 11. Alternative stories: Artificial countries and area groups

	(1)	(2)	(3)
	State centralization: Artificial countries		
Ecological diversity	0.842***	0.806***	0.804***
	-0.275	-0.107	-0.179
	State centralization: Drop Area Q1		
Ecological diversity	0.957***	0.914***	0.554*
	(0.327)	(0.269)	(0.326)
	State centralization: Drop Area Q5		
Ecological diversity	0.729**	0.665***	0.366
	(0.284)	(0.255)	(0.231)
	State centralization: Drop Area Q1 and Q5		
Ecological diversity	0.987***	1.017***	0.606**
	(0.281)	(0.268)	(0.299)
Other controls	No	Yes	Yes
Region F.E.	No	No	Yes
Observations	440	440	440

*** p<0.01, ** p<0.05, * p<0.1. Regressions estimated by ordered probit with coefficients reported. Standard errors in parentheses clustered by region. Other controls are those listed as "controls" in the table of summary statistics.

Table 12. Alternative stories: Additional controls and ethnic competition

	(1)	(2)	(3)	(4)	(5)	(6)
	State centralization: Additional controls					
Ecological diversity	0.718***	0.673***	0.392*	0.587*	0.535**	0.291
	(0.248)	(0.228)	(0.217)	(0.315)	(0.259)	(0.247)
Area	0.034*	0.021	0.026			
	(0.020)	(0.022)	(0.025)			
Ag. Constraints Range				0.082**	0.065*	0.055
				(0.038)	(0.035)	(0.035)
	State centralization: Additional controls					
Ecological diversity	0.762***	0.682***	0.430**	0.753***	0.703***	0.390*
	(0.260)	(0.230)	(0.208)	(0.273)	(0.230)	(0.211)
Pop. density	0.002	0.001	0.000			
	(0.002)	(0.001)	(0.001)			
Grain endemism				0.442	0.287	0.904**
				(0.310)	(0.403)	(0.395)
Other controls	No	Yes	Yes	No	Yes	Yes
Region F.E.	No	No	Yes	No	No	Yes
Observations	440	440	440	440	440	440

	State centralization: Artificial countries and ethnic competition			
Ecological Diversity	0.369	0.814***	0.749***	0.703***
	-0.285	-0.27	-0.104	-0.19
No. of Ethnic Groups		0.073	0.123**	0.145***
		-0.047	-0.048	-0.048
Other controls	No	No	Yes	Yes
Region F.E.	No	No	No	Yes
Observations	1524	1524	1524	1524

*** p<0.01, ** p<0.05, * p<0.1. Regressions estimated by ordered probit with coefficients reported. Standard errors in parentheses clustered by region. Other controls are those listed as "controls" in the table of summary statistics.

Table 13. Alternative stories: Six influential states

Name	Cent.	dfbeta	Name	Cent.	dfbeta
Songhai	3	0.1821782	Barea	0	0.122194
Yoruba	3	0.1704813	Shuwa	2	0.1131304
Chiga	0	0.1550042	Luba	3	0.1105842
Lozi	3	0.1492606	Kunama	0	0.1068234
Bagirmi	3	0.1482568	Rundi	3	0.0934491
Toro	3	0.145315	Fur	3	0.0893164
Laketonga	0	0.1378572	Suku	3	0.0849554

	Yoruba	Songhai	Toro	Suku	Luba	Lozi
Participated in trade?	Yes	Yes	Yes	Yes	Yes	Yes
Trade a source of wealth?	Yes	Yes	Yes	Arguable	Yes	Yes
Trade a source of state power?	Yes	Yes	Yes	Yes	Yes	Yes
Rose and fall with trade?	Arguable	No	No	No	Yes	Arguable
No capture of trading regions?	Yes	Yes	No	Yes	No	Yes

Table 14. Mechanisms: Other institutional outcomes

	(1)	(2)	(3)
		Local state	
Ecological diversity	-1.108***	-0.207	0.014
	(0.311)	(0.238)	(0.210)
Observations	439	439	439
		Class Stratification	
Ecological diversity	1.226***	1.474***	1.333***
	(0.346)	(0.230)	(0.241)
Observations	364	364	364
		Slavery	
Ecological diversity	-0.139	0.554***	0.012
	(0.355)	(0.137)	(0.014)
Observations	383	383	383
		Headman is appointed	
Ecological diversity	0.105	-0.085	0.000
	(0.419)	(0.633)	(0.045)
Observations	320	320	320
		High gods	
Ecological diversity	-0.029	-0.267	
	(0.454)	(0.910)	
Observations	242	242	
		Light density	
Ecological diversity	-0.013	0.088*	0.106**
(robust se)	(0.034)	(0.045)	(0.044)
(clustered se)	(0.072)	(0.086)	(0.093)
Observations	440	440	440
Other controls	No	Yes	Yes
Region F.E.	No	No	Yes

*** p<0.01, ** p<0.05, * p<0.1. Regressions estimated by ordered probit with coefficients reported. Standard errors in parentheses clustered by region. Other controls are those listed as "controls" in the table of summary statistics.

Table 15. Mechanisms: Other sources of trade

	(1)	(2)	(3)	(4)
	State centralization			
% dep. on fishing	0.003			
	(0.004)			
Iron production		0.047		
		(0.165)		
Gold production			0.020	
			(0.016)	
Salt				0.040
				(0.051)
Other controls	Yes	Yes	Yes	Yes
Region F.E.	No	No	No	No
Observations	440	440	440	440

*** p<0.01, ** p<0.05, * p<0.1. Regressions estimated by ordered probit with coefficients reported. Standard errors in parentheses clustered by region. Other controls are those listed as "controls" in the table of summary statistics.

Table 16. Mechanisms: Regressions of SCCS measures of trade on state centralization

Dependent variable	Coef	s.e.	N
v1: Trade for food	0.324	0.071	181
v2: Food trade intermediation	0.289	0.087	123
v93: Political power via commerce	0.064	0.018	181
v732: Importance of trade in subsistence	0.154	0.056	92
v1007: Trade and markets	0.382	0.104	52
v1733: Exchange within community	0.200	0.096	95
v1734: Exchange beyond community	0.098	0.079	98

Each row reports the estimated coefficient and standard error when the listed variable in the SCCS is regressed on state centralization and a constant (not reported). I have reversed the sign for variable 732 so that higher values correspond to greater trade. I have converted variable 93 into a binary ``power depends on commerce'' measure if v93 (the most important source of political power) is either 2 (tribute or taxes), 7 (foreign commerce), or 8 (capitalistic enterprises).

Table 17. Mechanisms: Local or long distance trade?

	(1)	(2)	(3)	(4)
	Ecological diversity	*State centralization*		
Ecological diversity		0.549	0.462	0.182
		(0.355)	(0.341)	(0.325)
Dist. ecological divide	-0.284***	-0.168	-0.179	-0.217*
	(0.016)	(0.126)	(0.113)	(0.130)
Other controls		No	Yes	Yes
Region F.E.		No	No	Yes
Observations	440	440	440	440
R-squared	0.424			

*** p<0.01, ** p<0.05, * p<0.1. Regressions estimated by ordered probit. Standard errors in parentheses clustered by region. Other controls are those listed as "controls" in the table of summary statistics.

Table 18. Mechanisms: Is Africa different?

	(1)	(2)	(3)
	State centralization		
Ecological diversity	0.892***	0.892***	0.604***
	(0.196)	(0.198)	(0.223)
Other controls	No	Yes	Yes
Region F.E.	No	No	Yes
Observations	1129	1076	1076

*** p<0.01, ** p<0.05, * p<0.1. Regressions estimated by ordered probit. Standard errors in parentheses clustered by region. Other controls are those listed as "controls" in the table of summary statistics.

Table 19. Full results

	(1)		(2)		(3)	
	State centralization					
Ecological diversity	0.794***	(0.266)	0.703***	(0.234)	0.437**	(0.219)
Ag. constraints			-0.018	(0.059)	-0.020	(0.056)
Dist. coast			0.024	(0.026)	0.036	(0.031)
Elevation			0.000	(0.000)	0.001**	(0.000)
Malaria			-0.501	(0.306)	-0.248	(0.302)
Precipitation			0.000	(0.000)	0.000	(0.000)
Temperature			-0.000	(0.000)	0.000	(0.000)
Dist. L. Victoria			0.000	(0.000)	-0.000	(0.000)
Date observed			-0.003**	(0.002)	-0.005**	(0.002)
Crop: None			-1.558**	(0.772)	-0.481	(0.818)
Crop: Trees			0.136	(0.325)	-0.020	(0.338)
Crop: Roots/tubers			0.456**	(0.203)	0.304	(0.205)
Major river			0.268*	(0.155)	0.283**	(0.138)
Ruggedness			0.000	(0.000)	0.000*	(0.000)
Dist. Atlantic ST			0.000	(0.000)	0.000	(0.001)
Dist. Indian ST			-0.001	(0.000)	-0.000	(0.000)
Dist. Saharan ST			-0.001	(0.001)	-0.001	(0.001)
Dist. Red ST			0.001	(0.001)	0.001*	(0.001)
Region F.E.	No		Yes		Yes	
Observations	440		440		440	

*** p<0.01, ** p<0.05, * p<0.1. Regressions estimated by ordered probit. Standard errors in parentheses clustered by region.

The End of Multi-Fibre Arrangement and Firm Performance in the Textile industry of Pakistan

Zara Liaqat

University of Southern California

March 12th, 2011

Introduction – The MFA

- Decades of bilateral Non-tariff-barrier protection in the T&C industry.

- MFA – The Multi-Fibre Arrangement (1974):
  - Restrictions on exports to industrialized countries through a system of bilaterally negotiated quotas on T&C products.
  - T&C were kept out of multilateral trade negotiations (GATT and WTO).

- Uruguay Round (1994) - Agreement on Textile and Clothing (ATC):
  - Ended MFA and began the process of integrating T&C products into GATT/WTO rules by removing their quotas.
  - Set the stage for a substantial reallocation of production and exports across countries.
  - Integration occurred over four phases.

Introduction – The MFA

Phase	Starting Date	Share of Export Volume Integrated	Increase in Quota Growth Rate	Number of HS Products Integrated
I	January 1, 1995	16	16	318
II	January 1, 1998	17	25	755
III	January 1, 2002	18	27	753
IV	January 1, 2005	49	n/a	3,013

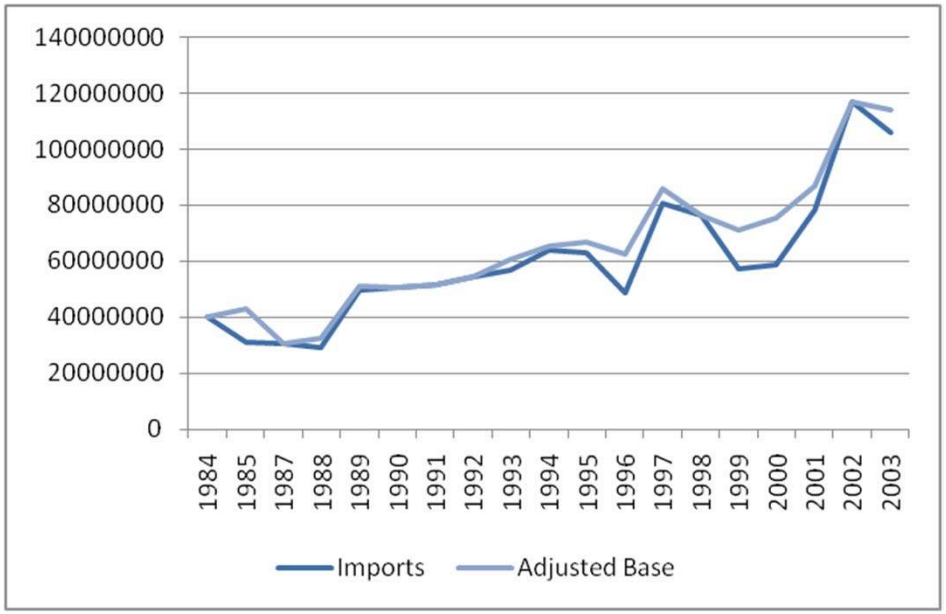
Notes: Table describes the four phases of the Agreement on Textiles and Quotas. First three columns describe aspects of the Agreement that were common to all signatories. Final column reports the integration of products as implemented by the United States. Quota growth acceleration was advanced one phase for countries with less than 1.2 percent of the importing country's total quotas in 1991. Source: OTEXA.

Table 1: ATC Integration Schedule

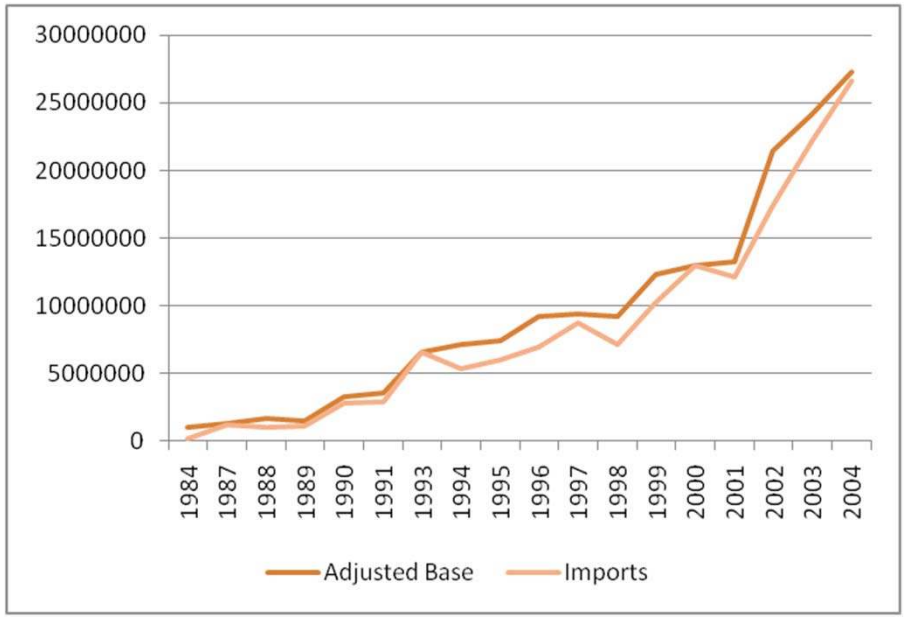
- In each phase, importing countries were to integrate a portion of T&C products covered by the ATC.
- Subject to two rules:
  - Products retired in each phase had to include goods from all four major T&C segments: Yarn, Fabrics, Made-Up textile products, and Clothing.
  - The chosen products had to represent a set portion of each country's 1990 T&C imports.

Level of Imports and Adjusted Quota Base (Examples)

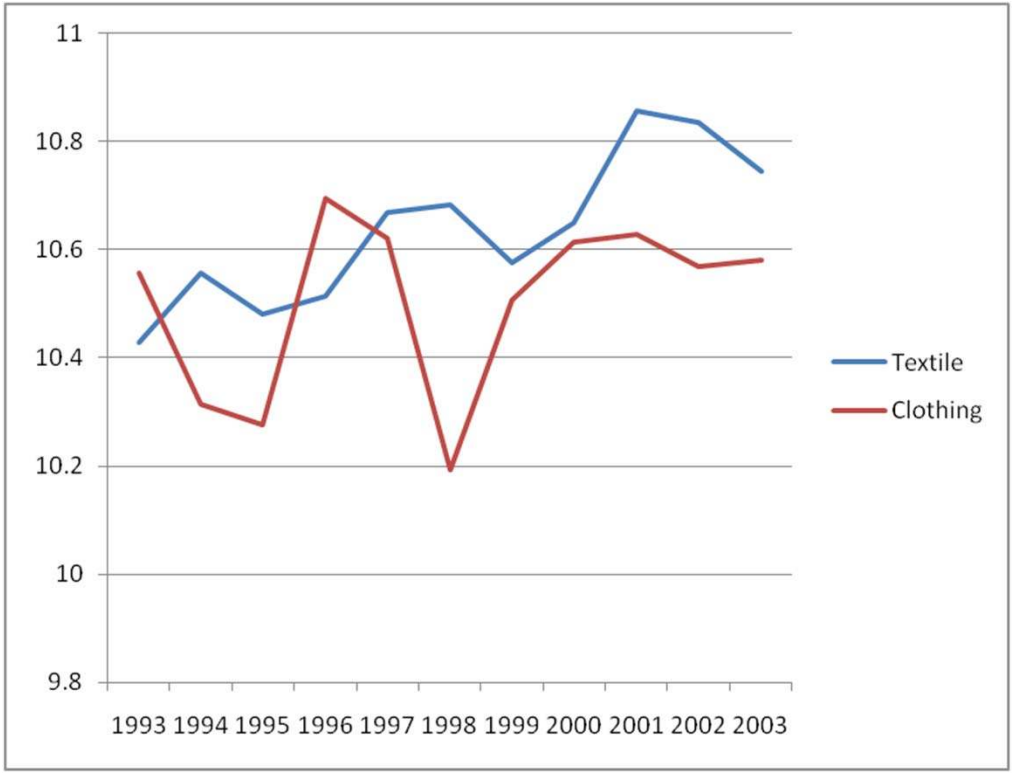
NAICS 313312: Textile and Fabric Finishing



