Using Mobile Phone Data to Measure the Ties Between Nations

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ABSTRACT

We introduce a novel method for measuring and evaluating the social ties between nations. Patterns of international communication, and in particular the *volume* and *direction* of international phone calls, reflect the interpersonal connections between the people of different countries, and add nuance to the coarse indicators more commonly used in the literature. This paper presents a preliminary investigation of the empirical properties of this metric using a log of all international phone calls to and from Rwanda. We find that patterns of international outgoing and incoming calls closely parallel patterns of international exports and imports. The fine-grained temporal resolution of the data also reveals international dynamics not captured in existing metrics. For instance, we observe spikes in communication that appear unrelated to economic ties following significant events such as natural disasters, elections, and soccer matches. We conclude with a discussion of the strengths and weaknesses of this metric, and point to promising directions for future research.

Keywords

Quantitative Methods, International Relations, Call Detail Records, CDR, Rwanda, Balance of Trade

1. INTRODUCTION

> "Friendship is the only cement that will ever hold the world together."
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> – *Woodrow Wilson, 1919* [1]

The nations of the world are bound together by a complex and interlocking set of economic, political, and social ties. Developing accurate methods for measuring these ties is important both to a positive understanding of international relations and for the normative design of foreign policy. However, few reliable methods exist for measuring the relationships between nations, and most existing metrics heavily emphasize political and economic factors such as treaties and trade.

This paper presents a novel metric, the volume and direction of international call traffic, that provides a rich indicator of the social connections between the people of different countries. In comparison with existing measures of international relationships, this metric offer two distinct advantages. First, it provides a means of assessing the strength and nature of the connections between the *people* of different countries, as opposed to the more formal and better-documented connections between official entities such as markets, governments, and large corporations and organizations. As we will show, these informal connections are strongly related to their formal counterparts, but the correlation is not perfect. Second, the call data captures variation at a temporal resolution far greater than other standard indicators. For instance, whereas bilateral trade data is typically recorded every quarter or month, the bilateral communication data we analyze is recorded every second. This feature of the data makes it possible to analyze changes in international relations at an arbitrarily fine-grained level of detail. For instance, it is possible to precisely identify the effects of geopolitical events on short- and long-term patterns of communication. In the latter half of the paper, we highlight the abnormal patterns of communication that are produced by an earthquake in Rwanda, a presidential election in Kenya, and a series of international soccer friendlies.

The primary objective of this paper is to provide an overview of the empirical properties of the new metric, in order to generate feedback and discussion for future work. Thus, is the following section, we focus our discussion of related work on prior empirical efforts to measure international relationships. Section 3 describes the communication data from Rwanda that we use as a case study. In section 4, we compare patterns of calls to patterns of trade, and demonstrate that the quantity of incoming and outgoing international calls is highly correlated with levels of imports and exports. This relationship remains highly significant even after controlling for standard factors such as distance, population, and GDP. In section 5, we exploit the temporal granularity of the data to show that call patterns do not simply reflect underlying economic ties. For instance, we note that Rwanda's two main trading partners respond very differently to a severe earthquake in Rwanda in 2008. In the final sections of the paper, we discuss the merits of our approach relative to the methods more commonly used in the literature.

2. RELATED WORK

In this paper, we develop a quantitative measure of the social ties between nations. This research thus relates to a diverse set of disciplines including international relations, demography, and communication studies. Scholars from these fields have developed a large body of theoretical work on the origins, nature, and consequences of international relationships. Closely related to our study is the robust literature on the deep connections between economic and social relations [19, 12], and recent work on the cultural and political foundations of real-world networks [8]. However, since ours is a predominantly empirical undertaking, we focus our review on empirical approaches to measuring and evaluating international ties.

In this literature, a number of studies have demonstrated that different types of international ties have a large and quantifiable impact on foreign policy. For instance, Agarwal [3] and Blonigen [6] show that foreign direct investment is heavily influenced by economic factors such as taxes, exchange rates, and trade flows. Alesina and Dollar [4] in turn demonstrate that foreign aid is as much determined by political and strategic considerations as by economic need. In quantitative studies such as these, the typical model examines the effect of economic and political factors (such as GDP, exchange rates, wages) on policy outcomes [5]. Thus, of central concern is the choice of metrics used to model international relationships. Commonly employed strategies include the use of international trade indicators [23, 2], levels of international migration [24], and cooperation on intergovernmental organizations [22]. More creative approaches have attempted to include cultural and social factors such as ethnic population shares, linguistic identity, and the structure of international business networks [20].

