PREFERENTIAL TRADE AGREEMENT FORMATION: ANALYSIS OF DETERMINANTS IN A PTA NETWORK WITH A STOCHASTIC ACTOR NON-DIRECTED ORIENTED (SANO) MODEL

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Abstract:

The paper seeks to find the determinants of the dynamics of the Preferential Trade Agreements (ACP) in the last 20 years. In particular, the hypothesis that apart from some well known domino effects and natural trade costs effects, commercial specialization between countries play a role in trying to understand the likelihood of two countries deciding to sign an ACP. We use a stochastic model oriented to actors (SAOM) developed by Snijders (2001) and we estimate the effect on the evolutionary dynamics of ACP (dependent variable) of three groups of exogenous variables: structural variables associated with the topology of the network in every moment of time; variables commonly used in gravitational models of commerce; matrix of commercial complementarity and rivalry between countries. Preliminary results show that the signs of the more traditional variables in general behave according to what was expected in the literature. Finally, trade complementarity and rivalry of countries are significant in explaining the dynamic

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I. INTRODUCTION

The evolution of PTA over the last decades shows a permanent increase in the number and a trend to their higher depth in the extensive and intensive margin. The role of the network structure in the dyadic relationship between two countries is studied in different ways in the literature on the determinants of PTA formation considering only the extensive margin side of the phenomena. Two main approaches are developed.

The first approach started with Baier and Bergstrand (BB) (2004), who developed a model to address the question of which pairs of countries have PTAs in a given year. They use a Krugman type numerical model (monopolistic competition and trade cost) with three continents and two countries in each one. The simulations show that the net welfare gain (with benevolent perspective) for a country to make a PTA increases with: the two countries’ economic sizes (or GDPs); similarity of GDPs; their proximity to each other; their remoteness from the Rest-of-World (ROW), and their relative capital-labor ratios. Then a choice model is estimated in cross section for the year 1996 and the results do not reject the general result predicted by the simulation exercise.

Baier, Bergstrand and Mariutto (BBM) (2014) take one step further including interdependence between PTA to the basic model of country characteristics. The aim is to rationalize the effects identified in the literature on trade liberalization, such as the domino effect (Baldwin, 1993) or competitive liberalization (Bergstend, 2006). This literature refers to how the incentives that a country has (net welfare gain associated to sign an additional PTA) are different according to how much preferential access to its own market has to gives as a counterpart for gaining preferential access in the market of the other country.

BBM distinguish between own and cross interdependence. Own interdependence represents the idea that the number of PTA that country i and country j have with any country is correlated to the probability of establishing an agreement between them. If country i has many agreements, the probability of having one additional with j will be greater as the preferential access is diluted in the others and also j will have incentives to subscribe with i given that it is discriminated against in this market.

For example, USA during the first half of the 1990s took initiative for the creation of NAFTA as a response to the process of deepening the European Union (access to new members and the

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3 In this paper, as it is usually in this literature we are going to denominate as a Preferential Trade Agreement (PTA) any trade agreement with a level integration equal or more deep than a FTA (Custom Unions, Common Markets, Economic Unions).
consolidation of the common market in 1992). As USA was discriminated in the neighborhood of an increasingly big market (EU) the response was to discriminate in its own neighborhood market. This is an illustration of the interdependence cross effect.

The evolution of the PTA between Latin America countries and the USA followed by the EU’s reaction illustrates the interdependence own effect. The historical sequences of PTAs show it: Mexico (signed in 1994 a FTA with USA and in 2000 with EU), Chile (2003 and 2004 respectively), Central America (2006 and 2013), Colombia (2012 and 2013), Peru (2009 and 2013), and Panama (2012 and 2013). Also the behavior of Latin America countries with the USA follows its own interdependence effect dynamic. As it is shown in the previous sequence given that Mexico has a preferential access to USA many others Latin American countries wish to have a PTA with USA.