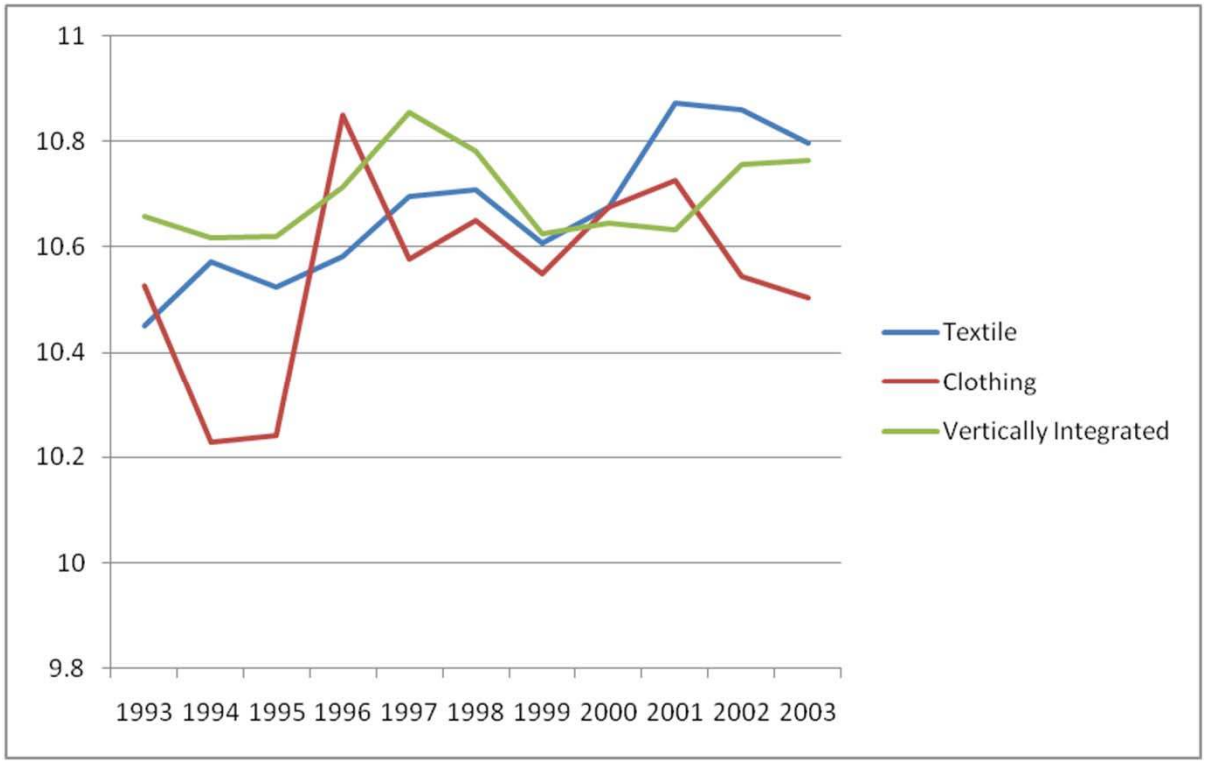
NAICS 315222: Men's and Boys' Cut and Sew Suit, Coat, and Overcoat



T&C sector in Pakistan (Levinsohn & Petrin Productivity Measure)



T&C sector in Pakistan (Levinsohn & Petrin Productivity Measure)



Overview of Results

- Using a sample of 321 T&C companies for the years 1992-93 to 2002-2003, this paper analyzes the effect of the phasing out of quotas on firm-level efficiency in Pakistan.

- In spite of an increase in the adjusted level of quotas taking place simultaneously for a group of competing developing countries, there is an increase in the level of imports.

- In the first step, plant-level productivity is estimated, and then the change in firm productivity is regressed on the adjusted level of quotas.
  - The MFA expiration led to an increase in the average productivity of textile producing firms but a significant reduction in the mean productivity of clothing producers.
  - I compare the productivity of clothing producers that buy their raw materials and that of vertically integrated clothing producers.

Literature Review

Brambilla, Khandelwal and Schott (2007) analyze China's experience under the US T&C quotas:

- China's share of US imports jumped from 10 to 33 percent.
- This expansion came at the expense of other exporters rather than domestic producers.

Evans and Harrigan (2004) analyze how MFA affects the sources and prices of US apparel imports:

- Binding quotas substantially raise import prices.
- Shift of US apparel imports away from Asia in favor of Mexico and the Caribbean.

Sasidaran and Shanmugam (2008) attempt to empirically investigate the implications of the phasing out of MFA on efficiency of firms in the Indian textiles industry:

- Using stochastic coefficients frontier approach, they estimate the overall and input specific efficiency values for 215 sample firms during 1993-2006.
- Average efficiency declined over the years.

Empirical Methodology

Semiparametric Estimation (Levinsohn & Petrin, 2003)

Regress change in firm productivity on the adjusted level of quotas:

$$\Delta tfp_{ijt} = \beta_0 + \beta_1 \Delta \log (AdjQuota)_{jt} + \beta_2 \Delta \log (Cost)_{jt} + X_{ijt} + \delta_t + \delta_j + \varepsilon_{ijt} \qquad (8)$$

Data

- Balance Sheet Data of Pakistani Listed and Non-Listed Companies (BSDPC) is a survey of a representative sample of 321 companies for the years 1992-2003.

- Brambilla, Khandelwal, and Schott (2007):
  - U.S. trading partners' Expired Performance Reports used by the U.S. Office of Textile and Apparel (OTEXA) to monitor trading partners' compliance with MFA/ATC quotas.
  - Document imports, base quotas and quota adjustments by OTEXA category and year for all countries with which the US negotiated a quota arrangement.

- Bernard, Jensen, and Schott (2006b):
  - Free-on-board customs value of imports, ad valorem duty and ad valorem freight and insurance rates for the underlying product-level U.S. import data.

Endogeneity

- Relationship between openness and performance can be taken to imply causality:
  - Liberalization not a part of broader package of reforms
  - MFA Expiration can be thought of as a ‘natural experiment’
  - Lobbying by firms?

- Regress change in *firm* productivity on the adjusted level of quotas at the six-digit NAICS *industry* level.

- Structural techniques proposed by Olley & Pakes and Levinsohn & Petrin take care of endogeneity in the estimation of production function.

Table 1: Effect of Elimination of Quota-Restrictions on Textile Firm Productivity
Levinsohn & Petrin

	(1)	(2)	(3)	(4)	(5)	(6)
Adjusted Quota	**0.0146**	**0.125**	**0.0376**	**0.577****	**0.593****	**0.599****
	(0.105)	(0.113)	(0.123)	(0.286)	(0.286)	(0.286)
Cost of Imports		**-0.0631**	**-0.0355**	**0.03**	**0.0311**	**0.0316**
		(0.169)	(0.151)	(0.156)	(0.156)	(0.156)
Age			0.0295	0.0658	0.0374	0.0453
			(0.151)	(0.164)	(0.166)	(0.166)
Age^2			-0.00663	-0.0148	-0.00252	-0.00621
			(0.0376)	(0.0397)	(0.0411)	(0.0414)
Herfindahl Index				0.00467	0.00484	0.00491
				(0.0251)	(0.0251)	(0.0251)
Multinational					-0.314	-0.318
					(0.29)	(0.291)
ISO Certified						0.512
						(0.628)
Industry Fixed Effects	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Time Fixed Effects	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
City Effects	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
No. of Observations	1216	1146	765	709	709	709

Table 2: Effect of Elimination of Quota-Restrictions on Clothing Firm Productivity
Levinsohn & Petrin

	(1)	(2)	(3)	(4)	(5)
Adjusted Quota	**-0.012**	**-0.0763**	**-0.077**	**-0.079**	**-0.0791**
	-0.0967	-0.12	-0.119	-0.0781	-0.0791
Cost of Imports		**10.55*** **	**10.37*** **	**13.28*** **	**13.28*** **
		-3.66	-3.652	-3.108	-3.196
Herfindahl Index			0.131	0.170*	0.170*
			-0.102	-0.103	-0.103
ISO Certified				0.747***	0.745***
				-0.221	-0.223
Multinational					0.152
					-1.05
Constant	10.88***	10.48***	10.29***	8.042***	8.041***
	-1.684	-2.451	-2.431	-1.366	-1.384
Industry Fixed Effects	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Time Fixed Effects	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
City Effects	*No*	*Yes*	*Yes*	*No*	*No*
No. of Observations	407	389	389	391	391

- MFA expiration will potentially boost competition, thereby resulting in technological advancement and productivity growth.

- The MFA expiration led to an increase in the average productivity of textile producing firms but a significant reduction in the mean productivity of garment producers.
  - Historically a relatively better textile sector
  - Harder to upgrade quality in the garment sector
  - Changes in product mix - shift to the production of lower-value products
  - Failure to fight the competition
  - Non-exporting firms become exporters - need time to adapt to new environment

- Change in composition of textile exports, from a broader category that benefits from MFA, to a narrower category focused on specific markets that offer preferential access through bilateral trade agreements:
  - Expect a fall in productivity as the mix of inputs utilized by the firm would no longer be dictated by rationally choosing the optimal mix.

Trade and Vertical Specialization in T&C Industry

- Compare productivity of clothing producers that buy their raw materials, and the productivity of vertically integrated clothing producers.
- The empirical findings show that increase in the adjusted level of quotas brings about a significant reduction in productivity of the clothing firms that are not vertically integrated.
- Conversely, the productivity of vertically integrated firms goes up as there is growth in the adjusted level of quotas.

Conclusion

- Given that there is a lack of empirical studies dealing with efficiency of textile industry in the light of phasing out of MFA, together with the growing significance of the T&C industry, leads us to investigate the efficiency issues related to Pakistan's T&C industry.

- In spite of an increase in the adjusted level of quotas taking place simultaneously for a group of competing developing countries, there is an increase in the level of imports - evidence for *trade creation*.

- The MFA expiration led to an increase in the average productivity of textile producing firms but a reduction in the mean productivity of clothing and garment producers.

Energy efficiency gains from trade

Leslie Martin

PAC-DEV conference at UC Berkeley
March 12, 2011

Potential impacts of trade liberalization

1. **Scale**: expansion of economic activity increases pollution
2. **Composition** (output reallocated):
   - Across industries: shift production towards pollution-intensive industries (pollution haven)
   - Across firms: increased competition and lower barriers to entry and exit shift market share to more productive, potentially less polluting, firms
3. **Technique** (within firm):
   - Short run: changes in capacity utilization - firms may temporarily bring online retired older vintages
   - Longer run: capital may become cheaper or more accessible, encouraging investment or upgrading to newer, often cleaner, technologies

In 1990s India experienced a dramatic IMF-driven trade liberalization

- Previous Indian industrial policy: import and industrial licenses, highest tariffs in Asia (average $> 90\%$), quotas to favor small producers and under-developed geographical regions
- Fuels used in manufacturing and construction are responsible for almost half of India's GHG emissions.

My empirical question: To what extent did this trade liberalization help green India's manufacturing sector, and how?

I examine impact of trade liberalization on environmental outcomes (particularly, fuel use) using firm-level data.

Research strategy:

1. Decompose fuel use trends into scale, composition (output reallocation), and technique (within-firm) effects using Olley-Pakes and Melitz-Polanec approaches
2. Tie industry fuel intensity trends to industry-specific changes in trade liberalization
3. Ask: how much of each trend is due to movement of market share away from small firms? away from public sector firms? to younger firms? to new entrants?

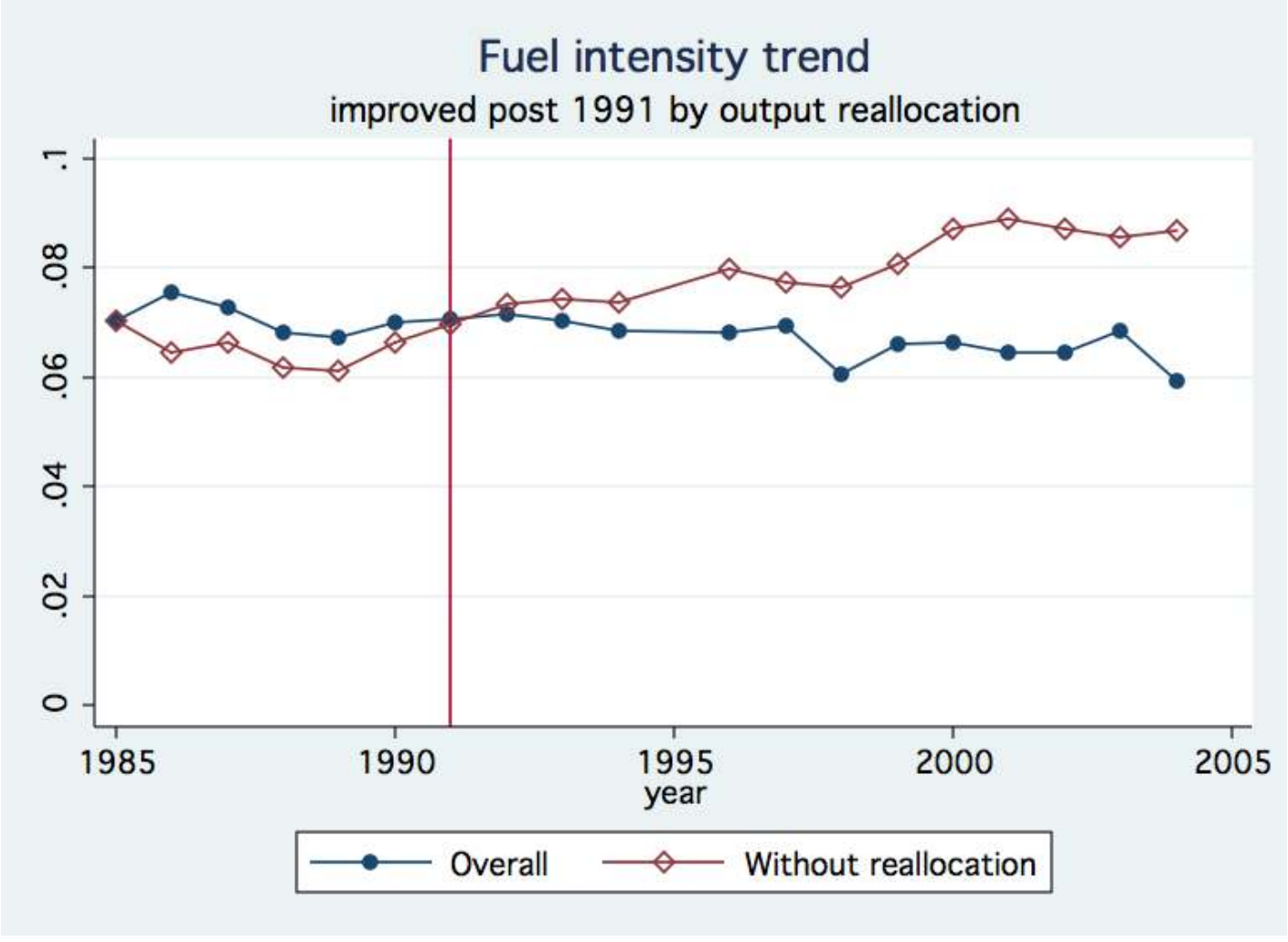
Data

Annual Survey of Industries (ASI): firm-level data from 1985-1995 and 1996-2004. 50,000+ firms: population of larger firms, 2-3 year sample of smaller firms, we created panel

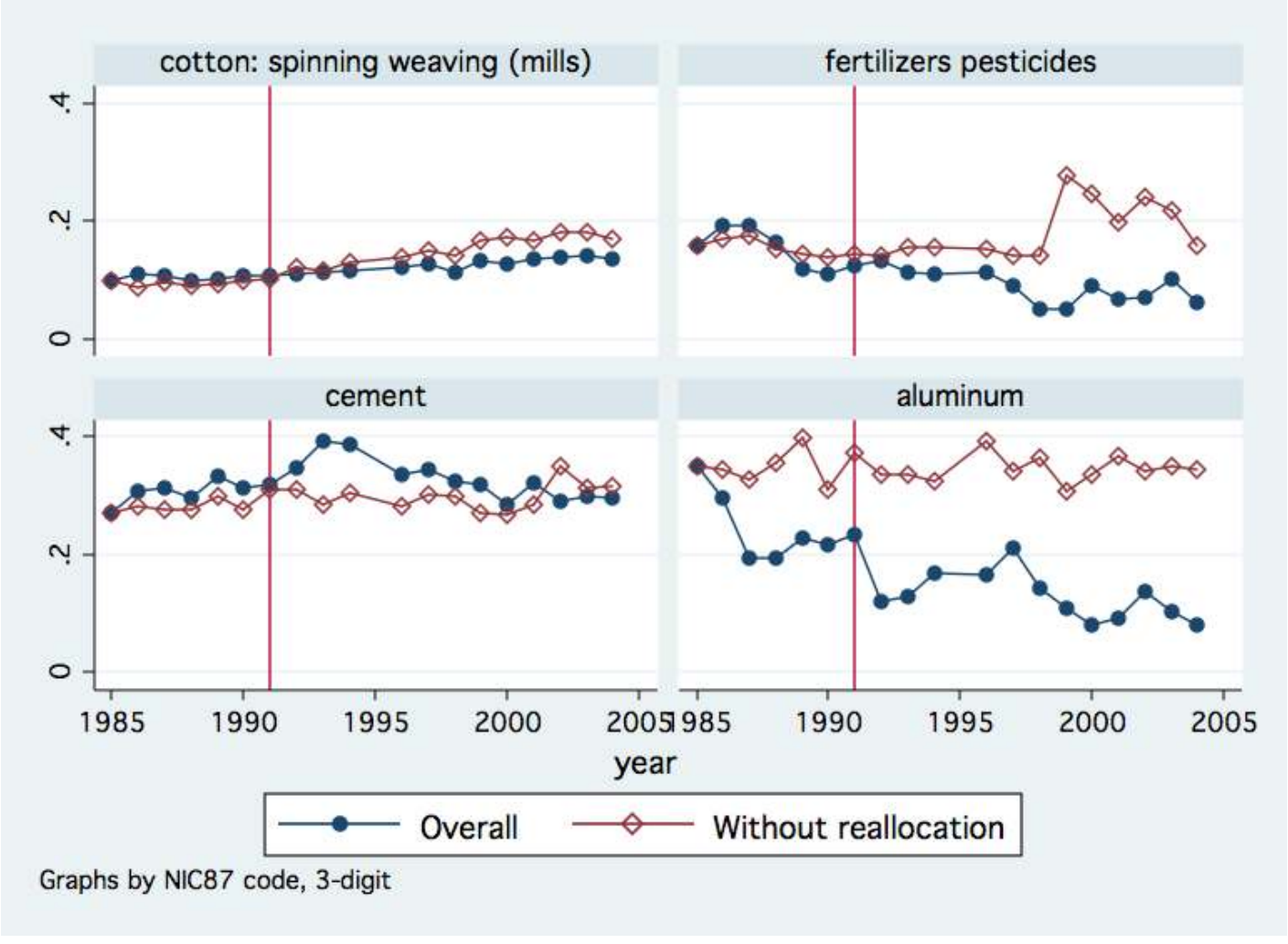
- ASI fuel use data includes expenditures on electricity, fuels used for captive generation and fuels used for thermal energy; all fuel and output variables deflated using sector-appropriate WPI to create fuel intensity indicators