Unfortunately, these measures of international connections are painstaking to collect and rarely comprehensive. Moreover, they are typically plagued by problems of data quality and reliability [17, 16]. Thus, a handful of researchers have sought more objective measures of international social networks, such as networks of scientific collaboration revealed by bibliometric analysis of publication and citation. More relevant to the current analysis, a number of scholars have advocated the use of communications data [21], which has been shown to overcome some of the subjectivity issues in self-reported data [14]. However, we are aware of no prior efforts to analyze international call traffic as an indicator of the social ties between countries.

In other domains, however, phone company records have been effectively used to measure the underlying social networks of individual users [18, 10]. For instance, Gonzalez et al. [11] use mobile phone data to better understand patterns of human mobility, Blumenstock and Eagle [7] use Rwandan CDR to show how the social networks of the rich are different from the social networks of the poor, and Eagle et al. [9] demonstrate that phone network structure is correlated with regional economic development. We seek to build on these results by adapting the general analytic framework to the context of international phone calls and international relations.

3. DATA

The analysis in this paper relies on two types of data: call detail records obtained from Rwanda's dominant mobile
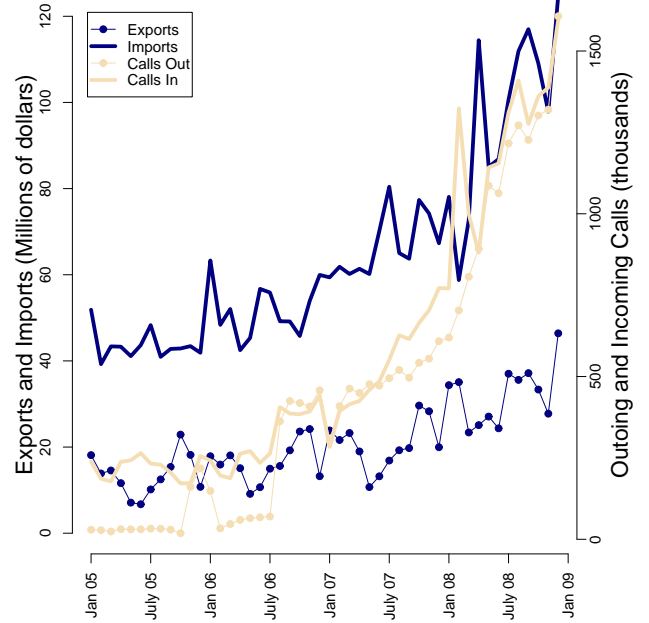

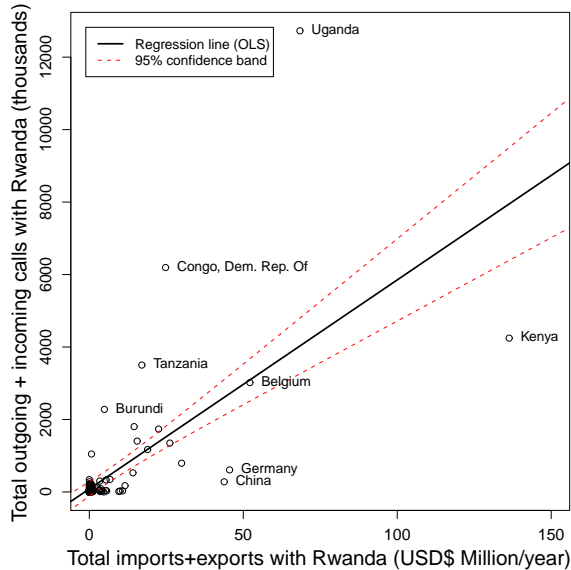**Figure 1: International trade and call volume**