BBM simulated the sign of the effect using also the Krugman type model with intra and intercontinental trade cost. The results in terms of net welfare are a combination of trade creation, trade diversion and terms of trade effects. However, both interdependence effects could be also rationalized with a political economy model of PTA formation as it is proposed by Grossman and Helpman (1995) and applied by Baldwin (1995) with the specification of the domino effect, with a predominant role of trade diversion effects.

For the empirical approach BBM use again a choice model. However, in this recent article they use a panel data variation (146 countries in the period 1960-2005) to estimate both interdependence effects. The country static characteristics are the log transformation of bilateral geographic distance and a continent variable (dummy variable for the same continent countries). Both are dyadic variables for each $ij$ bilateral relationship. Two additional transformations of distance and the continent variables are done. The purpose is to measure remoteness in both dimensions using multilateral resistance term (MR) and then construct a bilateral variable with the simple mean between the MR variables. Two types of time varying variables are used. The first two variables measure market size as the sum of natural logs of GDP and similarity as difference between natural logs GDP (both are bilateral). The second type of variables approach the interdependence dimension among PTAs: own (country

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4 PTAijt will have the value 1 for a pair of countries ($i$, $j$) with an FTA (specifically, FTA, customs union, common market, or economic union) in year $t$, and 0 otherwise. This variable was constructed using all bilateral pairings among 195 countries in the world annually from 1960-2005. The sample is reduced to 146 countries for the availability of GDP data in a full time series pattern for all the period. The data base is constructed with a compilation by Bergstrand and Baier using WTO Regional Agreements Data Base and may others multilateral and national sources See Baier and Bergstrand, 2017.

5 The multilateral resistance is an average distance and continent for each country ($MRD_i = \frac{\sum D_i}{C}$ and $MRC_i = \frac{\sum C_i}{C}$ respectively) and then the bilateral MR are: $MRD_{ij} = \frac{MRD_i + MRD_j}{2}$ and $MRC_{ij} = \frac{MRC_i + MRC_j}{2}$.
variable) and cross effect (bilateral variable)\(^6\). To avoid endogeneity problems with time variables they lag five years each.

The empirical basic estimation is a logit model to explain the probability to have a PTA. The results when all variables are considered do not reject the general result predicted by the simulation exercise. Distance is negatively associated with the probability to have a PTA. If both countries are in the same continent (less trade cost) the effect is positive. If both countries are -on average- remote to the rest of the world the probability to have a PTA is greater (multilateral resistance in distance), however if on average there are more countries in each continent the probability to have a PTA decrease (multilateral resistance in continent variable). Market size and difference in market size also follow the expected pattern (positive and negative effect respectively). Then the new effect introduced in the paper is the interdependence. Results do not reject prediction, related with both manifestations of domino effect (own and cross). The size of own effect is greater than cross (40 times). Many robustness checks are considered and basically all the empirical results are sustained.

The critic to BBM approach could be that they applied a choice model with data in cross sectional time-series form, estimated using a logit model. This mean they do not consider in a proper way the complex structure of the network as a determinant of the evolution of new linkages\(^7\). The critic is pertinent considering that the main identified mechanism is the network interdependence that could be characterized in a more detailed and refined way using a more proper methodological approach.

The second approach is applied by Manger, Pickup, and Snijders (MPS) (2012). The motivation is similar but with a different methodological approach based on a longitudinal network analysis. The new methodology is based in a new class of model proposed by Snijders (2001) denominated ‘stochastic actor-oriented models’ (SAOM). These models usually are applied to directed networks (non-reciprocal links) while non-directed networks are less frequent in the literature in SAOM. MPS (2012) use a modification for non-directional networks denominated “unilateral initiative with reciprocal confirmation”. The main goal of MPS is to identify a

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\(^6\) The own effects are: \(FTA_i = \sum_{x \neq i} FTA_{ix} + FTA_i\); \(FTA_j = \sum_{x \neq j} FTA_{xj}\). The cross effect is: \(ROWFTA_{ij} = \frac{\sum_{x \neq i} \sum_{y \neq j} FTA_{xy}}{2}\). Where \(FTA_{ix}\) is a binary variable 1 if there is an agreement and zero otherwise.