Policy variables: average tariffs on inputs and outputs, delicensing and FDI reform indicator variables for 145 industries (3-digit NIC level) over 19 years

Market share reallocation responsible for flattening trend post 1991



Role of market reallocation highly industry-specific



Input tariffs clean within-firm, delicensing cleans via reallocation

$$\text{Trend}_{jt} = \beta_1 \text{tariff-in}_{jt} + \beta_2 \text{tariff-out}_{jt} + \text{FDI}_{jt} + \text{Delicense}_{jt} + \sigma_j + \tau_t + \epsilon_{ijt}$$

	Fuel Intensity	Within Firm	Reallocation
	(1)	(2)	(3)
Output tariff, 1 year lag	-.00004	.0000	-.00004
	(.00005)	(.00006)	(.00005)
Input tariff, 1 year lag	.0006	.0005	.00007
	(.0002)***	(.0002)**	(.0002)
FDI reform, 1 year lag	-.005	.0001	-.005
	(.005)	(.006)	(.005)
Delicensed, 1 year lag	-.004	.005	-.009
	(.003)	(.004)	(.003)***
Industry FE	yes	yes	yes
Year FE	yes	yes	yes
Obs.	2472	2472	2472
R^2	.028	.057	.031

Standard errors clustered at the industry level

- Reducing tariffs on inputs leads to within-firm improvements in fuel efficiency, particularly for domestic firms
  - Estimated coefficient represents a 30% reduction in fuel intensity for average input tariff decrease experienced in India (-60 percentage points)
- Delicensing lead to reallocation-led improvements in fuel efficiency, but the effect differs significantly across industry-types, and may have been accompanied by within-firm worsening of fuel intensity of output
  - Estimated coefficient represents a 9% reduction in fuel intensity

Mechanisms

I explore in more detail:

- reallocation within surviving firms vs. to entrants and away from exiting firms
- impact small/large firms, private/public firms, young/older firms
- impact on import-/export-oriented sectors
- impact on sectors receiving small/large amounts of FDI

Next steps

May-August 2011 conducting firm-level survey of small textile finishing firms in Tamil Nadu (textile processing: shrinking, dying, printing)

- To what extent are firms purchasing used capital stock? What do they do with the capital stock that they discard?
- How does intensity of capital stock use change with ownership (and vintage, energy efficiency)?

Expatriates as Leaders of Technology Transfer and FDI: Theory and Evidence from Mexico.

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Abstract

Multinational companies (MNCs) are thought to be key in the spread of technology advances across countries. At the same time, the management literature argues that expatriates are key for information and technology transmission from headquarters to subsidiaries. While economic analysis on expatriates has been scarce, our analysis of Mexican plant-level data reveals that subsidiaries relying on foreign employees indeed engage in more technology transfer than those that do not. To understand why, we extend Hermalin (1998) leadership theory and model MNCs' choice of their subsidiaries CEOs and entry decisions. In the model, MNCs have to choose between the expatriate, who is better at transmitting the value of the project, and the local manager who can deal better with local conditions uncertainty. We find that MNCs employing expatriates engage in more technological transfer, and more so in technology intensive industries because expatriates can use their own effort to signal the value of this technology (lead by example), whose value increases with technological intensity. We also find that MNCs rely less on expatriates when local uncertainty is high due to the expatriate's lack of local knowledge. In terms of entry, we find that the attractiveness for FDI will be lower for locations with high local uncertainty that lack a supply of local managers. Yet, the composition of FDI for these areas will be biased towards multinationals in technology intensive sectors because only firms in those sectors find it profitable to enter. Additional empirical analysis finds a set of robust correlations that are not only consistent with our theory but are difficult to explain with the hypothesis that productivity is the only key factor driving both the use of expatriates and the performance of the firm. The theory thus provides a foundation to understand the nature and the barriers of technology transfer within MNCs and its implications for economic development.

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1 Introduction

Economists and policy makers have increased attention to Multinational companies (MNCs) as key in the spread of technological, managerial and organizational advances across countries. The economics literature has documented that MNCs are more productive, pay higher wages, and are more export oriented than domestic firms (Markusen, 2004, and Harrison and Rodriguez-Claire, 2009). Furthermore, their presence is likely to be associated with inter-industry positive spillovers (Blalock, 2002 and Jacorcik, 2004). Policy makers, in particular those from developing countries, have recently tried to attract MNCs expecting them to be bringing technological advances (UNCTAD, 1994).

Given the perceived importance of MNCs as a driver to technology transfer, the following question arises naturally: How do multinational firms transmit the technology and other useful information to their subsidiaries? The management literature has argued that expatriates are MNC's means of controlling and processing information within their organization (Egelhoff, 1984 and Gupta and Govindarajan, 1991). However, administrating the development and mobility of expatriate managers has been a major challenge for most MNCs, which has attracted much attention in the management literature (See for example Black et. al, 1999 and Ricks, 1999). Since expatriates tend to lack local knowledge, MNCs are facing a trade off when choosing between expatriates, who know better their firms, and local managers, who know better local conditions.[1]

In contrast to the much attention of practitioners and the management literature on the cost and benefit of expatriates, systematic economic analysis has been scarce. In this paper, we fill this gap by presenting both evidence from Mexican subsidiaries of MNCs and a theoretical framework that analyzes the causes and consequences of MNCs' choice of their subsidiaries CEOs and their entry decisions in foreign markets. This is the first paper to analyze both theoretically and empirically MNCs' choice of foreign employees and its implication on technology transfer and the type and amount of FDI flows developing countries attract.[2]

[1] An illustrative example of this trade off between transmission of technology and local knowledge can be found in the field study by Carrillo and Hinojoza (1999) in which a German autoparts firm has two subsidiaries in Mexico. The high end subsidiary employs a German CEO while the low end subsidiary employs no German.

[2] Tan and Mahoney (2006) analyze empirically the determinants of the choice between expatriates and local

We first document several facts from Mexican data that further motivates us to study the MNCs choice of managers in their subsidiaries. Our analysis of Mexican plant-level data reveals that subsidiaries relying on expatriates behave systematically different from those that do not in terms of their innovative activities and technology transfer. Namely, they engage in more knowledge transfer from abroad and innovative activities. After presenting theoretical results outlined in the next paragraph, we provide more concrete evidence of correlates of foreign expatriates and of equilibrium predictions regarding the entry both in terms of the quantity and its composition.

In the theoretical section of the paper, we analyze two aspects of MNCs expansion decision: the choice of their potential subsidiary CEO and their entry decision.[3] That is, whether the Headquarter (HQ) appoints an expatriate or a local CEO in the subsidiary where the company may choose to expand.

We argue that the subsidiary CEO shapes the ability to transfer technology and the costs incurred in the local economy. Similarly to Antràs (2005), we distinguish two parts in the production process of the MNC subsidiary. We call them transfer and execution stage. The transfer stage can capture from the actual transfer of technology to management expertise and processes for the best use of this technology or simply the HQ corporate culture. Its defining characteristic is that it requires information to flow from the HQ to the local environment. The technological and/or organizational edge of MNCs over local producers is one of the drivers of multinationals expansion given that "New technology generation is highly concentrated in a number of advanced industrial countries, taking place in large MNCs" (Chapter 2, Piscitello and Santangelo, 2007). The information relative to the transfer stage is known by the HQ but not in the local economy.[4]

The execution stage of the Multinational subsidiary captures, for example, selling the final

managers. Markusen and Trofimenko (2009) analyze theoretically and empirically the consequence of the use of foreign experts on workers, to which we will turn below.

[3] Although we use the term CEO for the concept of leader in the theoretical section, the concept can be interpreted as a team of managers or experts. Foreign workers in Mexico are likely to be at managerial positions or experts.

[4] An example are quality controls. These are a core aspect of Japanese firms corporate culture and were an essential component of the successful experience of Mitsubishi Belting in Singapore. As the following quote from the UNCTAD(1994) reflects, it involved information flows from the HQ to the subsidiaries: "Quality-control concepts have been adopted by enterprizes in India, Indonesia, Malaysia, the Philippines, Singapore and Thailand. The diffusion of quality-control methods in Asian developing countries has been accelerated by the presence of a considerable number of Japanese foreign affiliates"

product to local customers or buying inputs from local suppliers. It requires information from the local environment, which may include cultural, regulatory and political aspects of the subsidiary location. These are known by local inhabitants but not by the HQ. The key idea of the model is that the appointment of the CEO will determine the extent of information asymmetries between the HQ, the CEO and the workers in the transfer and the execution stages.

The information based theory of leadership of Hermalin (1998) is particularly suited to analyze the choice of MNCs subsidiaries CEOs and its implication on technology transfer.[5] This is so because Hermalin (1998) theory is information based: the leader is defined as someone who induces a voluntary following as a result of having superior information. Further, sending an expatriate the multinational expands the set of strategies to transmit information to the subsidiary, because the expatriate can use his effort in the subsidiary as a signal.[6]

In short, the model predicts, first, that multinationals employing expatriates engage in more technological transfer, and more so in technology intensive industries. This is so because expatriates, familiar with the technology, can use their own effort to signal the value of this technology, that is, lead by example. This is a cheaper way to communicate information than signaling from headquarters. Therefore, multinationals in technology intensive sectors find it more valuable to hire an expatriate, and the expatriate's leading by example boosts local efforts to adopt the technology. Second, our analysis of the entry decision reveals that the attractiveness for FDI will be lower for locations with high local uncertainty that lack a supply of local managers. Yet, our

[5]The leadership theory by Benjamin Hermalin has been extended and applied widely. For example, Kobayashi and Suehiro (2005) extend the model to allow for imperfect information available to all the team members to endogenize the emergence of leadership while Majumdar and Mukand (2007) analyze the leader's ability to promote reforms, while Gervais and Goldstein (2007) introduce over confidence of the leader in the analysis. Further, Hermalin's theory has been brought to the experimental lab. Potters et al., 2001, 2005; and Gchter and Renner, 2003 find support for the leading-by-example model. Yet, Meidinger and Villeval (2002) suggest that this is due not to signaling but to reciprocity. Huck and Rey-Biel (2006) introduce the role of conformism among followers and the endogenous determination of who will be the leader.

[6]That is, in Hermalin (1998) parlance, he can lead by example. In Hermalin (1998) the leader has two potential signaling strategies to credibly transmit information. He can either lead by sacrifice (giving a gift) or he can lead by example (exerting effort prior to workers). The first means that in the transfer stage the expatriate CEO and the Headquarter can act as leaders, while the local CEO cannot. The second means that only an expatriate manager, physically present in the subsidiary and acquainted with the technological information, and neither the headquarter nor the local manager can lead by example. That is, although we have not explored the two different forms of leadership in our empirical analysis, Hermalin (1998) allow us to open the black box of technological transfer by focusing on the information transmission mechanisms available to the MNCs. This is something other types of organizational theory cannot allow us to do.

model also shows that the composition of FDI that countries in these conditions will receive will be biased towards multinationals in technology intensive sectors. Therefore, developing countries face quantity-composition biases when developing a supply of local managers.[7] These biases depend on the uncertainty over local conditions. Finally, the theory predicts that firms whose transfer-stage is a more important input than the execution stage will find it more valuable to hire an expatriate. Therefore, if exports are less execution stage oriented, which is likely to be especially true if subsidiaries are exporting their products to their headquarter's country, we expect that export oriented firms are more likely to rely on expatriates. Similarly we do not expect the same for domestic sales. This is important because it shows that not all the performance measures of plants are positively correlated with expatriates. While the model highlights the benefits from hiring an expatriate it also makes explicit its costs, which differentiates itself from the simple alternative productivity-driven story that more productive firms employ expatriates and at the same time excel in every measure. We take these predictions on expatriates to the data and find consistent results.

We find that Mexican subsidiaries of MNCs hiring foreign employees spend more in technology purchase from abroad, and this correlation is stronger in industries whose R&D intensity is high in the U.S., a typical headquarter country. Second, we find that the relation between the likelihood of employing foreign employees and judicial efficiency (an inverse measure of local inefficiency, whose increase will increase local uncertainty at low levels and decrease it at high levels) reveals a U-shape pattern. This is because in the low judicial efficiency regime, an increase of it leads to an increase of local uncertainty reducing the attractiveness of expatriates, while the opposite is true in the high judicial efficiency region. Third, we find that Mexican states with higher levels of judicial efficiency attract more foreign firms, but the composition of the industries of such firms is biased towards low R&D intensive industries.[8] In the model this is because for high values of local inefficiency, the technology intensiveness of entering firms decreases as local efficiency increases

[7] If high-technology FDI is more beneficial than low-technology FDI for the same level of activities this means that MNCs are actually facing a trade-off, which is left to a future investigation.

[8] We use R&D intensity in the U.S. because the technology intensity parameter in the model reflects the one at the headquarter.

since the firms induced to enter are low-tech firms that have more profit with local managers. Finally, we find that the reliance on foreign employees is correlated with export status, but not domestic sales, which rules out the simple alternative productivity-driven story mentioned above in which more productive firms employ expatriates and at the same time excel both in exports and domestic sales.

This paper is related to several strands of literature. First this paper is related to an emerging international trade literature on MNCs' strategy.[9] Recent papers by Antràs (2003, 2005), Antràs and Helpman (2004) and Feenstra and Hanson (2005) extend the property rights models of Grossman and Hart (1986) and Hart and Moore (1990) to explain the MNCs' organizational choice. A series of papers by Grossman and Helpman (2002, 2004, 2005) analyze this choice using the transaction-cost approach. See Lin and Thomas (2008) comparing the empirical predictions of the two approaches above.[10] Puga and Trefler (2010) extend the model of formal and real authority by Aghion and Tirole (1997) to explain the rise of local innovation in developing countries.[11] Tan and Mahoney (2006) analyze empirically the choice between expatriates and local CEOs using data of Japanese MNCs and relate the findings to agency theory. Our paper differs from the papers above in that we focus on the organizational choice of MNCs in developing countries and its implication on technology transfer and composition of FDI.

This paper is also related to the literature on the entry decision of MNCs.[12] Markusen (1995) and Ramondo (2008) empirical evidence shows that around three quarters of all possible country pairs do not engage in multinational production exchanges. Ramondo (2008) shows that bilateral geographical distance and country size are major components of multinational production costs, preventing them from expanding.[13] Burstein and Monge-Narajnjo (2009) explain the unrealized exchanges through the scarcity of managers in the local economy that makes replication of tech-

[9]For surveys of this literature, see Helpman (2006) and Antràs and Rossi-Hansberg (2010).

[10]For an earlier study to investigate the role of informational asymmetries and knowledge nonexcludability in determining the choice between direct investment and licensing, see Ethier and Markusen (1996).

[11]Hanson and Xiang (2010) also extend Aghion and Tirole (1997) to analyze the characteristics of U.S. denominations.

[12]For this and next strands of literature, Markusen (2004) is a standard textbook.

[13]She argues that plants face a fixed and exogenous cost to replicate the productivity level of the "source" plant that is country pair specific.

nology across countries impossible. We complement these studies by providing micro-level facts and by modeling how fixed entry cost affect not only the magnitude of FDI but its composition.[14] For example, our framework allows us to discuss the type of firms and local conditions for which the scarcity of local managers will impede entry and whether local development policies should give priority to investments in human capital of managers or of blue collar workers.[15]

Finally, we also contribute to the literature of the effect of MNCs. Aitken and Harrison (1999) found that foreign presence is negatively associated with the performance of local firms, while Javorcik (2004) found that foreign plants lead productivity growth of the plants in the supplying industries of those plants.[16] Branstetter, Fisman and Foley (2006) shows that legal reforms on intellectual property rights in countries where subsidiaries locate induce MNCs to transfer more technology. We are pointing out additional channels through which host countries' conditions or policies could affect technology transfer. Markusen and Trofimenko (2009) is the closest to this paper in the sense that they also focus on foreign employees. They find that plants with foreign experts have experienced increases in wages of domestic workers and on the value added per worker. Our paper is different from Markusen and Trofimenko (2009) in two senses. First we explicitly model the choice of MNCs on using foreign employees in their subsidiaries and confirm the model's predictions. Second, we provide evidence on a direct measure of knowledge transfer: the expenditure on technology transfer from abroad.

The paper is organized as follows: In section 2, we present some features of Mexican subsidiaries of MNCs. In Section 3, we present the model and its predictions. In particular, we model multinationals choice of their subsidiaries CEOs and entry decision. Section 4 discussion summarizes the model predictions and the results that we bring to the data. Section 5 presents data and additional empirical results. Section 6 concludes. Results not derived or proved in the

[14]Nocke and Yeaple (2008) analyze theoretically the composition of FDI arising from MNCs' choice of greenfield investment or in cross-border acquisitions, while Kesternich and Schnitzer (2009) analyze both theoretically and empirically find that as political risk increases the foreign ownership share decreases but leverage increases

[15]There are several universities in Mexico, most notably Tecnológico de Monterrey, whose main role is to educate potential managers. Our framework in principle allows us to evaluate the consequences of these institutions, which have implications on education policies.