phone operator, and economic and demographic data from the International Monetary Fund and World Bank.
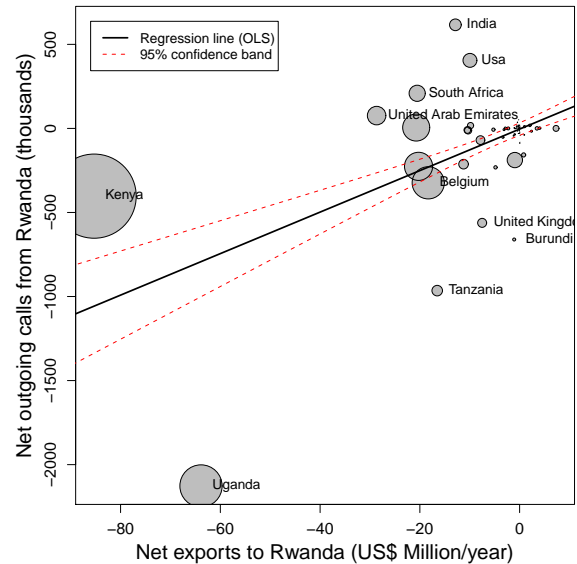
3.1 Call Detail Records

We obtained a log of all international phones calls made to and from Rwanda, on the country's primary mobile phone network, from January 2005 through December 2008. These data do not capture calls made on other Rwandan phone networks, nor do they capture calls to and from landlines in Rwanda. However, for the period in question, the network we observe had over 90 percent market share, and fixed-line penetration was less than 0.2 percent. Our call detail records thus capture the vast majority of phone-based international communication. We therefore treat these data as reliable indicators of the level of international communications, which we in turn assume is a noisy proxy for the strength of the social ties between Rwanda and other nations. Limitations of this approach are discussed in section 6.

In this period, roughly 23.66 million outgoing calls and 29.17 million incoming calls were made. For each call, we extract the country of origin and destination based on international country code prefixes.[1] It is worth noting that there was considerable growth in traffic over the four year period for which we have data. As can be seen in Figure 1, total international call volume increased from roughly 250,000 calls per month in early 2005 to over 3 million calls per month in late 2008. Moreover, whereas international call traffic was initially dominated by calls to Rwanda, more recently the ratio between incoming and outgoing international calls has come closer to unity.

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[1]Of the 52.82 million total calls, we can successfully classify 49.42 million (94 percent). The remaining 6 percent are not classified either because they come from international roaming numbers, or because of unknown discrepancies in the operator logs.

(a) Aggregate Trade Volume vs. Total Call Volume

(b) Net Exports vs. Net Outgoing Calls

Figure 2: Comparison of trade and phone traffic between Rwanda and 125 nations. Figure (a) plots the total number of calls made between Rwanda and other nations against the total trade volume Rwanda and those same nations. Figure (b) plots net (outgoing minus incoming) calls against net exports (exports minus imports). In Figure (b), points are sized proportional to the total trade volume.

3.2 Economic and Demographic Data

In the following sections we compare international calling patterns with international patterns of trade. We obtain bilateral trade data between Rwanda and 125 other countries from the International Monetary Fund Direction of Trade Statistics [15]. In Rwanda, a landlocked and agricultural economy, imports account for only 22 percent of total trade. Temporal trends in imports and exports are shown in Figure 1. The two-fold growth in international trade over the four year period is impressive, but not as pronounced as the twelve-fold increase in international phone traffic.

We supplement the direction of trade data with a rich set of demographic and economic indicators obtained from the World Bank.[2] We use a variety of standard metrics such as gross domestic product per capita (GDPpc), total population, and measures of telecommunications infrastructure. All data are reported at 2005 levels, to coincide with the date range covered by the mobile phone data.

Finally, we collected data on the distance between Rwanda and other countries for use in the gravity model described in section 4.[3]

4. DO SOCIAL RELATIONS PARALLEL ECONOMIC RELATIONS?

The temporal trends depicted in Figure 1 suggest that patterns of international communication may be correlated with patterns of international trade. A priori, there is strong reason to expect that economic ties, as measured by the IMF's direction of trade data, will be tightly correlated to social

ties, as measured in communications data captured by the network operator. Superficially, an increase in trade would be expected to produce a corresponding increase in communication, if only because economic entitties must communicate about trade-related matters. More fundamentally, we would expect an increase in communication to cause an increase in trade, since strong social ties facilitate strong economic ties by increasing trust, information exchange, and a number of mechanisms [13][19]. Alternatively, the observed correlation may not be causal. Instead, it is possible that unobserved factors such as political institutions, seasonal fluctuations, and unrelated events are driving changes in both social and economic ties.