\(^7\) The arguments by MPS are the following: “The dynamics of networks are complicated because network (structural) effects have an endogenous feedback. Structural effects imply that the presence of some ties will depend on the presence of other ties, as in the case of transitivity (effects involving three actors) or endogenous popularity (the more ties an actor has, the more attractive the actor for future ties). Therefore, network evolution requires a model that includes monadic and dyadic variables as well as the relevant structural effects. Network effects are of particular importance if they are of substantive interest themselves, and also if they prevent spurious findings.”
hierarchy in the PTA network according to the level of development (high, medium and low). The hypothesis is that the high income countries have a preference to sign PTA with themselves and with medium income countries; medium income countries will do it among themselves, while all other combinations are less frequent. In MPS the interdependence effects through the structure of the network are also included. However, with this new methodological approach the driver of the interdependence effects are the triangles closures (with an expected positive effect) and/or indirect ties (with an expected negative effect). The interdependence effect deals with the amount of discrimination each country faces in market access to the global market. Each country when considering to proposing or accepting a PTA wants to increase global markets access (increasing positive discrimination and /or diminishing negative discrimination).

Diagram 1
Interdependence and probability to have a PTA

The diagram 1 displays the type of interdependence previously identified. In the left panel we show the own interdependence effect defined by BBM: the probability to have a PTA between H and M increases with the number of agreement each have with third countries (3 and 2 respectively in the example). This is a monadic type effect, i.e. it depends on each actors’ characteristics. The BBM cross effect means that the probability to have a PTA between N and F increases with the amount of PTAs the rest of countries have. This effect is dyadic as it changes for each pair of NF relationship.

In the right panel the interdependence effect as specified in MPS considers the increase of probability of a PTA between M and Z by the incentives to closure triangles (this means to have direct access to a market that otherwise M will have only indirect access). In the opposite the probability to sign a PTA decreases if as a result M creates a new indirect tie (distance two path to F).
The period of the data base (1962-2004) is similar to BBM. MPS considered that countries’ rationale for engaging in PTA change over a long period so estimation is divided in two samples, 1962-1993 and 1994-2004. The result is presented for the second sub period 1994-2004 and starts with the creation of NAFTA. In this second sub period is when the density of the network accelerates its growth pattern. One fundamental difference from earlier studies is that they consider the European Union as a single actor and the data set comprises at most 145 actors. As the European Union behave as a national jurisdiction in trade policy matter, each time the EU sign a PTA with third countries imply several bilateral new relationships.

MPS results show two types of interdependence effects. The first is similar to the own interdependence effects previously mentioned. Countries want to have an additional PTA, because the satisfaction function increases in the degree (number of PTA). The other new interdependence effect comes from the fact that countries prefer paths with triangle closure compared with indirect ties (diagram 1). The other result is related to the types of countries, considering the level of development. It is twice more likely to have two high income country or a high income and a medium income country, than two medium income country engaged in a PTA. The other combinations are much less possible. They use other controls: geography (through distance); the level of trade openness; and the type of regime using a democracy index. Later, Manger and Pickup (2016) based in the observed association between the propensity of PTA and democracy status in MPS, extended the analysis to a more complex framework, adding a new related network which also could explain democracy behavior and its interaction with PTA formation.

The objective of this study is to analyze the dynamics of the linkages between countries through PTA. For that we propose a simple theoretical framework based in an extension of Badlwin (1995) to rationalize the determinants of PTA formation as a way to maximize preferential market access and/or diminish market discrimination. All the interdependence effects could be rationalized using this perspective. Additionally we test whether relative commercial specialization of countries has any effect on the probability to sign agreements. The main controls are associated with natural trade cost. It is expected that when natural trade costs are smaller and so the incentives to reduce political trade cost with PTA formation increases. Methodologically the model is based in a Stochastic Actor Non-directed (SANO) model.

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8 The basis of PTA information is similar to BBM a compilation of different sources (WTO, Tusk Data Base) unless the documentation of data base construction it is not available.
The article is organized in this introduction and four more section. In the second section a
description of the evolution of PTA in the long period is presented. The third section developed
the theoretical and methodological framework. Section four presented the results and the last
section highlighted the main conclusions.