[16]See Rodríguez-Clare (1996) for a theoretical analysis emphasizing the linkage. Recent papers explore mechanisms of spillover effects by analyzing what kind of plants are benefitting more (Blalock and Gertler, 2007 and Miyamoto and Todo, 2008).

Table 1: Technology Transfer of Mexican Subsidiaries of Multinational Firms

	Plants with no foreign employees	Plants with foreign employees	Total
Dummy (1 if $Transfer > 0$)	0.09***	0.21***	0.15
	(0.02)	(0.03)	(0.02)
Total Transfer	1999.43**	5496.73**	3626.08
	(914.36)	(2755.95)	(1370.12)
Log of total Transfer	8.73	8.85	8.81
	(0.60)	(0.34)	(0.30)
Total transfer/Sales (%)	0.20**	0.45**	0.32
	(0.06)	(0.10)	(0.06)
Number	209	182	391

Notes: The table reports summary statistics of amount spent on technology transfer from abroad. The first column is the statistics for plants without any foreign employee, while the second with at least one foreign employee, and the third for all plants pooled together. Standard deviation of the means in parentheses. Expenditure on technology transfer is in nominal thousand pesos (A dollar was 9.5 pesos in the beginning of 2000). Significance of the test of the equality of the mean of the two groups: * 10 percent, ** 5 percent, *** 1 percent.

text are found in the appendix.

2 Preliminary Facts

Does the identity of the managers of local subsidiaries, i.e. expatriates or local managers, matter? We first provide facts that plants with expatriates and without them do indeed differ in terms of their innovative activities, technology transfer from abroad and $R\&D$. We use confidential plant-level data from Mexico.[17] Table 1 presents statistics of expenditure on the acquisition of technology from abroad for Mexican subsidiaries of MNCs in the data. Subsidiaries of MNCs are defined as plants that report a foreign capital ratio bigger than 33 %.[18] There are 391 such plants in the data. Of 391 subsidiaries, 209 plants report having no foreign employees, where as 182 plants report having at least one foreign employee. We assume that plants with at least one foreign employee have foreign expatiates as managers.[19] Table 1 shows that plants with at

[17] We explain the data in Section 5.

[18] The choice of this threshold does not affect the qualitative results in this paper.

[19] As the analysis of German plants in Mexico in Carrillo and Hinojoza (1999) shows, this is a realistic assumption: "The presence of Germans based in Mexico represents less than 1% of total employment. Yet, in their majority they hold managing positions".(translated from the text)

Table 2: R&D Intensity of Mexican Subsidiaries of Multinational Firms

	Plants with no foreign employees	Plants with foreign employees	Total
Dummy (1 if $R\&D > 0$)	0.2	0.16	0.18
	(0.03)	(0.03)	(0.02)
Total $R\&D$	2576.56	5492.13	3930.22
	(914.36)	(2755.95)	(1370.12)
Log of total $R\&D$	7.85*	8.77*	8.23
	(0.33)	(0.37)	(0.25)
Total $R\&D$/Sales (%)	0.18*	0.38*	0.27
	(0.04)	(0.10)	(0.05)
Number	209	182	391

Notes: The table reports summary statistics of R&D variables. The first column is the statistics for plants without any foreign employee, while the second with at least one foreign employee, and the third for all plants pooled together. Standard deviation of the means in parentheses. R&D expenditure is in nominal thousand pesos (A dollar was 9.5 pesos in the beginning of 2000). Significance of the test of the equality of the mean of the two groups: * 10 percent, ** 5 percent, *** 1 percent.

least one foreign employee have a statistically significantly higher likelihood of spending a positive amount in technology transfer from abroad. The amount of the expenditure as well as the ratio of the expenditure on total sales are also statistically significantly higher for plants with at least one foreign employee than for plants with no foreign employee. The comparison of the log of the expenditure suggests that, conditional on spending a positive amount of expenditure, there is no difference of the amount of expenditures between the two types of plants.

The fact that technology transfer from abroad is higher for plants with expatriates may not be surprising if expatriates are substitute of local $R\&D$. However, plants with expatriates are also spending higher amounts on $R\&D$. Table 2 presents summary statistics of $R\&D$ expenditure for Mexican subsidiaries of MNCs. Table 2 shows that there is no statistically significant difference of the likelihood of engaging $R\&D$ between the two types of the plants. However, conditional on engaging $R\&D$, the $R\&D$ expenditure is statistically significantly higher for plants with at least one foreign employee than plants with no foreign employee. These together show that foreign plants with expatriates are engaged in more technology-intensive activities both in terms of technology transfer from abroad and local $R\&D$.

3 A Theory of Multinational Expatriates: Leadership meets Culture

We present an information based leadership theory of multinational expatriates.[20] The model studies whether the Headquarter (HQ) appoints an expatriate or a local CEO in the subsidiary where the company may expand. The key idea of the model is that the appointment of the CEO will determine the extent of information asymmetries between the HQ, the CEO and local workers. In particular, we assume that only the HQ and the subsidiary CEO, if he is an expatriate, are familiar with the technology of the parent company. On the other hand, they ignore local conditions, which are known by local workers and the subsidiary CEO if he is local. Figure 1 summarizes the distribution of information asymmetries as function of the subsidiary CEO. The relative importance of transferring the technology and adapting to local conditions in the profits of the subsidiary as well as the distributional properties of both information sets determines what CEO minimizes the overall negative impact of information asymmetries. Because the expatriate CEO knows the headquarter technology, but the local CEO knows local conditions, multinationals have to choose between who is the best leader, i.e. the expatriate, and who is the best supervisor, i.e. the local manager. This trade off depends on the technological intensity of the subsidiary production and the uncertainty of local conditions. We proceed as follows: The first section describes the assumptions of the model. The second section analyzes the multinational's choice of their subsidiaries CEO. The third section analyzes the entry decision. Proofs and derivations not found in the text are in the model's appendix.

[20]The model is a modified version of the model developed in the theoretical paper "Leadership meets Culture: Multinationals subsidiaries CEOs" by Santacreu-Vasut(2010).

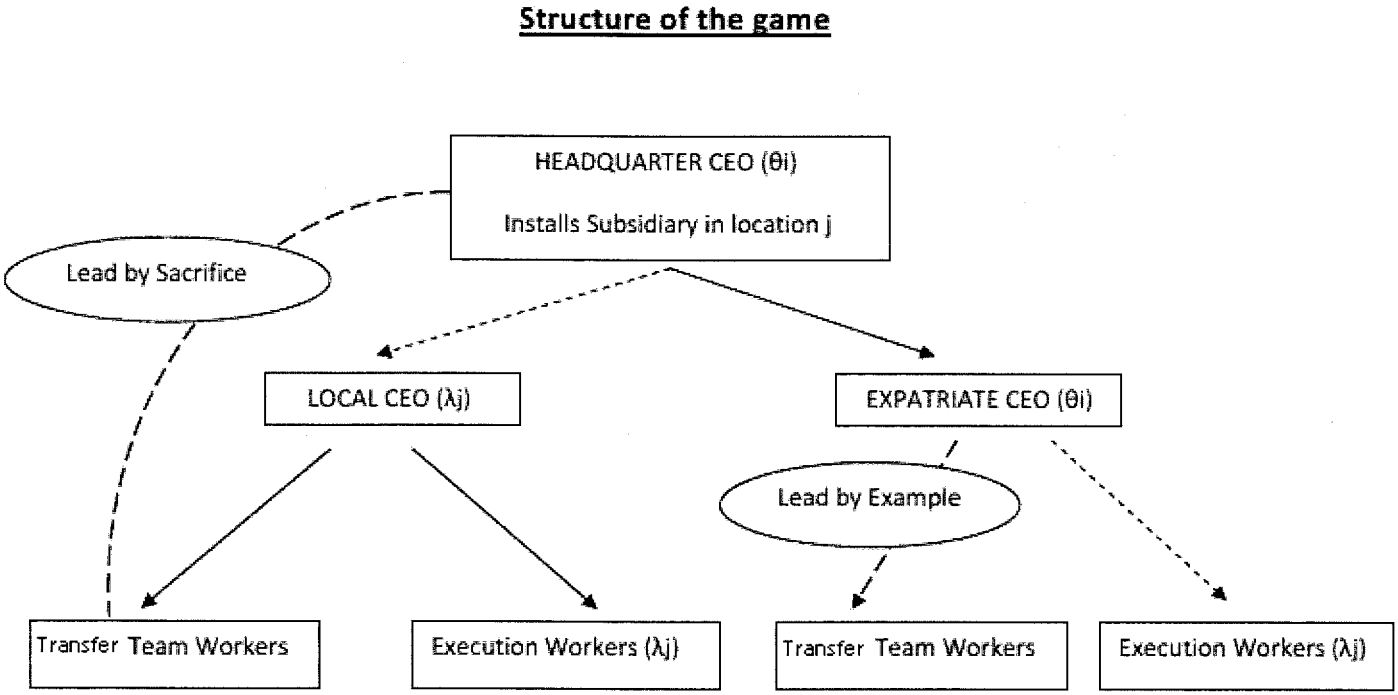

Figure 1: MNCs choice of their subsidiary CEO and information asymmetries along the hierarchy

3.1 Assumptions

3.1.1 Technology

Let V be the total value of the subsidiary production. It is a function of the value generated in a transfer and an execution stage.[21] Namely, V= F(T,X). V is strictly increasing in T and X.[22]

The transfer stage involves team production. There are N_t workers in the transfer team. The CEO is part of the team and exerts effort as well.[23] The effort provided by a member of the team, e_n, is unobservable and cannot be contracted upon. The transfer value is equal to $T = \sum_{n=1}^{N_t} \theta_i e_n$ where θ_i denotes the value of the technology to be transferred.

There are N_x workers in the execution stage, distinct from the transfer stage workers. The CEO does not exert effort at this stage.[24] The effort exerted by a given execution worker is observable and contractible upon for all n. The execution stage value is equal to $X = \sum_{n}^{N_x} e_n$.

3.1.2 Workers Preferences

Workers in the transfer team enjoy utility is $w - d(e)$, where w is a wage and $d(.)$ is an increasing, convex and thrice differentiable function s.t d(0)=0, d'(0)=0. Let $d(e) = \frac{1}{2}e^2$ and normalize reservation utilities U_r of every worker to zero.

Workers in the execution stage enjoy utility: $w - d(e)$ where w is a wage and $d(.)$ is an increasing, convex and thrice differentiable function s.t d(0)=0, d'(0)=0. Let $d_i(e) = \lambda_i e^2$ and normalize reservation utilities U_r of every worker to zero. λ_i reflects the inefficiency of local conditions.

3.2 Information Structure

The distributional properties of θ_i are common knowledge. If the CEO is an expatriate, he knows the realization of θ_i . If the CEO is a local manager he ignores θ_i. Workers ignore the

[21] The execution stage can be interpreted as the relation between the firm and external suppliers.
[22] We will impose further assumptions on F later on.
[23] We can think of them as white collar workers.
[24] We can think of them as blue collar workers.

realization of θ_i. The Headquarter learns the realization of θ_i after deciding whether to rely on an expatriate or a local manager, but before the transfer team members choose their effort.

The distributional properties of λ_i are common knowledge. If the CEO is from the local economy, he learns the realization of λ_i before paying workers. If the CEO is an expatriate from the headquarters, he ignores λ_i. Workers know the realization of λ_i.

3.3 Contract Space

A contract in the transfer team is a set of contingent wages $w_n(T, \hat{\theta})$ for all $n \epsilon N_t$ where $\hat{\theta}$ is the announced value of θ. We restrict attention to renegotiation proof and feasible contracts, that is, such that $\sum_n^{N_t} w_n(, \hat{\theta}) \leq T$. We assume that each worker holds the same beliefs on θ conditional on the announcements. By proposition 1 of Hermalin (1998), this allows us without loss of generality, to consider only affine shares contract. We restrict contracts to be equal shares contract. We do so because the transfer value is likely to be nonmonetary or indivisible and so will be equally shared by all the workers involved at that stage. We do discuss the implications of relaxing this assumption for the results we obtain. The headquarter appropriates a fraction η of the transfer value.[25] The local team shares $1 - \eta$ of the transfer value.

The execution stage takes place after the transfer stage. Given T, the CEO is given a positive but negligible bonus as a function of X.

Table 3 summarizes the parameters and main variables of the model.

3.4 Multinational's Choice of Subsidiary CEO

Conditional on entry, the multinational chooses who to hire as its subsidiary CEO. Given the information structure described above, the multinational faces a trade off between hiring an expatriate, who knows the value of the technology, and hiring a local manager, who is familiar with local conditions. In what follows we start by deriving the advantages of the expatriate in transferring technology. We then derive his disadvantages in dealing with local conditions.

[25] η can be either exogenous or endogenous. In the former case, it may be so due to some technological property of the production process. In the latter case, the optimal fraction the HQ appropriates is $\eta = \frac{1}{2}$.

Parameter	Parameter space	Description
θ_i	(θ_h, θ_l)	Value of the project (technology) transfered
p_i	(p_h, p_l)	Probability of high value or low value project
λ_j	(λ_h, λ_l)	Local inefficiency
q_i	(q_h, q_l)	Probability high or low local inefficiency
η	[0,1]	Share of the transfer stage appropriated by Headquarters.[26]
N_t	$[2,+\infty)$	Size of the transfer team
N_x	$[1,+\infty)$	Size of the execution stage workforce
Variable	**Function**	**Description**
V	$V = F(T, X)$	Production output of subsidiary
T	$T = \sum_{n=1}^{N_t} \theta e_n$	Output of the transfer stage
X	$X = \sum_{n}^{N_x} e_n$	Output of the execution stage

Table 3: Parameters and main variables of the model

Finally, we show under what conditions (properties of the technology to be transferred and the extent of local inefficiency and uncertainty) the former outweighs the latter and so an expatriate is hired (and viceversa).

3.4.1 Technology Transfer

Transferring technology to the subsidiary involves both a flow of information from the Headquarter to the local workers and an adoption effort from the local team. In particular, assume that the value of the technology transferred can be high (equal to θ_H), with probability p_H, or low (equal to θ_L) with probability $1-p_H$. The marginal product of effort to adopt the technology is, therefore, increasing in the value of the technology. As a result of this complementarity, and because local workers ignore the technology, workers' effort at this stage will depend on their beliefs about its value. Announcing the value of the technology from the Headquarters will not be credible, as the HQ has incentives to fool workers.[27] Therefore, transmitting information on the value of the technology must be costly to be credible.

The first option of the Multinational is to choose an expatriate CEO. Because the expatriate knows the value of the technology, his presence in the subsidiary means that he can use his own effort to credibly transmit information. That is, in terms of Hermalin (1998) leadership theory, he can *lead by example*. Alternatively, the expatriate can make side payments to the members

[27]Please refer to the appendix for the derivation and proof.

of his team whenever the technology is of high value. This is what Hermalin (1998) calls *lead by sacrifice*. The second option of the Multinational is to hire a local CEO. In this case leading by example is not in the set of available strategies because the local CEO ignores θ_i. Therefore, the headquarter must make side payments to the members of his team to transmit the information. Hermalin's leadership theory finds a natural application in this setting allowing us to analyze how the choice of the subsidiary CEO affects the set of available strategies to transfer the technology.

By assumption, the fraction $(1-\eta)$ of team's output is shared evenly among the team members. Consequently the utility of worker j in the transfer team is:

$$\frac{\theta}{\frac{J}{1-\eta}}(e_j + \sum_{m \neq j} e_m) - \frac{1}{2}e_j^2 \tag{1}$$

Let $\theta^E(\mu)$ be the expected value of θ given $p_H = \mu$. The best response of a given workers to $\theta^E(\mu)$ is

$$e^{BR} = \frac{\theta^E(\mu)}{\frac{J}{1-\eta}} \tag{2}$$

Let $r(\mu) = (J-1)e^{BR} = \frac{J-1}{\frac{J}{1-\eta}}\theta^E(\mu)$ be the collective reaction of the workers in the transfer team.

Expatriate CEO: leading by example

Assume that the CEO can exert effort prior to the rest of workers and that this effort is observable but not verifiable. If so, he can signal the value of the technology using his own effort. In principle the expatriate could also lead by sacrifice, but Hermalin (1998) shows that leading by example is superior because it boosts the team's total effort (which is optimal given teams free riding problem). For completeness the appendix derives the case in which the expatriate leads by sacrifice.

The utility of the CEO is:

$$u(\mu, x, \theta) = \frac{\theta}{\frac{J}{1-\eta}}(x + r(\mu)) - \frac{1}{2}x^2 \tag{3}$$

If $\theta_i = \theta_L$, the CEO chooses

$$x(\theta_L) = \frac{\theta_L}{\frac{J}{1-\eta}} \tag{4}$$

that maximizes $u(0, x(\theta_L), \theta_L)$. In that case, the rest of workers choose $e = \frac{\theta_L}{\frac{J}{1-\eta}}$ and $T_L = (1-\eta)\theta_L^2$.

If $\theta_i = \theta_H$, the CEO chooses

$$x^e(\theta_H) = \frac{\theta_L + \sqrt{2}\sqrt{(J-1)\theta_L(\theta_H - \theta_L)}}{\frac{J}{1-\eta}} \tag{5}$$

such that $u(1, x(\theta_H), \theta_L) = u(0, x(\theta_L), \theta_L)$. In that case the rest of workers choose $e = \frac{\theta_H}{\frac{J}{1-\eta}}$ and

$$T_H = \theta_H^2 \frac{J-1}{\frac{J}{1-\eta}} + \theta_H\left(\frac{\theta_L + \sqrt{2(J-1)\theta_L(\theta_H - \theta_L)}}{\frac{J}{1-\eta}}\right) \tag{6}$$

Result 1: Assume that the transfer team is big enough, namely assume $J > (1 + \frac{2(\theta_H - \theta_L)}{\theta_L})$. *Then, the CEO effort in the transfer stage is higher when he leads by example than when he leads by sacrifice. Furthermore, this difference is increasing in* θ_H.