In this paper we will not attempt to separately identify the effect of trade on communications and the effect of communications on trade. However, we will more precisely quantify the correlation between the two indicators, and we will test whether the correlation is due to an omitted third factor. We will analyze the relationship along two dimensions. First, we look at the *aggregate* volume of transactions between Rwanda and 125 countries for which trade and communications data exist. Second, we look at the *net* direction of trade and calls, to ascertain whether relations of economic dependency are reflected in communication patterns.

4.1 Aggregate trade and call volume

We begin by comparing the aggregate economic traffic between Rwanda and other nations with the aggregate phone traffic between Rwanda and those same nations. Aggregate economic traffic is measured as the sum of imports and exports; aggregate phone traffic is the total volume of incoming and outgoing calls. Figure 2a highlights the strong positive relationship between these two indicators. Countries with

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[2]Accessed from `http://databank.worldbank.org`, August 2010.

[3]Accessed from `http://distancefromto.net`, August 2010.

strong economic connections to Rwanda also tend to log high levels of communication with Rwanda. Quantitatively, the correlation between the indicators is high at 0.657.[4]

To understand *why* the observed relationship between social and economic ties exists is a topic beyond the scope of the current paper. However, we can provide preliminary evidence that the relationship is not due to an obvious third factor such as GDP or population. We do this by estimating the relationship between phone calls and trade in a simple multivariate regression:

$$Y_i = \alpha + \beta TRADE_i + X_i'\gamma + \epsilon_i \qquad (1)$$

In equation (1), Y_i is a measure of the aggregate call traffic between Rwanda and country i, $TRADE_i$ measures the aggregate trade between Rwanda and i, X_i' is a vector of characteristics of i in 2005, and ϵ_i is a random error term. Estimates of β and γ thus represent the association across Rwanda's trade partners between call volume, trade volume, and other factors.[5] Whereas Figure 2 can only show the bivariate correlation between calls and trade, equation (1) can reveal whether that correlation is due to an obvious omitted variable.

Results from the estimation of equation (1) are presented in columns 1 and 2 of Table 1. We first estimate, in column 1, the bivariate relationship between trade and communications. As expected, the association is strong and highly significant. The estimated coefficient for $\hat{\beta}$, if taken at face value, implies that for each additional \$1,000 in bilateral trade, we would expect to observe an additional 58 calls (though again we emphasize that this is not a causal relationship). In column 2, we then add a large number of control variables, such as the GDP and land area of each country, to the regression.

There are at least three noteworthy results in Table 1. First, the estimated association between trade and calls remains large and significant after the addition of many omitted variables. This indicates that the relationship visible in Figure 2a is not caused by an obvious third factor that is correlated with both trade and communication. Second, we note that though the increase in explanatory power gained by the addition of the ten control variables is large (R^2 increases from 0.43 to 0.78), 83 percent of this increase is driven by the inclusion of the dummy variable that indicates whether a country shares a border with Rwanda. When that variable is omitted from column (2), the corresponding R^2 is only 0.49. Together, this evidence indicates that aggregate trade captures a very large amount of the variation in aggregate calls. Finally, we find it surprising that the only variable other than trade that is independently correlated with

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[4]Although part of the correlation is driven by the extreme values of Uganda and Kenya, Rwanda's two main trading partners, excluding these countries from the analysis the correlation only reduces the correlation to 0.590.

[5]We hasten to add that we do not mean to imply a causal relationship between X_i and Y_i. Moreover, the current setting does not satisfy many of the assumptions necessary for ordinary least squares to produce unbiased estimates. A more appropriate analysis would, along the lines of Anderson and van Wincoop [5], require careful consideration of empirical irregularities (for instance, certain variables should almost certainly be taken in logs). However, as our intent is merely to demonstrate the robustness of the relationship between communication and trade flows to the inclusion of omitted variables, we believe the parsimonious model is sufficient.