That is, normalizing $\theta_L = 1$ across firms, those for which the good project has a higher value, for instance in high technology industries, benefit relatively more from the ability of the expatriate to lead by example.

By boosting the CEO's effort, leading by example boosts the team's overall effort, which is optimal and welfare improving given the chronic under provision of effort involved in team production. As discussed in Hermalin (1998), one can improve further effort provision by not

imposing equal sharing rule. In particular, because the manager has an extra motive to provide effort (convince workers), one could decrease the manager's share of the transfer value and increase the rest of the team share. This would be welfare improving and increase total effort as long as the team is big enough.

The expected value of the transfer stage if the CEO is an expatriate and leads by example is equal to:

$$E(T^e|LE) = p_H(\theta_H^2 \frac{(J-1)}{\frac{J}{1-\eta}} + \theta_H(\frac{\theta_L + \sqrt{2(J-1)\theta_L(\theta_H - \theta_L)}}{\frac{J}{1-\eta}})) + (1-p_H)(1-\eta)\theta_L^2 \quad (7)$$

Result 2: The expected value of the transfer stage, $E(T^e|LE)$ when the expatriate leads by example is increasing in θ_H and in p_H. Further, $\frac{\delta E(T^e|LE)}{\delta \theta_H \delta p_H} > 0$

That is, firms that are more likely to have a good project, and whose good project is of higher value generate higher value in the transfer stage. Further, having a potentially high value good project is of more value to firms with higher likelihood of having a good project.

Corollary of result 2: When $\theta_H = \theta_L$ and/or when $p_H = 0$, the value of the transfer stage is identical under an expatriate CEO that leads by example or by sacrifice.

Local CEO: Headquarter leading by sacrifice

If the CEO is a local manager, he ignores the realization of θ_i. Consequently, he cannot lead, neither by sacrifice nor by example, and he behaves as a regular worker in the transfer stage. The headquarter, on the other hand, knows the realization of θ_i. To transmit the value of technology the only option the HQ has is to lead by sacrifice.[28]

By assumption, the HQ gets ηT of the value of the transfer stage. Let $\Omega(\mu, x, \theta_i)$ be the fraction of profits accrued to the HQ when workers believe that the probability of the good state

[28]This is so because we assume that the HQ CEO does not exert effort in the subsidiary. This assumption can be relaxed. The crucial aspect is that the headquarter are geographically distant from the subsidiary and therefore cannot exert effort prior to the rest of workers in an **observable** manner.

is equal to μ, the HQ sacrifices x and the true state is θ_i.

In particular,

$$\Omega(\mu, x, \theta_i) = \eta(1-\eta)(\mu\theta_H + (1-\mu)\theta_L)\theta_i \tag{8}$$

In the least cost separating equilibrium, $x^{HQ}(\theta_L) = 0$ and $x^{HQ}(\theta_H) = \eta(1-\eta)[\theta_H\theta_L - \theta_L^2]$. That is, such that $\Omega(1, x, \theta_L) = \Omega(0, x, \theta_L)$. The expected cost of transmitting information is $p_H x^{HQ}(\theta_H)$.

Result 3: Headquarters expected cost of credibly transmitting the information when they rely on a local manager is increasing in p_h and in θ_H.

Given these

$$E(T^l|HQ) = p_H(1-\eta)\theta_H^2 + (1-p_H)(1-\eta)\theta_L^2 \tag{9}$$

Result 4: The transfer expected value is lower when the subsidiary CEO is local than when he is an expatriate that leads by example.[29]

Result 5: Expected profits obtained in the transfer stage are higher under an expatriate CEO than a local CEO, and this is even more so for firms with high probability of high value technology (with high p_h and high θ_H).

There are two reasons for the first part of this result. First, when an expatriate CEO is relied upon, he can lead by example and has an additional motive to exert higher effort (convince workers that the technology is of high value). Second, an expatriate internalizes the cost of information transmission, given that he is part of the team, a cost that the headquarters has to afford when they rely on a local CEO. The value of relying on an expatriate CEO is increasing in p_h and θ_H because they make the need and cost of credibly transmitting information more acute.

[29] In the appendix we derive the case when the expatriate manager can only lead by sacrifice and compare the cost of transmitting information.

Let LT denote the loss in the transfer stage from relying on a local CEO. LT is equal to

$$LT = p_H\eta(1-\eta)[\theta_H(\underbrace{\frac{\theta_H}{J} - \frac{\theta_L + \sqrt{2(J-1)\theta_L(\theta_H-\theta_L)}}{J}}_{example<0}) - \underbrace{(\theta_H\theta_L - \theta_L^2)}_{sacrifice>0}] \tag{10}$$

.

$LT < 0$ follows from result 5.

3.4.2 Local Conditions

$\lambda_i = \{\lambda_H, \lambda_L\}$ captures the inefficiency of local conditions. It may be high, with probability q_H, or low, with probability $1 - q_H$. This parameter is common to all local workers and captures aspects of the cultural, political and legal local conditions. In particular, we assume that λ_i is the marginal cost of effort of local workers in the execution stage.[30]

If a local manager is relied upon, he knows λ_i and can obtain first best level of effort from workers.[31] On the contrary, if an expatriate is relied upon, he ignores local conditions and can only obtain second best level of effort. We derive the optimal contract in the case in which workers are able to collude against the manager. The appendix includes the optimal contract, a direct revelation mechanism, when workers are unable to collude, that achieves first best.[32] In the appendix we also show that if the expatriate manager offered the contract designed by the local CEO, workers would have incentives to fool him and extract rents from him. In particular, they would work as if local inefficiency was always high, that is $\lambda_i = \lambda_H$.

The expatriate manager will offer a state contingent contract, (w_j^e, e_j^e) for $j = H, L$ in order to maximize expected profits, $E[\prod^e]$, s.t participation and incentive constrains, IR_L, IR_H, IC_L, IC_H.[33]

In particular, he will offer

[30] An alternative interpretation is that λ_i reflects the inefficiency of local suppliers.

[31] The first best contract he offers and its derivation is available in the appendix.

[32] The assumption that collusion is impossible and that the manager relies on the "shot them all mechanism" is unrealistic and uninteresting.

[33] The derivation is included in the appendix.

$$w_H^e = \lambda_H \frac{1}{4[\frac{\lambda_H - \lambda_L}{q_H} + \lambda_L]^2} \tag{11}$$

and

$$w_L^e = (\lambda_H - \lambda_L)\frac{1}{4[\frac{\lambda_H - \lambda_L}{q_H} + \lambda_L]^2} + \frac{1}{4\lambda_L} \tag{12}$$

with

$e_L^e = \frac{1}{2\lambda_L}$

$e_H^e = \frac{1}{2[\frac{\lambda_H - \lambda_L}{q_H} + \lambda_L]}$

Expected output per worker when an expatriate CEO is hired is equal to

$$E[e^e] = q_H(\frac{1}{2[\frac{\lambda_H - \lambda_L}{q_H} + \lambda_L]}) + (1 - q_H)(\frac{1}{2\lambda_L}) \tag{13}$$

and the difference in expected output between an expatriate and a local CEO is

$$E[e^e] - E[e^l] = q_H(\underbrace{e_H^e - e_H^l}_{<0}) + (1 - q_H)(\underbrace{e_L^e - e_L^l}_{=0}) \tag{14}$$

Result 7: In the execution stage the expatriate secures as much effort from local workers as the local CEO when local inefficiency is low, but less effort when local inefficiency is high.[34] *Therefore, expected output is lower under an expatriate manager.*

Result 8: Higher local uncertainty increases the expected output loss in the execution stage derived from relying on an expatriate CEO (relative to a local CEO)

The expected wage bill when an expatriate is relied upon is equal to

[34]This result is known as "efficiency at the top".

$$E[w^e] = q_H(\lambda_H \frac{1}{4[\frac{\lambda_H - \lambda_L}{q_H} + \lambda_L]^2}) + (1 - q_H)((\lambda_H - \lambda_L)\frac{1}{4[\frac{\lambda_H - \lambda_L}{q_H} + \lambda_L]^2} + \frac{1}{4\lambda_L}) \tag{15}$$

and the difference in expected wage between an expatriate and a local CEO is equal to

$$E[w^e] - E[w^l] = q_H(\underbrace{w_H^e - w_H^l}_{<0}) + (1 - q_H)(\underbrace{w_L^e - w_L^l}_{>0}) \tag{16}$$

Result 9: The expatriate CEO pays workers more than the local CEO when inefficiency is low. When inefficiency is high, the expatriate CEO pays workers less than the local CEO.

The expected profit per worker is equal to

$$E[\Pi^e] = q_H(\frac{1}{2[\frac{\lambda_H - \lambda_L}{q_H} + \lambda_L]} - \lambda_H \frac{1}{4[\frac{\lambda_H - \lambda_L}{q_H} + \lambda_L]^2}) + (1 - q_H)(\frac{1}{4\lambda_L} - (\lambda_H - \lambda_L)\frac{1}{4[\frac{\lambda_H - \lambda_L}{q_H} + \lambda_L]^2}) \tag{17}$$

Result 10: Expected profits in the execution stage under an expatriate manager are a decreasing and convex function of q_h and of λ_H.

Result 11: The expected profits in the execution stage under an expatriate manager are lower than under a local manager. The difference is decreasing in λ_H and increasing with local uncertainty. That is, the difference in profits is a U-shaped function of q_H.

Let GE denote the expected gain in the execution stage from relying on a local CEO rather than an expatriate. GE is equal to

$$GE = N_x[q_h(\underbrace{e_H^l - e_H^e}_{>0} - \underbrace{w_H^l - w_H^e}_{>0}) + (1 - q_h)(\underbrace{e_L^l - e_L^e}_{=0} - \underbrace{w_L^l - w_L^e}_{<0})] \tag{18}$$

$GE > 0$ follows from result 11.

3.4.3 Choice of Subsidiary CEO

As shown before, the expatriate is better at transferring technology but worse at dealing with local conditions. When does the gain in the transfer stage out weight the loss in the execution stage? Assume that expected output from the subsidiary operation is additive in the transfer and the execution stages. That is, $V = T + X$ This assumption means that in terms of the total output generated by the subsidiary, these are perfect substitutes.[35]

Result 12: In the transfer stage, an expatriate CEO will outperform a local CEO. In the execution stage, a local CEO will outperform an expatriate.

The multinational will choose the CEO, local or expatriate, that maximizes expected profits, which are equal to $E[\Upsilon] = E[V-(1-\eta)T-\sum_{N_x} w_x]$. Let's define $\Psi \equiv E[\Upsilon \mid Local]-E[\Upsilon \mid Expat]$, be the net impact on profits resulting from relying on a local manager rather than an expatriate. Therefore, $\Psi = GE + LT$.

The following graphs plot the profits generated under local and expatriate.

[35]We can relax this assumption in two ways. First, we can let T and X be imperfect substitutes, with $V = \alpha T + (1-\alpha)X$. In this case we can express Ψ as the weighted sum of the expected gain in the execution stage, GE, and the expected loss in the transfer stage, LT. It is straightforward to see that higher α (for export oriented firms, for example) increases the attractiveness from relying on an expatriate manager. Second, T and X may be complement inputs. That is, $V = T^{\alpha}X^{1-\alpha}$. The formal derivation of how potential complementarities affect multinationals choice is ongoing work. Still, note that if complementary, it may happen that neither the expatriate nor the local CEO generate positive profits and that the multinational decides not to install a subsidiary even if there are no entry costs. That is, the model could generate endogenously barriers to multinational's expansion.

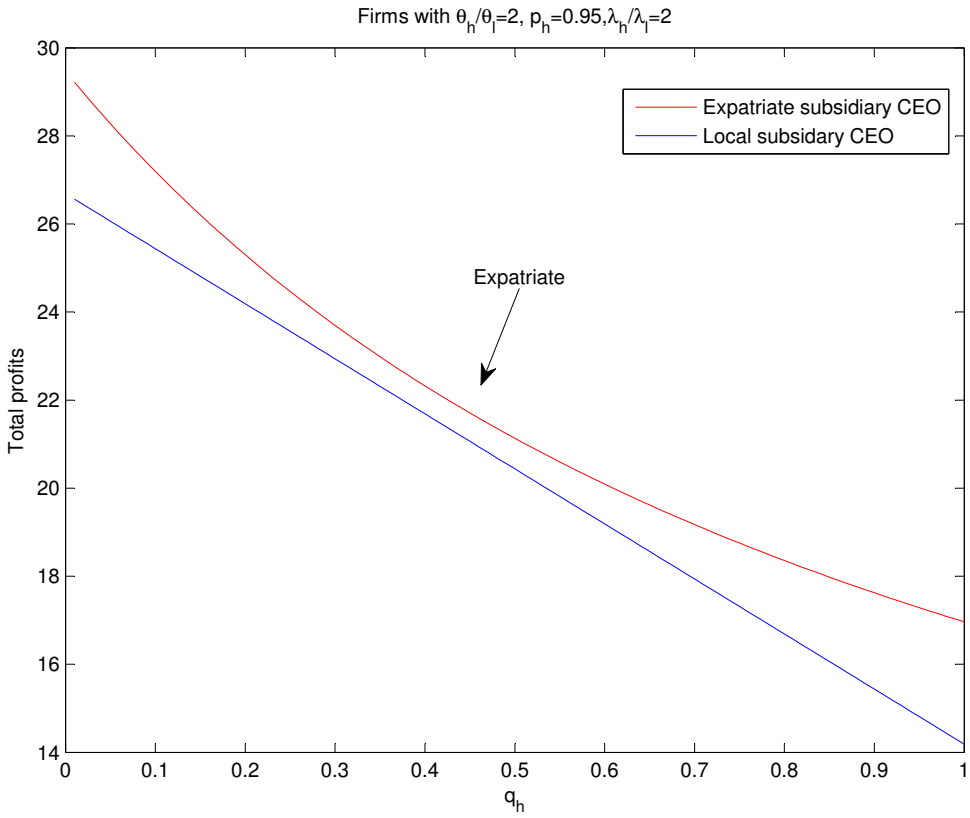

Figure 2: Case I: The expatriate is always preferred

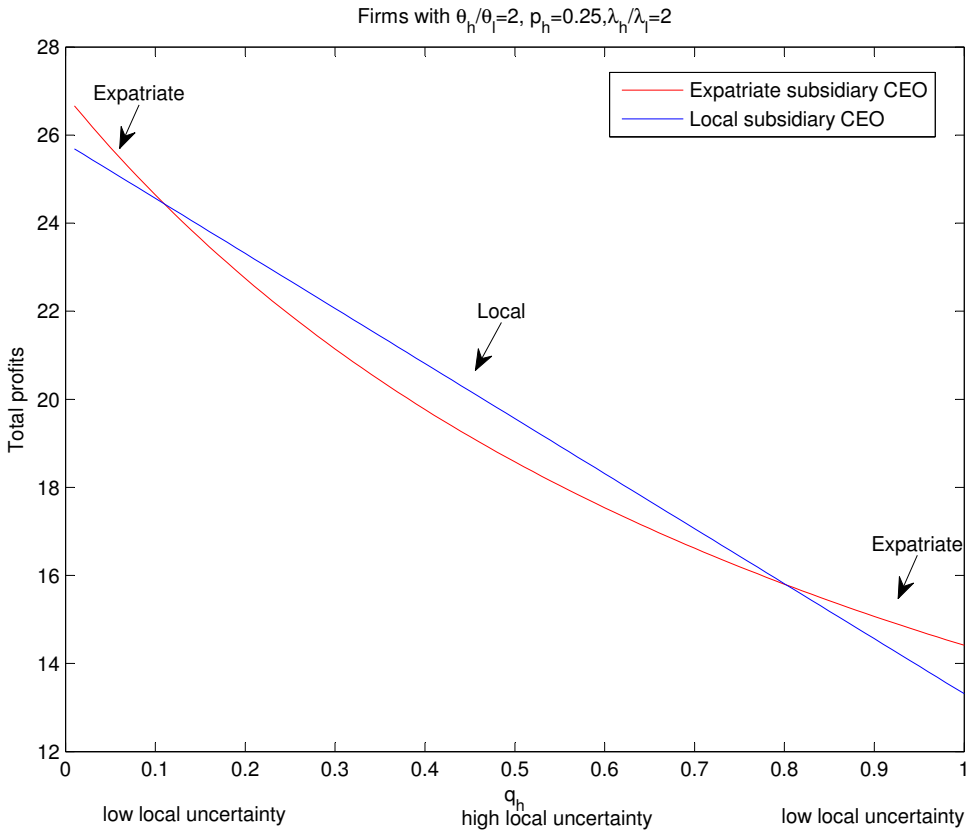

Figure 3: Case II:The expatriate (local) manager is preferred when local uncertainty is low (high)

As figure 2 illustrates, firms with very high value technology, and/or very high likelihood of good project in the transfer stage will always prefer to rely on an expatriate. This is true regardless of the amount of local uncertainty (which is highest when $q_H = 0.5$). The intuition is that for these type of firms the expatriate is very valuable in the transfer stage, overcoming his relatively lower performance as manager in the execution stage. In contrast, as figure 3 illustrates, firms that are not at the cutting edge of their technological sector will choose their subsidiaries manager as a function of local uncertainty. While they will rely on expatriates if uncertainty is low (when q_h is very low or very high), they will prefer local managers when uncertainty is high (for middle range values of q_h).

This analysis allows us to address the following question: Are multinationals relying on expatriates doing so because they are constrained by a shortage of local managers?[36] Empirically, it is hard to distinguish multinationals for which an expatriate is optimal versus those for which a local manager was unavailable. Yet, the model allow us to identify conditions under which the multinational relying on an expatriate was constrained to do so.[37] In particular, let (q^d, q^u) denote the interval of q_H such that a multinational relying on an expatriate is constrained, where q^d and q^u are the roots of $\Psi = 0$. The interval is bigger for firms with lower p_H, lower θ_H and lower λ_H. That is, firms transferring projects to highly unstable economies, specially those with low technological content, would be better off relying on a local manager. If they do not, it must be that they are constrained by a shortage of local managers.

3.5 Entry Decision

In this section we derive the conditions under which the Multinational decides to enter (with an expatriate or with a local manager) and those under which it decides not to enter. To do so, we assume that the multinational faces a positive fixed and exogenous cost of entry, C. We analyze

[36] Alternatively, multinationals may rely on expatriates because they have higher ability not because they need to transfer technology. Although we do not have data to proxy for ability, the case study of German plants in Mexico by Carrillo and Hinojoza (1999) supports our information based story in which German employees are said to be used for the "introduction of new product or process" (translation from Spanish)

[37] We say a multinational is constrained to rely on an expatriate manager when a local manager would have generated higher profit.

six cases according to the magnitude of the cost of entry. Let's index C from highest to lowest such that $C_a > C_b > C_c > C_d > C_e > C_f$ and these thresholds are chosen as the graph shows.

This exercise allows us to ask the following relevant and other related questions. What types of projects get implemented in high risk economies? Unstable developing economies are more likely to attract what type of multinationals? Should governments in developing countries invest in high education of future managers or in primary schooling? What are the consequences for the type of FDI they will attract? And for long run development? These questions are broad, and have consequences for the spread of technology across countries and economic development. In answering them, two issues are at hand: The amount of FDI a given country is able to attract and its composition.

Case 1: $C = C_a$ The multinational enters only if it can hire an expatriate and $q_H < q_a$.

Case 2: $C = C_b$ The multinational enters if $q_H < q_b$ and, if available, relies on an expatriate manager.

Case 3: $C = C_c$ The multinational enters if $q_H < q_c^e$ and, if available, relies on an local manager. If $q_c^e < q_H < q_c^l$, the multinational enters only if a local manager is available.

Case 4: $C = C_d$ The multinational enters if $q_H < q_d$ and, if available, relies on an local manager.

Case 5: $C = C_e$ The multinational enters if $q_H < q_e^l$ and, if available, relies on an expatriate manager. If $q_c^l < q_H < q_c^e$, the multinational enters only if an expatriate manager is available.

Case 6: $C = C_f$ The multinational enters if $q_H < q_f$ and, if available, relies on an expatriate manager.

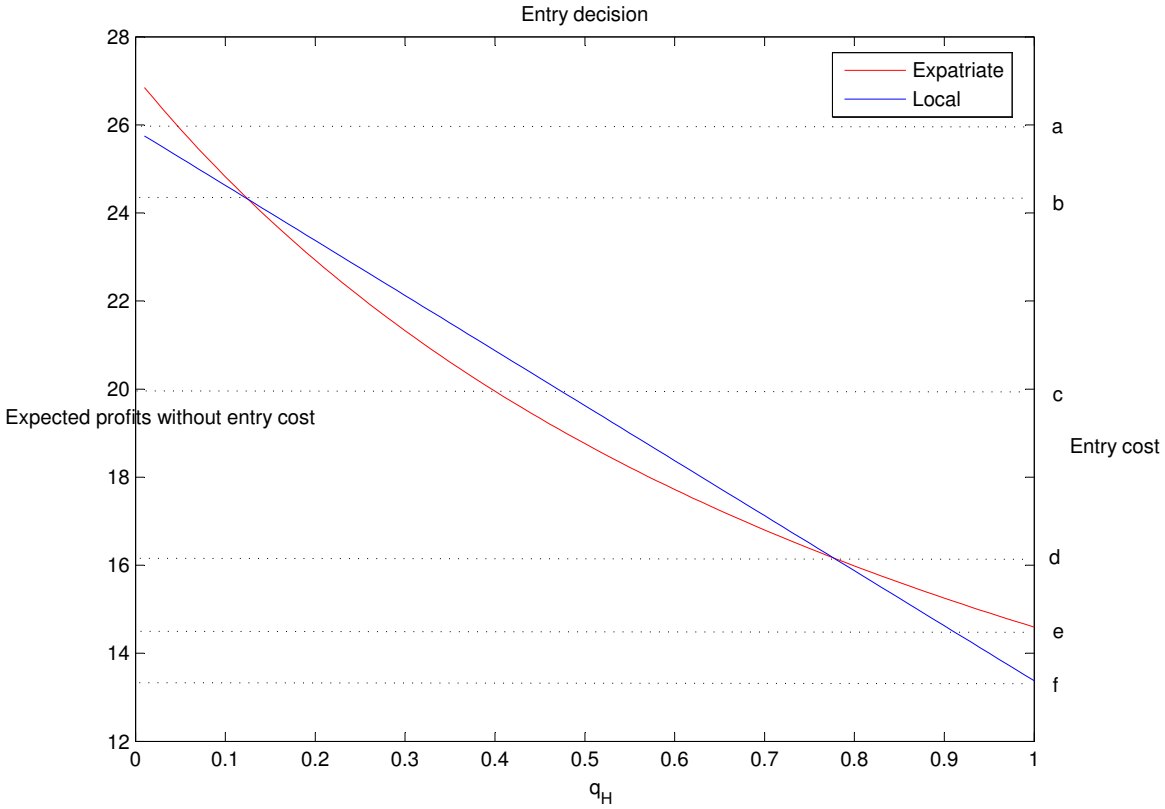

Figure 4: Entry cost, managerial choice and entry decision

Case 3 is particularly interesting. It allows us to understand the consequences from lacking a pool of local managers for a developing country. For multinationals facing a fixed cost of entry that is neither very high nor very low, lacking a pool of local managers will impede entry in countries with high local uncertainty. Under these circumstances, therefore, such countries will attract lower amounts of FDI and its composition will be biased towards firms in the technological edge. That is, with good projects of high value (high θ_H relative to θ_L) and with high probability of being successful (high p_H). The intuition behind this result is that these type of firms, even when facing high local uncertainty will benefit greatly from relying on an expatriate in the transfer stage. Unstable economies that lack a pool of local managers will benefit from this composition bias if spillovers are higher for this type of firm but will attract lower overall FDI levels. On the other hand, they may also suffer from a some kind of mismatch in which they attract only too-high tech FDI from which they cannot benefit much. Investing in educating local managers will therefore increase the absolute attractiveness of the country but will also affect the composition of FDI. The consequences of this composition-quantity biases for economic development are an interesting issue for future exploration. Rather than investing on creating a local pool of managers, a country can invest in primary schooling (equivalent to decrease λ_L). This will represent a shift in the profit function of the multinational both when relying on expatriate and local subsidiaries manager. This shift will increase the absolute attractiveness of the country for a given cost of entry. What are the consequences for the composition of FDI? The answer depends on the degree of local uncertainty and the availability of local managers. If local managers are available, it will bias the composition of FDI towards firms with lower value of good projects (low θ_H). If local managers are not available, it will bias the composition of FDI towards firms with higher value of good projects. Consequently, unstable economies that lack a pool of local managers will benefit more from investing in primary education if their goal is to attract firms at the technological edge.

This section constitutes a first attempt to address issues of composition-quantity biases in developing countries FDI educational related policies. Matching the model's predictions with cross country data on entry, industry composition of FDI flows, local uncertainty and subsidiaries

managerial choices is next in our research agenda.

4 Discussion

In this section we summarize and discuss the theoretical results derived from the model that we bring to the data.

Regarding the relation of expatriates and technology transfer the following results are relevant:

Result 1: Assume that the transfer team is big enough, namely assume $J > (1 + \frac{2(\theta_H - \theta_L)}{\theta_L})$. *Then, the CEO effort in the transfer stage is higher when he leads by example than when he leads by sacrifice. Furthermore, this difference is increasing in* θ_H.

Result 2: The expected value of the transfer stage, $E(T^e|LE)$ *when the expatriate leads by example is increasing in* θ_H *and in* p_H. *Further,* $\frac{\delta E(T^e|LE)}{\delta \theta_H \delta p_H} > 0$

Result 3: Headquarters expected cost of credibly transmitting the information when they rely on a local manager is increasing in p_h *and in* θ_H.

Result 4: If the subsidiary CEO is local, the transfer expected value is lower than when the subsidiary CEO is an expatriate that leads by example.[38]

According to these results, multinationals employing expatriates engage in more technological transfer, and more so in technology intensive industries. The mechanism behind this result is as follows. Transferring technology involves sending information about the value of the technology, as well as the effort of a team of local workers, among them the subsidiary CEO, in receiving and making effective the use of this technology. Because the effort of workers in the transfer stage is complementary to how good the technology is, sending information on its value will be costly and more so for firms in technology intensive industries. Expatriates, familiar with the technology, can use their own effort to signal the value of this technology, that is lead by example. This is a cheaper way to communicate information on the value of the technology than signaling giving gifts from the headquarters, that is lead by sacrifice. This is so because the expatriate internalizes part of the cost and boost the transfer stage team's overall effort, given that he has an extra

[38] In the appendix we derive the case when the expatriate manager can only lead by sacrifice and compare the cost of transmitting information.

motive to exert effort (signaling). Therefore, multinationals in technology intensive sectors find it more valuable to hire an expatriate, and the expatriate's leading by example boosts local efforts to adopt the technology.

Regarding the relation between the local conditions (local inefficiency and local uncertainty) and the reliance on expatriates the following results are relevant:

Result 10: Expected profits in the execution stage under an expatriate manager are a decreasing and convex function of q_h and of λ_H.

Result 11: The expected profits in the execution stage under an expatriate manager are lower than under a local manager. The difference is decreasing in λ_H and increasing with local uncertainty. That is, the difference in profits is a U-shaped function of q_H.

In the model, uncertainty over local conditions, in particular labor costs, is captured by the probability, q_H, that worker's cost of effort is high ($\lambda_i = \lambda_H$).[39] The model results mean that higher uncertainty over local conditions increases the relative value from hiring a local manager, who is familiar with local conditions and so outperforms the expatriate in the execution stage. That is, when q_h is low, increasing it leads to lower reliance on expatriates. When q_h is high, increasing it leads to higher reliance on expatriates. Therefore, the model predicts that subsidiaries in more unstable locations (with middle range values of q_h) are more likely to rely on local managers. This is more so for firms in non-technological intensive industries, that may be more willing to afford the (lower) cost of not relying on an expatriate in terms of technology transfer. Result 11 also states that locations with lower inefficiency in the bad scenario, that is lower λ_H, will benefit more from having the local manager.

Regarding the analysis of the entry decision we find that the supply of local managers will be most critical for locations with high local instability and average fixed costs of entry. This is because the value of local managers is higher in more unstable locations, as previously discussed. Therefore, the attractiveness for FDI will be lower for locations with high local uncertainty. Yet,

[39] In particular, uncertainty is maximized when $q_H = 0.5$. An example of such uncertainty is related to political risks or political willingness to undertake reforms. Location with high political risks may be more likely to experience strikes, which increase the cost of effort, for example, making commuting to the workplace more costly for workers. Local managers, familiar with the political, legal and cultural conditions of the location will be better positioned to anticipate these risks than the expatriate.

our model allow us to say more than that. In particular, our analysis shows that the composition of FDI to an unstable location that lacks a supply of local managers will be biased towards multinationals in technology intensive sectors. This is so because for these type multinationals it is key to rely on expatriates, and they are willing to afford the costs this involves in the execution stage. Therefore, developing countries face quantity-composition biases when developing a supply of local managers.

In addition to the predictions mentioned above, the model bears predictions on the type of firms hiring expatriates with an additional assumption. In particular, result 4 and the following results

Result 7: In the execution stage the expatriate secures as much effort from local workers as the local CEO when local inefficiency is low, but less effort when local inefficiency is high. Therefore, expected output is lower under an expatriate manager.

Result 12: In the transfer stage, an expatriate CEO will outperform a local CEO. In the execution stage, a local CEO will outperform an expatriate

Under the assumption that export oriented firms are more transfer-stage intensive activities while domestic sales oriented firms are more execution intensive activities, the theory predicts that firms hiring expatriates are more likely to be export oriented (while less likely to serve the domestic local market). The mechanism behind this result is that expatriates are particularly valuable for the transfer of technology, while disadvantaged when dealing with local conditions. Consequently, firms whose transfer-stage is a more important input than the execution stage will find it more valuable to hire an expatriate. This shows that not all the performance measures of plants are positively correlated with expatriates. While the model highlights the benefits from hiring an expatriate it also makes explicit its costs, which differentiates itself from a simple alternative productivity-driven story that more productive firms employ expatriates and at the same time excel in every measure.

5 Additional Empirical Results

5.1 Data

The source of information is the *Encuesta Sobre Investigación y Desarrollo de Tecnología* (ESIDET) [Survey on Research and Development of Technology]. This is a confidential survey carried out by the Instituto Nacional de Estadísticas, Geografía (INEGI) [National Institute of Statistics and Geography] of Mexico for the Consejo Nacional de Ciencia y Tecnología (CONACYT) [National Council of Science and Technology]. It has surveys for three sectors: production, education, and government. We will use the data for production, which includes both manufacturing and service sectors. The survey contains information on several aspects of innovative activities: expenditures, human resources and collaborating firms and institutions. It includes information on expenditures for each type of R&D: product R&D and process R&D. We use the 2002 surveys.[40] Each survey elicits information for the previous two years, but for this paper we focus on the cross-sectional variation and report the result for 2000.[41] The key variable is technology transfer, which is defined in the survey as expenses for international technology transfer [egresos por transferencia de technología (internacional)] and includes the cost for purchase or licence of patents and other non-patented inventions, revelation of know-how, and technical assistance. One limitation of the data is that we are not able to distinguish between technology transfer from parents and from other firms. However, we think that the variable mainly consists of technology transfer from the headquarters, as Branstetter, Fisman and Foley (2006) suggest that the mean of royalties paid by affiliates to their headquarters is 0.7 percent (after the patent reform for all the countries), which is actually larger than the mean of the variable in our sample (0.3 percent).

[40] Surveys were done in 1996, 1998, 2002, 2004 and 2006. Teshima (2008) has used the same data to analyze the impact of import competition on different types of innovative activities.

[41] The qualitative results do not change if we use 2001. The advantage of using a panel would be to allow for plant-fixed effects, but the use of expatriates does not change within plants much over a few years, which leaves us little variation within plants.

5.2 Summary Statistics

Table 5 presents summary statistics. We report the mean and the standard deviation of each variable by whether plants have foreign expatriates. Plants with expatriates have larger volumes of total sales and employment. The summary statistics for domestic sales and exports show that plants with expatriates are more export-oriented. They are consistent with the model's prediction that higher productive plants and export-oriented plants are more likely to choose expatriates. We do not find a statistically significant difference of the number of domestic employees. Plants with foreign expatriates have on average 12 foreign employees.

5.3 Empirical Results

We proceed in the following way. We first investigate whether Mexican subsidiaries of MNCs hiring foreign employees spend more in technology purchase from abroad, and if this correlation is stronger in industries whose R&D intensity is high in the U.S., a typical headquarter country. In the following section, we investigate whether Mexican states with higher levels of judicial efficiency (an inverse measure of local inefficiency whose increase will also increase local uncertainty at low levels and decrease it at high levels) find more/less expatriates and foreign firms. We also explore the composition of the industries in terms of R&D intensity. Finally, we examine whether the reliance on foreign employees is correlated with export status, domestic sales and total sales, as a robustness check rather than a direct test of our hypothesis.

5.3.1 Plant-level correlates of expatriates

As we discussed at length in the previous section, the theory prediction that we confirm in this section is that technology transfer is positively correlated with the use of expatriates and more so for technology intensive industries. It is important to note that we are not directly identifying the causality of either the causes or the consequences of MNCs' decision regarding expatriates. The theory predicts correlates of expatriates both as causes and consequences and more importantly the theory predicts that this correlation is stronger for plants or industries with

some characteristics.

First, we analyze the correlation between expatriates and technology transfer. We run the following regressions.

$$\begin{aligned}(Tech\,Transfer/Sales)_{ij} &= \beta_1 D(Foreign\,Expatriates_{ij}) \\ &+ \beta_2 D(Foreign\,Expatriates_{ij}) * R\&D\,Intensity_j \\ &+ \beta_3 Exporter\,Dummy_{ij} + \beta_4 Log(Employees_{ij}) + \mu_j + \epsilon_{ij}\end{aligned}$$

where $(TechTransfer/Sales)_{ij}$ is the expenditure on technology transfer from abroad over sales; $D(Foreign\,Expariates_{ij})$ is the dummy variable indicating whether a plant i in industry j has foreign expatriates, and μ_j is a industry fixed effect. We control for the exporter dummy and the log of the number of the employees to control for size and export orientation.[42]

The measure of $R\&D\,Intensity_j$ deserves detailed explanation. This is R&D intensity at the industry level and corresponds to the value of technology for the headquarter. We draw this information from a standard source, the U.S. Federal Trade Commission (FTC) Line of Business Survey from 1974 to 1977. The Line of Business Survey required firms to report separately R&D expenditures by industry, thus providing the most reliable industry-level information on R&D expenditures. The measure has been used in leading studies in international trade, such as Antràs (2003) and Kugler and Verhoogen (2008), for example. We made the concordance between FTC industry classification and Mexican industry classification by verbal industry descriptions.