Table 1: Regression of calls on country properties

	Total Calls		Net Calls	
	(1)	(2)	(3)	(4)
Total trade	57.66***	45.95***		
in \$1000's	(5.99)	(4.90)		
Net trade			12.34***	8.55***
in \$1000's			(1.71)	(1.29)
Border w/		4.8e6***		-1.0e6***
Rwanda		(4.8e5)		(8.5e5)
Distance to		8.141		6.141
Rwanda (mi)		(46.16)		(7.89)
Population		0.694		0.845***
in 1000's		(0.95)		(0.16)
Land Area		0.021		0.012
		(0.06)		(0.01)
GDP pc.		9.003		-1.812
		(10.08)		(1.73)
GDP growth		22490		-4167
		(36264)		(6221)
Net FDI		0.000		-0.000
		(0.00)		(0.00)
Net Migration		0.120		0.068**
		(0.13)		(0.02)
Mobile		-0.001		-0.003
subscribers		(0.01)		(0.00)
Landlines		-0.008		0.001
		(0.01)		(0.00)
R^2	0.43	0.78	0.30	0.82
N	124	91	124	91

Notes: Outcome is the total volume of calls per year (columns 1 and 2) and the net volume of calls (columns 3 and 4), for the 124 countries for which data exist. Columns 2 and 4 include geographic controls and country-level controls taken from the World Bank database; 23 observations are dropped because of missing data. Standard errors reported in parentheses. * $p<0.05$, ** $p<0.01$, *** $p<0.001$.

phone calls is the border variable (the coefficient indicates that Rwandans call and are called by neighbor countries, on average, an additional 5 million calls per year). There appears to be no significant relationship between call traffic and GDP, migration, or the number of mobile subscribers, after having controlled for trade and proximity.[6]

4.2 Net Trade and call volume

Having established the strong relationship between total trade (exports plus imports) and total call volume (outgoing plus incoming calls), we turn briefly to the balance and direction of trade and calls. Echoing the analysis of the previous section, Figure 2b shows the relationship between net exports (exports minus imports) and net outgoing calls (outgoing minus incoming calls). To draw attention to those countries with whom Rwanda has the strongest economic ties, we represent each country as a point, where the size of

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[6]Before controlling for other factors, the bivariate relationships exist. For instance, the simple correlation between mobile subscribers and call volume is 0.048. This relationship, however, becomes insignificant in the multivariate regression.
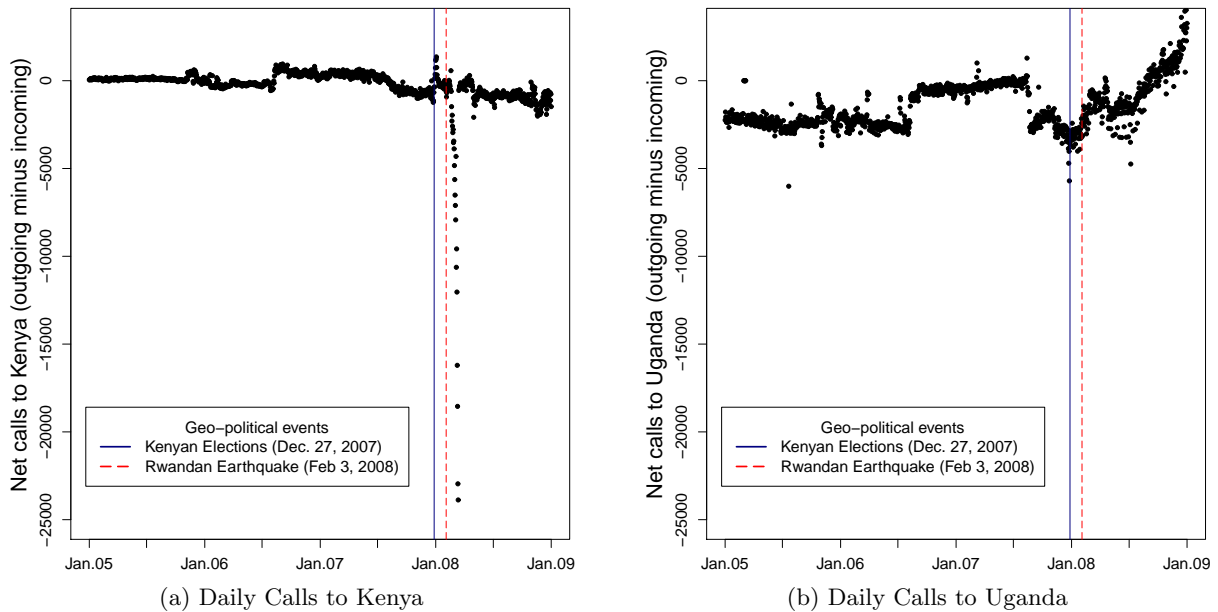
Figure 3: Net call traffic to Uganda and Kenya, Jan. 2005 - Dec. 2008

the point is determined by the total trade between the two countries. The correlation is weaker but still quite large, at 0.547, and remains strong even after controlling for a number of other factors (columns 3 and 4 of Table 1).