Table 6 shows the results. We find significant positive effects of expatriates on the intensity of technology transfer even after controlling for size (log employment), exporter-dummy and industry dummies. The results indicate that plants with expatriates have a 0.2-0.3 % higher technology transfer intensity, which is economically very large.[43] This is consistent with theory prediction that plants that rely more on expatriates are more likely to introduce technology from the parents

[42] We did not use total sales for independent variables because it appears in the left hand side variable.
[43] Note that the average intensity is 0.3 %.

abroad. Columns (1)-(4) confirm that this is true for both all the industries and for manufacturing industries. Column (5) confirms our prediction that the correlation is stronger for more R&D intensive industries. Furthermore, the coefficient on the expatriate dummy is exactly zero, which indicates that there is no relation between expatriates and technology transfer for a (hypothetical) industry with zero R&D intensity. This is consistent with the information transmission role of expatriates in our theory. These results suggest that foreign expatriates may be a big determinant of the technology transfer from the parent MNCs to their subsidiaries and this relation is stronger for R&D intensive industries.

5.3.2 Regional determinants of expatriates, foreign entry and technology contents of FDI

This section brings the predictions regarding the effect of local inefficiency and uncertainty to the data. We use the data on lawyers' perception about the judicial efficiency, in terms of protecting financial contracts, of each Mexican state collected by ITAM/GMA (1999) as measure of average local efficiency[44]. Though the ITAM study collected the data focusing on the legal enforcement of financial contracts, it fits our model if we reinterpret the workers in the execution stage in our model as suppliers of intermediate products. The measure captures the mean score along dimensions such as the quality of judges, the adequacy of judicial resources or the efficiency of enforcement of rulings, among others, and mainly reflects variations on q_h (the probability that local inefficiency is high) across states rather than variations in λ_h(which would reflect different legislations, for example).

In the discussion section we saw that at a high levels of q_h (low level of judicial quality), the dependence on expatriates is decreasing in judicial quality, while at a low levels of q_h, the dependence on expatriates is increasing in judicial quality. The mean and the standard deviation

[44]This measure has been used by Laeven and Woodruff (2007), who discuss it in detail. Briefly, the measure is the mean score along several dimensions such as the quality of judges, the adequacy of judicial resources, the efficiency of enforcement of their rulings, the efficiency of the judicial administration, completeness of property registries and the adequacy of local legislation related to contract enforcement. They also make the geographic pattern of the variable in Figure 1 of their paper and note that "While there is some pattern of legal institutions improving as we move north in Mexico, Figure 1 makes clear that geography alone does not explain the variation in judicial effectiveness."

of the measure are 2.78 and 0.56, respectively.

We run the regression of the following form:

$$D(ForeignExpariates_{ijs}) = \beta_1 JudicialEfficiency_s + \beta_2 (JudicialEfficiency_s)^2 + (X_{ij}) + \mu_j + \epsilon_{ijs}$$

$Judicial\ Efficiency_s$ is the measure of the Judicial efficiency at state s. Our theory predicts that the effect of judicial efficiency (representing $1 - q_h$) has a U-shaped effect on the reliance of expatriates, therefore indicating that β_1 should be negative, while β_2 should be positive. Table 7 shows the results of the estimation using Probit. The table reports the marginal effects. For both all the industries (Columns (1) to (3)) and manufacturing (Columns (4) to (6)), β_1 is negative while β_2 is positive. The results are not sensitive to the inclusion of industry fixed effects and other controls. The results suggest that, consistent with our theory, judicial efficiency reduces the likelihood on employing foreign employees in the low judicial efficiency regime while the opposite is true in the high judicial efficiency regime.

The results indicate that one standard deviation increase from the mean in judicial efficiency is associated with a decrease of about 3 to 5 percent points in the likelihood of employing foreign employees while the same decrease lead to 20 to 25 percent point increase in probability of employing them. (The mean is 46.5 percent).[45] The level of judicial efficiency that predicts the lowest probability of employing foreign employees is about 3.1, which is about 0.3 standard deviation positively away from the mean. One standard deviation away from this point in either way implies about 10 to 13 percent point increase in the probability of employing foreign employees. The magnitude of coefficients indicate that the only state that is in the high judicial efficiency regime is Aguascalientes which has by far the best score (4.59) while the second best state has a score of 3.4. If we exclude Aguascalientes, the square term of judicial efficiency loses significance, but the judicial efficiency itself is statistically significantly negative, confirming that all the other

[45]The mean level of judicial efficiency is at the low efficiency region. Therefore, if judicial efficiency increases, the predicted likelihood of relying on foreign employees decreases first until the bottom of the U-shape and increases after it, while if judicial efficiency decreases from the mean, the predicted likelihood of relying on foreign employees increases monotonically (This asymmetry happens anywhere not at the bottom).

states are in the low judicial efficiency regime. This is in line with the theory indicating that an increase in judicial efficiency in that regime leads to less dependance on expatriates.[46]

Now we turn to our predictions on entry and the technology composition of foreign firms. The model predicts that there will be more entry of foreign firms associated with an increase in judicial efficiency because judicial efficiency increases the profit of MNCs. The rate of the increase in profit associated with higher judicial efficiency depends on the choice of subsidiary CEOs: the profit is a linear function of judicial efficiency when the CEO is local and non-linear if the CEO is an expatriate. Therefore, we include the square term of judicial efficiency in the regression to capture the potential nonlinear effects. In terms of the technological intensity of the entering foreign plants, the model predicts that for the low judicial efficiency regime an increase in judicial efficiency (which rises uncertainty) will lead to lower technology intensity because only high-tech firms generate positive profits. For the high judicial efficiency regime, the model has two opposing effects: an increase in judicial efficiency makes it easier for low-tech firms to enter while the same increase makes expatriates more attractive thus lead to more high-tech firms. Therefore, we include the square term of judicial efficiency in the regression to capture the potential nonlinear effects also for the technological intensity analysis.

Therefore, we run the following regressions to confirm the predictions stated in the previous paragraph:

$$D(ForeignOwnership_{ijs}) = \beta_1 JudicialEfficiency_s + \beta_2 (JudicialEfficiency_s)^2 + (X_{ij}) + \mu_j + \epsilon_{ijs}$$

and

$$R\&DIntensity_{js} = \beta_1 Judicial\ Efficiency_s + \beta_2 (Judicial\ Efficiency_s)^2 + (X_{ij}) + \epsilon_{ijs}$$

[46]Following Laeven and Woodruff (2007), we also used the share of indigenous population in 1900s and the indicator of crop production as instrumental variables for judicial efficiency. However, these instrumental variables are weak in the sense that the F value for the first stage regression is only 2.5 and lead to effects quantitatively too large, though qualitatively consistent with our theory.

Note that we cannot control for industry effects in the latter regression because $R\&DIntensity$ is defined at the U.S. industry level, allowing variations only at the industry level. Note also that the sample for the foreign ownership equation now includes all the plants, i.e. non-foreign plants from ESIDET.

Table 8 shows the results. The first to fourth columns show the results of the Probit estimation of the effect of judicial efficiency on likelihood of foreign ownership, while the fifth and sixth columns show the results of OLS estimation of the effect of same uncertainty on $R\&DIntensity$ defined at the U.S. industry level of the foreign firms that the state attracts. The first to the forth columns suggest that one standard deviation (0.56 point) increase in the judicial efficiency from the mean is associated with about 3 to 4 percent increase in the likelihood of the plants in the area being classified as foreign owned (the mean is 21 percent). The fifth and the sixth columns suggest that one standard deviation (0.56 point) increase in the judicial efficiency is associated with about 1.4 percent decrease on $R\&DIntensity$ (defined at the U.S. industry level) of the foreign firms that the state attracts. The magnitude of β_1 and β_2 suggests that the highest point for predicted entry level and the lowest point for predicted $R\&DIntensity$ level is above the maximum potential judicial efficiency, so that entry is always increasing in judicial efficiency and $R\&DIntensity$ is always decreasing in judicial efficiency for the values of judicial efficiency we observe.[47] This is quantitatively very large because the average $R\&DIntensity$ is 2.8 percent. These results are consistent with the theory prediction that an increase in judicial quality for low values of judicial efficiency leads to more entry of foreign firms, but with a low-tech bias. The opposite is true when the increase in judicial quality happens for high values of judicial efficiency.

6 Robustness check

Finally, we run regressions of the following form to examine more systematically whether plants with foreign expatriates are more likely to have higher total sales, export sales and domestic sales.

[47] Again, if we exclude Aguascalientes, the square term loses significance, but judicial efficiency affects significantly positively the entry but negatively the technological intensity, confirming again all the other states are in the region of low judicial efficiency.

We run the following regression:

$$Y_{ij} = \beta_1 D(Foreign\ Expariates_{ij}) + \beta_2 Log(Employees_{ij}) + \mu_j + \epsilon_{ij}$$

Columns (2) and (3) of Table 9 show that both the exporter dummy and exports sales are positively correlated with the use of expatriates, which is consistent with the conjecture that exports are positively correlated with the use of expatriates if exports are more transfer-stage intensive activities. Column (4) shows that domestic sales are not statistically significantly correlated with the use of expatriates, which is not perfectly consistent with the conjecture that domestic sales are negatively correlated with the use of expatriates if domestic sales are more execution-stage intensive activities. It may be the case that expatriates' technology transfer affect also positively the domestic sales which may offset their potential disadvantages in the execution stage. Although the results suggest that exploring the consequences of complementarities between transfer and execution stages is worthwhile, the fact that we do not find positive significant correlation between expatriates and domestic sales allows us to rule out the cases where (a) high productive firms choose expatriates for reasons unrelated to our model and drives everything or where (b) some other factors are affecting both productivity and choice of expatriates. Finally, Column (1) shows that total sales as a whole is positively correlated with the use of expatriates.

7 Conclusion

In this paper we have analyzed multinationals choice of their subsidiaries CEOs and related entry decisions in foreign markets. Namely whether, conditional on entry, they rely on foreign expatriates or local managers. We applied the information based theory of leadership of Hermalin (1998) and find that multinationals using cutting edge technology are more likely to employ foreign expatriates. These are key in fostering technological transfer to the subsidiary, given their ability to lead by exerting effort in the subsidiary. Doing so, they can convince workers of the value of the

multinationals technology. In highly unstable economies, nevertheless, the expatriate managers are unable to provide high incentives to local workers. Regarding multinationals entry decision, our theory shows that developing countries face quantity-composition biases when deciding to create a pool of local managers. Not doing so they may attract less FDI but its composition will be biased towards firms at the technological cutting edge. Multinationals choice of their subsidiary CEO and entry decisions, as we analyze in the data, have important consequences in the local economy.

In particular, Mexican plant level data reveals that plants with higher productivity and higher export orientation are more likely to rely on expatriates. We also show that plants relying on foreign expatriates are more likely to engage in technology transfer, and more so in R&D intensive industries. The magnitude of these results suggests that foreign expatriates may be a big determinant of the technology transfer from the parent MNCs to their subsidiaries. Further, using data on lawyers' perception about the judicial efficiency of each Mexican state collected by ITAM/GMA (1999) as measure of average local inefficiency we find that judicial efficiency reduces the likelihood on employing expatriates in the regime with low level of judicial quality while the opposite is true in high level judicial quality regime. This is consistent with the U-shape relation between local uncertainty and expatriates predicted in the theory. Finally, regarding FDI entry and composition, we find that an increase in judicial quality is associated with more entry of foreign firms, while these are more likely to be low-tech.

The current analysis has important policy implications for developing countries. For example, regarding human capital policies, our theoretical analysis shows the disparity of consequences from promoting primary schooling versus promoting top management education. While the latter allows these countries to develop a pool of local managers, potentially hired by multinationals, it also makes it profitable for low tech multinationals to enter. We plan to investigate, both theoretically and empirically, the impact of these quantity-composition biases of FDI for economic development in our future work. Regarding visa policies, our analysis shows that restrictive visa policies may come at the cost of lower technology transfers from abroad, since expatriates are

found to be a key channel behind those transfers.

Regarding future work, at the empirical level, addressing the causal impact of expatriates is next. At the theoretical level, investigating further the impact of expatriates on local development by incorporating the amount and nature of spillovers from multinational companies to local firms is a natural extension.

A Appendix

A.1 Information Transmission and Incentives to Fool Workers[48]

Recall that a fraction $(1-\eta)$ of team's output is shared evenly among members of the transfer team. Consequently the utility of worker j in the transfer stage is:

$$\frac{\theta}{\frac{J}{1-\eta}}(e_j + \sum_{m \neq j} e_m) - \frac{1}{2}e_j^2 \tag{19}$$

Let $\theta^E(\mu)$ be the expected value of θ given $p_H = \mu$. The best response of a given workers to $\theta^E(\mu)$ is

$$e^{BR} = \frac{\theta^E(\mu)}{\frac{J}{1-\eta}} \tag{20}$$

Let $r(\mu) = (J-1)e^{BR} = \frac{J-1}{\frac{J}{1-\eta}}\theta^E(\mu)$ be the collective reaction of the workers in the transfer team.

Given $r(\mu)$ the CEO utility is equal to

$$\frac{\theta_i}{\frac{J}{1-\eta}}(e + r(\mu)) - \frac{1}{2}e^2 \tag{21}$$

Regardless of the realization of θ_i, the expatriate CEO utility is increasing in $r(\mu)$. Consequently, he has incentives to fool workers and announce $\hat{\theta} = \theta_H$ regardless of the truth.

[48] We show that an expatriate CEO has incentives to fool workers. It follows that the HQ has the same incentives.

Anticipating this fact, workers will disregard any announcement from the CEO, and $\theta^E(\mu) = \mu\theta_H + (1-\mu)\theta_L$.[49]

A.2 Expatriate Leads by Sacrifice

To transmit information on the value of the project credibly, the CEO can *lead by sacrifice*. For example, he can spend resources in training workers or give them a gift. Let $\widehat{x}(\theta_i)$ be the amount the manager sacrifices (side payments) as a function of the value of the technology.[50] To minimize the cost of transmitting information, he will only give workers a monetary gift when the true state is θ_H.[51]

If $\theta_i = \theta_L$, the leader makes no sacrifice, $\widehat{x}(\theta_L) = 0$ and workers are certain that $\theta_i = \theta_L$. In that case, he and the rest of workers choose $e = \frac{\theta_L}{\frac{J}{1-\eta}}$. $T_L = (1-\eta)\theta_L^2$.

If $\theta_i = \theta_H$, the leader will make a sacrifice to convince workers that the true state is θ_H. In particular, he will choose to give up a gift that would be too costly if the true state was θ_L and workers believed it was θ_H. That is, the CEO will choose

$$\widehat{x}(\theta_H) = \{x|\theta_L(\frac{2(J-1)\theta_L + \theta_L}{2(\frac{J}{1-\eta})^2}) \geq \theta_L(\frac{2(J-1)\theta_H + \theta_L}{2(\frac{J}{1-\eta})^2}) - x\} \tag{22}$$

The CEO will choose the minimum possible sacrifice,

$$\widehat{x}(\theta_H) = \frac{(J-1)\theta_L(\theta_H - \theta_L)}{(\frac{J}{1-\eta})^2} \tag{23}$$

In that case, he and the rest of workers choose $e = \frac{\theta_H}{\frac{J}{1-\eta}}$ and $T_H = \theta_H^2(1-\eta)$.

[49] From Hermalin(1998): "Valuable information is not utilized, which is suboptimal relative to a situation in which the leader is induced to announce her information truthfully."

[50] In a dynamic extension of the model that we are working on training will have not only a signaling value but will increase workers human capital next period. Depending on the substitutability or complementarity of manager and workers effort in the transfer team production this will have consequences for the choice of the manager itself. The Mexican data we analyze reveals that firms with foreign workers spend more on general purpose training of workers with above bachelor degree.

[51] This corresponds to the one shot least cost separating equilibrium analyzed in Hermalin(2007).

The expected value of the transfer stage if the CEO is an expatriate and leads by sacrifice is equal to:

$$E(T^e|LS) = (1-\eta)(p_H\theta_H^2 + (1-p_H)\theta_L^2) \tag{24}$$

Assume that the expatriate manager can only lead by sacrifice. Who needs to sacrifice more to convince the local design team on the value of the project, the headquarter or the expatriate manager?

The HQ will sacrifice more than the expatriate CEO if the following condition holds:

$$\eta(1-\eta) > \frac{J-1}{J^2} \tag{25}$$

That is, if what the HQ appropriates out of fooling workers is higher than what the expatriate CEO does then the former needs to sacrifice more than the latter. This is so because he has more incentives to fool workers. If the HQ can choose η, then it will optimally set $\eta* = \frac{1}{2}$ and $x^e(\theta_H) < x^{HQ}(\theta_H)$.[52] That is, it is more costly to transmit information from the HQ than via an expatriate CEO.

The cost of transmitting information from the headquarter is strictly increasing in η for $\eta < \frac{1}{2}$ and strictly decreasing in η for $\eta > \frac{1}{2}$.

[52] As long as $J > 2$ this condition holds.

A.3 First Best Contract of the Local CEO in the Execution Stage

The local CEO is familiar with the local environment and he is able to offer a contract contingent on the realization of λ_i. In particular, for each worker he chooses (e_{nj}, w_{nj}) to max $e_{nj} - w_{nj}$ s.t $w_{nj} - c(e_{nj}) = 0$ for $j = H, L$. The optimal contract, which achieves first best effort levels, is to offer, for all n, $(w_j^l = \frac{1}{4\lambda_j}, e_j^l = \frac{1}{2\lambda_j})$ for $j = H, L$.[53] That is, when local inefficiency in the local economy is high, the manager offers a low wage and demands a low level of effort. Vice versa when local inefficiency is low.