While the strong correlation between total calls and total trade is not surprising, the association between net calls and net trade is more revealing. It is clearly the case that Rwandans make more calls than they receive to those countries with whom they export more than they import. Similarly, the countries from which Rwanda imports the most tend also to be the countries whose citizens call Rwandans the most. At first glance, this seems to merely reflect the fact that Rwanda is a relatively poor country that relies heavily on imports, remittances, and foreign aid. However, the insignificant coefficient on GDP per capita in column 4 of Table 1 indicates that the relationship is not driven entirely by relative wealth; if that were the case we would expect a strongly negative coefficient (which would imply that people in rich countries call Rwandans, and Rwandans call people in poorer countries). Instead, the factors that appear to be significant in determining the direction of net call traffic are geographic proximity, population and net migration: countries that share a border with Rwanda are the ones that tend to call Rwanda, while populous countries with lots of Rwandan immigrants tend to receive calls from Rwanda.

While we hesitate to draw grandiose conclusions from such a limited dataset, the strong and consistent correlation between net calls and net exports is consistent with a certain form of structural dependency. International calls are quite expensive to make but free to receive, thus it appears that Rwandans are socially dependent on people in the countries on whom the Rwandan economy is economically dependent. In future work, we hope to more systematically investigate this hypothesis by analyzing communications data from countries of diverse economic standing.

5. EXPLOITING TEMPORAL RESOLUTION IN MOBILE PHONE DATA

Thus far we have focused on static measures of international ties, aggregating data over the four-year period from 2005 through 2008. This cross-sectional analysis was necessary to facilitate comparison with existing sources of international data, since standard economic and political indicators are rarely collected more than once per year per country. The mobile phone data, however, is captured every second, and can be analyzed at arbitrarily small temporal intervals. In this section, we exploit this increased resolution and analyze network responses to significant social and geopolitical events.

5.1 Geopolitical events

In the four year period for which we have records of international calls, two exceptional events occurred in East Africa: the Kenyan election in December of 2007, and a massive earthquake in the Lake Kivu region of Rwanda in February of 2008.[7] In Figure 3a, we present graphical evidence of the impact of these events on international phone traffic between Rwanda and Kenya. For each day between January 2005 and December 2008, we plot the net international calls from Rwanda to Kenya. Vertical lines are drawn to indicate the dates of the Kenyan elections and Rwandan earthquake.

The responsiveness of call traffic to both of these events is immediately apparent. Though the four-year period contains a large number of small blips and irregularities, the two most significant anomalies occur immediately following

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[7]Following the controversial presidential election on December 27, there were widespread riots and violence that resulted in the death of over 800 people and the displacement of hundreds of thousands. In the magnitude 6 earthquake that occurred on February 3 in Western Rwanda, roughly 40 people were killed and over 1,000 were seriously injured.

the election and the earthquake. The direction of the change is also relevant: after the elections, Rwandans started calling Kenyans; after the earthquake, Kenyans started calling Rwandans in unprecedented numbers.

The remarkable influx of calls from Kenya to Rwanda following the earthquake is not surprising given the strong ties between Kenyans and Rwandans. As was discussed earlier, and as is apparent in Figure 2a, Kenya is Rwanda's main trading partner, and the two countries maintain a high volume of communication even under normal circumstances. What is surprising, however, is the fact that there is very little change in communication patterns with Uganda following the earthquake (Figure 3b). The historical and demographic ties between Rwanda and Uganda are arguably much richer than the ties between Rwanda and Kenya, Uganda is Rwanda's second largest trading partner, and Uganda is the country with whom Rwanda communicates the most under normal circumstances. Yet, following the earthquake, there is only a modest change in the net call traffic between the two nations.