Ex-ante, total expected output in the execution stage per worker when a local CEO is hired is equal to

$$E[e^l] = q_H(\frac{1}{2\lambda_H}) + (1 - q_H)(\frac{1}{2\lambda_L}) \tag{26}$$

and the expected wage bill and the expected profit per worker is

$$E[w^l] = E[\Pi^l] = q_H(\frac{1}{4\lambda_H}) + (1 - q_H)(\frac{1}{4\lambda_L}). \tag{27}$$

Result 6: Expected profits in the execution stage when a local CEO is relied upon are a linear and decreasing function of q_H and λ_H.

Is the "local CEO contract" in the execution stage possible for the expatriate?

Is the first best solution in the execution stage available to the expatriate manager?

Assume the expatriate CEO decides to mimic the local CEO and offers workers two options: (x_{nH}^l, w_{nH}^l) and (x_{nL}^l, w_{nL}^l).

Will a given worker have the incentives to choose (x_{nH}^l, w_{nH}^l) when $\lambda_i = \lambda_H$? If he does so, he gets his reservation utility, that is equal to zero. If he chooses the contract intended for the low-cost scenario, and given that $\lambda_H > \lambda_L$, he gets $u(x_{nL}^l, w_{nL}^l; \lambda_H) = \frac{1}{4\lambda_L} - \frac{\lambda_H}{4\lambda_L^2} < 0$. Clearly,

[53] The superscript, l, denotes the solution under the local CEO.

when the marginal cost of effort is high the worker has no incentives to pretend to be in the low cost scenario. The intuition is the following: In the low cost scenario, the worker is given his reservation utility. If in reality he has a higher cost of effort such a contract can only leave him worse off.

Similarly, will a given worker have the incentives to choose (x^l_{nL}, w^l_{nL}) when $\lambda_i = \lambda_L$? In the low cost scenario, the worker has an incentive to fool the manager and pretend to have high cost of effort. This is so because in the high cost scenario, the worker is given his reservation utility. If in reality he has a lower cost of effort such a contract can only leave him better off. In particular, $u(x^l_{nH}, w^l_{nH}; \lambda_L) = \frac{1}{4\lambda_H} - \frac{\lambda_L}{4\lambda_H^2} > 0$.

That is, if the expatriate tries to mimic the local CEO offer, he will invariably obtain low levels of efforts from workers, which will obtain a positive rent when their marginal cost will be low.

A.4 Optimal contract if collusion impossible

If workers are unable to collude with each other, the following direct revelation mechanism is optimal: For all n, $w_n(\hat{\lambda}) = 0$ if $x_n(\hat{\lambda}) \neq \frac{1}{2\hat{\lambda}}$ or $\hat{\lambda}_n \neq \hat{\lambda}_j$ for some $n \neq j$
and $w_n(\hat{\lambda}) = \frac{1}{4\hat{\lambda}}$ if $x_n(\hat{\lambda}) \geq \frac{1}{2\hat{\lambda}}$ and $\hat{\lambda}_n = \hat{\lambda}_j$ for all n,j. Where $\hat{\lambda}_n$ for $n = 1...N_x$ are the simultaneous announcements by the execution workers and $\hat{\lambda}$ is the vector of announcements. Under such a mechanism, workers incentive compatibility and participation constraints are satisfied in a truth-telling Nash Equilibrium characterized by $e_n = e^*(\lambda_i) = \frac{1}{2\lambda_i}$ for all n. $e^*(\lambda_i)$ denotes the first best level of effort. Given announcements are simultaneous and assuming that there is no communication among execution workers and so, no collusion risk, truth-telling is a focal point.

The CEO is, in principle, able to obtain the first best solution in the execution stage. In such a case, his expected profits are identical as the ones the local CEO obtains. This result is, nevertheless, not robust to collusion risks if workers can communicate. In particular, it follows from the preceding analysis that workers will have incentives to collude and announce $\hat{\lambda} = \lambda_H$ regardless of the true local conditions.

B Proofs and Derivations

B.1 Proof of Result 1

CEO's effort when he leads by example is equal to $x^e(\theta_H) = \frac{\theta_L + \sqrt{2}\sqrt{(J-1)\theta_L(\theta_H-\theta_L)}}{\frac{J}{1-\eta}}$ and when he leads by sacrifice is equal to $\frac{\theta_H}{\frac{J}{1-\eta}}$.[54] For the first part of the result note that the difference, $D = \frac{\theta_L - \theta_H + \sqrt{2}\sqrt{(J-1)\theta_L(\theta_H-\theta_L)}}{\frac{J}{1-\eta}}$ is positive when $J > 1 + \frac{\theta_H - \theta_L}{\theta_L}$ which is satisfied under the assumption $J > (1-\eta)(1 + \frac{2(\theta_H-\theta_L)}{\theta_L})$ For the second part, the sign of the derivative of D with respect to θ_H is equal to the sign of $-1 + \frac{(J-1)\theta_L}{\sqrt{2(J-1)\theta_L(\theta_H-\theta_L)}}$ which is positive when $J > 1 + 2\frac{\theta_H-\theta_L}{\theta_L}$ and so the result follows.

B.2 Proof of Result and Corollary 2

It is straightforward to see that $\frac{\delta E(T^e|LE)}{\delta \theta_H} > 0$ and that $\frac{\delta E(T^e|LE)}{\delta \theta_H \delta p_h} > 0$.

$\frac{\delta E(T^e|LE)}{\delta \theta_H \delta p_h} > 0$ follows from the fact that $\theta_H > \theta_L$ and from result 1.

The corollary of the result follows from the fact that the CEO never leads if $p_h = 0$ and has no incentives to lead if $\theta_H = \theta_L$.

B.3 Proof of Result 3

The first part of the result follows from the fact that the headquarter only leads when the project is good.

The second part follows from the fact that $\frac{\delta x^{HQ}}{\delta \theta_H} = \eta(1-\eta)\theta_L > 0$

The intuition is that the higher is the value of the good project, the bigger are the incentives of the headquarter to fool workers. To be credible, then, the HQ needs to sacrifice more.

B.4 Proof of Result 4

We need to show that $E(T^l|HQ) - E(T^e|LE) < 0$, which follows from Result 1. That is from the fact that the subsidiary CEO exerts higher effort than the local CEO in the transfer stage. Namely, $\frac{\theta_L + \sqrt{2(J-1)\theta_L(\theta_H-\theta_L)}}{\frac{J}{1-\eta}} > \frac{\theta_H}{\frac{J}{1-\eta}}$.

[54] Recall that the CEO leads only when $\theta_i = \theta_H$

B.5 Proof of Result 5

The first part of result 5 follows directly from result 4, $E(T^l|HQ) - E(T^e|LE) < 0$ and the fact that $p_H(\eta(1-\eta)[\theta_H\theta_L - \theta_L^2]) > 0$ which means that $(E(T^l|HQ) - p_H(\eta(1-\eta)[\theta_H\theta_L - \theta_L^2]) - E(T^e|LE)) < 0$. The second part follows from results 2 and 3.

B.6 Proof of Result 6

It follows from

$\frac{\delta E[\Pi^l]}{\delta q_H} < 0$

$\frac{\delta E[\Pi^l]}{\delta \lambda_h} < 0$

B.7 Derivation of contract offered by expatriate in execution stage

$E[\prod^e]$ is equal to

$$q_H(e_H - w_H) + (1 - q_H)(e_L - w_L) \tag{28}$$

and the four constraints are:

$$IC_H : w_H - \lambda_H e_H^2 \geq w_L - \lambda_H e_L^2 \tag{29}$$

$$IC_L : w_L - \lambda_L e_L^2 \geq w_H - \lambda_L e_H^2 \tag{30}$$

$$IR_H : w_H - \lambda_H e_H^2 \geq 0 \tag{31}$$

$$IR_L : w_L - \lambda_L e_L^2 \geq 0 \tag{32}$$

IR_H and IC_L will be binding. Consequently IR_L will be satisfied and slack. Given that it is optimal to set $e_L > e_H$, IC_L will also be satisfied and slack.[55]

[55] If IR_L was binding then IR_H would not be satisfied. If $e_L > e_H$ and IC_H was binding then IC_L would not be satisfied.

IR_H becomes $w_H = \lambda_H e_H^2$ and IC_L becomes $w_L = (\lambda_H - \lambda_L)e_H^2 + \lambda_L e_L^2$

Plugging in the objective function, and maximizing the result in the text follows.

B.8 Proof of Result 7

Note that $e_L^e = \frac{1}{2\lambda_L} = e_L^l$ and that

$e_H^e - e_H^l = \propto (1 - \frac{1}{q_H})(\lambda_H - \lambda_L) < 0$

given that $\lambda_H > \lambda_L$ and that $(1 - \frac{1}{q_H}) < 0$ for $q_h \epsilon (0, 1)$

B.9 Proof of Result 8

First note that $\frac{\delta(E[e^e] - E[e^l])}{\delta q_H} = \frac{e_H^e - e_H^l}{e_H^e} + \varepsilon_{e_H^e, q_H}$, where $\varepsilon_{e_H^e, q_H}$ denotes the elasticity of effort with respect to q_H when local inefficiency is high and the CEO is an expatriate.

Given that $\varepsilon_{e_H^e, q_H} = \frac{\lambda_H - \lambda_L}{\lambda_H - \lambda_L + q_H \lambda_L}$ and $\frac{e_H^e - e_H^l}{e_H^e} = (\frac{1}{q_H} - 1)(1 - \frac{\lambda_L}{\lambda_H})$

and simplifying,

$\frac{\delta(E[e^e] - E[e^l])}{\delta q_H} > 0$ if $q_H > 0.5$ and $\frac{\delta(E[e^e] - E[e^l])}{\delta q_H} < 0$ if $q_H < 0.5$.

Because local uncertainty is maximized when $q_H = 0.5$, the result follows.

B.10 Proof of Result 9

The first part follows from the fact that $w_L^e - w_L^l = (\lambda_H - \lambda_L) \frac{1}{4[\frac{\lambda_H - \lambda_L}{q_H} + \lambda_L]^2} > 0$

The second part follows because $\frac{\lambda_H}{4[\frac{\lambda_H - \lambda_L}{q_H} + \lambda_L]^2} < \frac{1}{4\lambda_H}$ for $q_H \epsilon (0, 1)$

B.11 Proof of Result 10

It follows from $\frac{\delta E[\Pi^e]}{\delta q_H} < 0$, $\frac{\delta^2 E[\Pi^e]}{\delta^2 q_H} > 0$ and $\frac{\delta E[\Pi^e]}{\delta \lambda_H} < 0$, $\frac{\delta^2 E[\Pi^e]}{\delta^2 \lambda_H} > 0$.

B.12 Proof of Result 11

The local manager optimization problem is unconstrained the expatriate faces a constrained optimization problem. Therefore, the expatriate profits must be lower.

B.13 Proof of Result 12

It follows directly from results 5 and 9.

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Table 5: Summary statistics of plant variables in 2000 (ESIDET)

	Plants with no foreign employees	Plants with foreign employees	Total
Total Sales	1528.0	1897.9	1699.7
(in thousand)	(392.6)	(572.5)	(338.6)
Log(Total Sales)	12.68***	13.25***	12.95
	(0.11)	(0.10)	(0.08)
Domestic Sales	1216.0	1003.1	1117.1
(in thousand)	(361.6)	(195.3)	(213.)
Log(Domestic Sales)	12.28**	12.71**	12.48
	(0.14)	(0.14)	(0.10)
Exports	312.0	894.8	582.6
(in thousand)	(154.3)	(398.1)	(202.7)
Exporter Dummy	0.69***	0.82***	0.75
	(0.03)	(0.03)	(0.02)
Exports/Total Sales	0.28*	0.35*	0.31
	(0.03)	(0.03)	(0.02)
Domestic Employees	1246.52	1472.24	1351.32
	(198.51)	(189.81)	(138.06)
Foreign Employees	0.00***	12.82***	5.95
	(0.00)	(2.14)	(1.04)
Number	209	182	391

Notes: The table reports summary statistics of basic plant variables. The first column is the statistics for plants without expatriates, while the second for plants with expatriates, and the third for all plants pooled together. Standard deviation of the means in parentheses. Sales and exports are in million nominal pesos (A dollar was 9.5 pesos in the beginning of 2000). Significance of the test of the equality of the mean of the two groups: * 10 percent, ** 5 percent, *** 1 percent.

Table 6: Regression of the technology transfer on expatriates. ESIDET 2000.

	(1)	(2)	(3)	(4)	(5)
Dependent Variable	Technology Transfer: Intensity				
Method	All Industries		Manufacturing Only		
Expatriates Dummy	0.2695**	0.2331*	0.3201***	0.3039***	-0.0000
	(0.1260)	(0.1257)	(0.1071)	(0.1155)	(0.1785)
Expatriates Dummy*					3.7652*
Industry R&D					(2.2291)
Exporter Dummy		0.4104***		0.1913	0.3876**
		(0.1485)		(0.1211)	(0.1710)
Log Employment		-0.0282		-0.0442	-0.0510
		(0.0503)		(0.0573)	(0.0648)
R^2	0.1774	0.1933	0.0318	0.1690	0.2029
N	391	391	297	297	297

Notes: The table reports coefficients on the organizational form (the dummy variable indicating whether plants have foreign employees), its interaction term with U.S. R&D intensity at the industry level, the log of the number of employees and exporter dummy from plant-level regressions of the expenditure on technology transfer from abroad on the combinations of the dummy variable indicating whether a plant has expatriates, its interaction term with the U.S. industry-level R&D intensity, the log of the number of workers, exporter dummy and industry fixed effects. The technology transfer intensities measure is the expenditure divided by total sales. Robust standard errors in parentheses. Significance: * 10 percent, ** 5 percent, *** 1 percent.

Table 7: Regression of the effect of judicial efficiency on expatriates. ESIDET 2000.

	(1)	(2)	(3)	(4)	(5)	(6)
Industry	All Industries			Manufacturing		
Dependent Variable	Expatriates Dummy					
Judicial Efficiency	-1.5389***	-1.6216***	-1.7174***	-1.6143***	-1.6881***	-1.8340***
	(0.4776)	(0.5459)	(0.5808)	(0.5027)	(0.5676)	(0.6501)
Judicial Efficiency^2	0.2512***	0.2596***	0.2722***	0.2673***	0.2717***	0.2986***
	(0.0788)	(0.0899)	(0.0965)	(0.0829)	(0.0932)	(0.1100)
Exporter Dummy			0.2280***			0.1489*
			(0.0754)			(0.0888)
Log Employment			0.0797***			0.0989***
			(0.0275)			(0.0318)
Industry Effects	No	Yes	Yes	NO	Yes	Yes
N	391	349	349	297	281	281

Notes: The table reports marginal effects of the judicial efficiency, exporter dummy and the log of the number of workers on the dummy variable indicating whether a plant has foreign employees. Some firms are dropped when we include industry fixed effects due not colinerality, leading the changes in the sample size between Columns (1) and (2)(3) and between Columns (4) and (5)(6). The results for all the industries are shown in Columns (1)-(3), while the results for manufacturing industries are shown in Columns (4)-(6). Robust standard errors in parentheses. Significance: * 10 percent, ** 5 percent, *** 1 percent.

Table 8: Regression of the effect of judicial efficiency form on foreign entry and R&D intensity. ESIDET 2000.

	(1)	(2)	(3)	(4)	(5)	(6)
Industry	All Industries		Manufacturing			
Dependent Variable	Foreign Ownership Dummy				R&D Intensity	
	Probit				OLS	
Judicial Efficiency	0.4604***	0.4024**	0.4006**	0.3109*	-0.0780**	-0.0776**
	(0.1578)	(0.1718)	(0.1714)	(0.1888)	(0.0337)	(0.0335)
Judicial Efficiency^2	-0.0743***	-0.0647**	-0.0629**	-0.0498*	0.0102*	0.0101*
	(0.0269)	(0.0284)	(0.0281)	(0.0287)	(0.0053)	(0.0052)
Exporter Dummy	0.2173***	0.1994***	0.2311***	0.1850***		0.0033
	(0.0181)	(0.0236)	(0.0201)	(0.0241)		(0.0066)
Log Employment	0.0506***	0.0581***	0.0554***	0.0635***		0.0017
	(0.0069)	(0.0085)	(0.0092)	(0.0108)		(0.0019)
Industry Effects	No	Yes	No	Yes	No	No
N	1955	1709	1407	1325	297	297

Notes: The table reports coefficients marginal effects of the judicial efficiency, exporter dummy and log of the number of workers on the dummy variable indicating whether a plant has foreign ownership (Columns (1) to (4)) and on U.S. R&D intensity of the industry that firms belong to (Columns (5) and (6)). The analysis of foreign ownership (Columns (1) to (4)) uses all the firms including non-foreign plants while the analysis of R&D intensity (Columns (5) and (6)) uses only foreign plants. Some firms are dropped when we include industry fixed effects due not colinerality, leading to the changes in the sample size between Columns (1) and (2) and between Columns (3) and (4). Robust standard errors in parentheses. Significance: * 10 percent, ** 5 percent, *** 1 percent.

Table 9: Regressions of the total sales, exports and domestic sales on expatriates, ESIDET 2000.

	(1)	(2)	(3)	(4)
Dependent Variable	Log Total Sales	Exporter Dummy	Log Exports	Log Domestic Sales
Expatriates Dummy	0.39***	0.11***	0.50**	0.09
	(0.12)	(0.041)	(0.21)	(0.42)
Log Employment	0.80***		0.91***	0.41*
	(0.07)		(0.12)	(0.22)
R^2	0.59	0.40	0.48	0.33
N	391	391	293	391

Notes: The table reports coefficients on the expatriates dummy from plant-level regressions of the log of sales, exporter dummy, the log of exports and the log of domestic sales on the expatriate dummy and the log employment and industry fixed effects. Robust standard errors in parentheses. Significance: * 10 percent, ** 5 percent, *** 1 percent.