We can only speculate as to why Kenya and Uganda respond so differently to the earthquake in Rwanda. Perhaps, because of Uganda's geographic proximity to Rwanda and the earthquake region, Ugandans were already well-informed of the earthquake and had no need to call Rwanda to obtain information. Perhaps a large share of the abnormal traffic was due to business or trade-related matters, and the difference is due to the fact that Kenya has a stronger trade relationship with Rwanda. While we leave a more thorough investigation of this paradox to future work, we will return to this topic in later discussion.

5.2 Social events

In addition to the communication response to cataclysmic geopolitical events, we observe statistically significant changes in calling behavior for more mundane events such as international soccer matches. Figure 4 presents the net outgoing calls from Rwanda to Mauritania, following the same methodology that was used to produce Figure 3a. With Mauritania, we observe no meaningful changes in communication following the Kenyan elections or Rwandan earthquake. Instead, the two anomalies in phone traffic correspond exactly to the dates of soccer games played between Rwanda and Mauritania during stage 2 of the 2010 world cup qualifiers. Similar patterns are observed in the communications data with Ethiopia and Morocco, the two other teams that Rwanda played in run-up to the world cup.

Somewhat paradoxically, we note that the change in direction of calls in response to soccer matches is opposite the change in direction of calls in response to the two geopolitical events discussed above. Previously, it appeared that people affected by disasters generally received calls from contacts abroad. With soccer matches, however, it is the citizens of the country hosting the match that call the away team's country. This regularity holds in all six matches for which we have data. Whether or not the home team wins does not appear to affect the direction of calls.

5.3 What do these events reveal about the underlying social relations?

To a certain extent, the event analysis presented above is intended as a "proof of concept" that changes in the international geopolitical and social climate are immediately
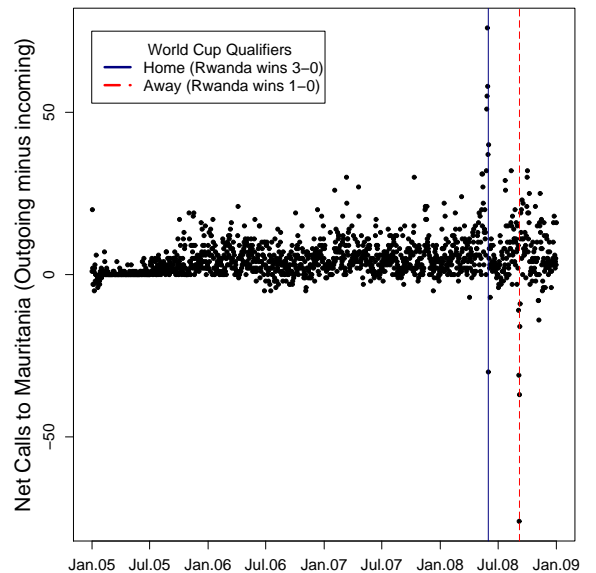

Figure 4: Daily calls to Mauritania

reflected in international communication patterns. While we have not attempted to do so in this paper, we believe that a more thorough analysis of these events could provide new perspective on the nature of social ties between nations. This is because different types of events elicit different responses from different countries, and a careful analysis of which countries respond to what events could help characterize the underlying relationships. As we have seen, Mauritanians did not call Rwandans following a major natural disaster in Rwanda, but they did call Rwandans after losing to them in a soccer match. Similarly, a cursory analysis seems to indicate that the countries which responded most dramatically to the earthquake were *not* Rwanda's main trading partners. Thus, there is not a simple unidimensional spectrum from "weak tie" to "strong tie" along which all countries can be placed. Rather, the connections between Rwanda and other countries have texture and nuance that, we believe, is reflected in patterns of international communication.

6. DISCUSSION

The preceding pages introduced international phone traffic as a potential indicator of the strength and nature of international relations. We demonstrated in a static setting that patterns of communication are very strongly correlated with patterns of trade, even after conditioning on a number of economic and political factors. We then showed that the temporal granularity of mobile phone data enables a richer dynamic analysis of international relationships, and pointed to some promising areas for further investigation. Before concluding, we now briefly step back and provide some perspective on the usefulness of these results by highlighting some of the advantages and limitations of our approach.

6.1 What is being measured?

Throughout this paper, we have maintained that patterns of international telephone calls reflect some intrinsic aspect of international relationships. This assumption is founded

on the intuition that aggregate call traffic is composed of millions of interpersonal phone calls, which in turn are built upon the social ties between citizens of different nations. While this chain of logic is hopefully sufficient to motivate the quantitative analysis, it is frustratingly imprecise and atheoretical. Communications between countries reflects some aspect of the underlying relationship, but what aspect, and why is it important?

While we cannot provide a definitive answer at present, the preceding analysis offers some clues. Superficially, patterns of communication are very closely tied to levels of trade. This comes as no surprise, given the extensive literature on the social foundations of economic exchange. However, international communication is not solely determined by relative economic factors. Rather, it is driven by a large number of forces that are not easily captured in aggregate indicators such as GDP and FDI. In section 5 we provided further evidence that call data capture more than unidimensional economic relationships. If calling patterns were merely a reflection of trade patterns, we would expect all countries to respond similarly to a disaster such as an earthquake, perhaps with response proportional to the strength of the economic ties. Instead, we note highly divergent patterns of communication in response to different events.

To summarize, communication patterns do not serve merely as proxies for economic relationships. What communications patterns do measure is more complex. Fundamentally, call traffic is determined by the relationships *between people*, rather than between economic entities, and it therefore reflects the myriad subtleties of interpersonal relations. In future work, we plan to conduct a more systematic investigation of how different countries respond to different events, in order to ascertain whether the temporal dynamics of international calls reflect a more subtle aspect of international relations.

6.2 Advantages of using call data to measure international ties

As a measure of the ties between nations, international communications data offers a number of distinct advantages over other metrics.

1. *International calling data can be obtained at incredibly fine temporal resolution.* This feature allows not only for the study of instantaneous responses to exogenous events, as demonstrated in section 5, but also for longitudinal analysis of changing dynamics over time.

2. *The data is comprehensive and objective.* As opposed to most other international indicators, international call data from a given operator are recorded in the same way for every country in the world. Moreover, the data are automatically collected and curated, and are much less susceptible to the measurement errors and subjectivity biases that affect most data collected manually.

3. *Communications data provide a quantitative measurement of the relationships between the people of different countries.* This facet of international ties is chronically under-emphasized by most standard indicators, which focus primarily on the relationships between political and economic entities.

6.3 Limitations and disadvantages

Throughout the paper, we have attempted to be frank about the theoretical shortcomings of using mobile phone data to understand international relationships. In addition, there are a number of practical limitations that are worth ennumerating.

1. *Our data only measures the international communications of Rwandans who own mobile phones.* For the 90 percent of citizens who do not own mobile phones, and who have been shown to be significantly poorer and less privileged than the population of phone owners [7], our conclusions do not necessarily apply.

2. *We do not observe the entire universe of phone calls.* Our data are Rwanda-centric, but even accepting that limitation we are missing activity on landlines and other phone networks. Even though landline penetration is extremely low in Rwanda, it is plausible that international business communications disproportionately occur on landlines, which could bias our analysis.

3. *The data has its own sources of error and bias.* As mentioned in an earlier footnote, our algorithms uncovered a noticeable number of inconsistencies in the way phone calls were logged by the mobile operator. We hope that such errors are random, but there is always the possibility that the inconsistencies are systematic and could bias our results.

4. *Mobile phone data can be quite difficult to obtain.* There are numerous privacy concerns involved in the analysis of personal communications, and mobile operators are rightfully hesitant to let third parties analyze their data.

7. CONCLUSIONS

This paper provides an empirical investigation of international phone traffic originating and terminating in Rwanda over a four-year period beginning in January 2005. We compare patterns of communication to patterns of trade, and find the two to be very closely related. However, the one is not a substitute for the other, and we note important differences between the economic relations reflected in the trade data and the social relations reflected in the call data. The differences are also reflected in the ways different countries respond to different events. While some countries with strong trade links respond to a humanitarian crisis with an influx of calls, no such change is observed for other important trading partners.

Through this paper, we have attempted to highlight the fact that international phone calls can provide a rich source of information on the social ties between nations. In future work, we see a number of different ways to achieve a deeper understanding of the nature of these ties: through a more structured analysis of the responsiveness of communications to different types of real-world events; a comparison to data from a different country (which ideally would not be situated in the periphery of the world economy); a quantitative study of how social relations relate to foreign policy and international migration. Pushing the analysis in these directions, we believe this novel source of data can provide new types of insight into the dynamics of international relations.

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