2. PTA EVOLUTION

This section provides a brief description of the evolution of PTA network connections among
countries over a period of forty years. We use Baier and Bergstrand (2017) PTA database. The
PTA network can be characterized based on two assumptions in relation to the European
Union. The first would be to consider the EU members as separate countries as BBM do. The
second is to explain EU agreements with third parties, like the rest of the agreements but to
leave out of the analysis the growth in EU membership and the network of intra-EU trade
agreements that this phenomenon generates. The latter is the path MPS declare to undertake.
This assumption is consistent with the idea that the actor who takes the decision of the
agreements with third parties is the complex actor EU. The rationale for this assumption will
be clearly stated in the next section. The option that was taken in this work is to follow the
MPS assumption, which has the technical complication that the number of countries (nodes)
that defines the PTA network changes depending on changes in EU membership.

The descriptive results of this evolution are presented in figure 1. It is clear that in the long
period from the beginning of the eighties to the beginning of the nineties no significant
changes occurred, it is from 1992 that the acceleration in the growth rate of PTA takes place.
In addition, the figure shows the two developments considering the EU countries as separate
countries or as a single country.

Figure 1  
Evolution PTA in the period 1981-2011 (numbers of links in the PTA network)
In figure 2 data only for the case with the EU as one country is presented combined also with the value of the network density (Density= #Links/(C.(C-1)), C=#countries). The evolution shows that at the beginning of the nineties density was a bit more than 1% and at the end of the whole period in 2012 more than 8%. Number of countries decreases is the result of the permanent increase in membership of the EU (see figure 2.b). Vertical divisions in this figure account for moments of changes in EU composition.

In figure 3 the structure of the network with all types of reciprocal trade agreements is presented (also Partial PTA- PPTA- are included). Different colors in links can be associated

Partial PTA is defined considering both the level of liberalization and sectors coverage.
with the different type of agreements according to the typology developed by BB in their database. The continents are distinguished also with different colors at nodes level.

It is notorious that the relevance of PPTA decreases in a substantial way comparing 1981 and 2012, in favor of greater deepness agreements (Free Trade Area, Customs Unions and Economic Unions). At the beginning of the period few countries are connected and the pattern of connection is mainly regional inside de continents.

At the end, the regional pattern is still evident but continents are also connected between them through countries that act as bridges. It should be noticed that there are no isolated countries in this last picture of PTAs.
Evolution of reciprocal preferential agreements

**a) 1981**

*Source:* Data Base of PTA by Baier and Bergstrand (2017).

*Cytoscape* software used to create the graph visualization. We used force directed layout.

**b) 2012**

*Source:* Data Base of PTA by Baier and Bergstrand (2017).

*Cytoscape* software used to create the graph visualization. We used force directed layout.
Besides regional patterns, other variables can explain the dynamics of PTA formation in terms of how much change could be expected, who is changing and to whom is it connecting. In figure 4 we show some partial evidence to this prior to test our model. Upper left graph shows the changes in time of closed triads of PTAs (triangles of PTAs) in terms of country size (GDP). In the 80’s triangles were more common among small countries (negative linear tendency) while towards the end of the period this tendency tends to disappear, meaning that both small and big countries are part of PTA triangulated agreements. Something similar but less intense can be observed in terms of countries wealth, measured with GDP pc (upper right graph).

When considering dyad connection instead of triangles, bigger and wealthier countries seem to be more active towards the end of the period (positive slope in the tendency line in both lower graphs).

**Figure 4**

*Triangles, degrees and socioeconomic variables*

Source: Data Base of PTA by Baier and Bergstrand (2017).
3. THEORETICAL MODEL AND METHODOLOGY

3.1 Government value function to sign PTA

The two mechanisms identified in the literature are sustained with different arguments. BBM used a simulation model that allows building a gain for trade function according to the perspective of a benevolent government. It is a monopolistic competition model with transport costs, and a particular geography of the world economy (3 continents and 2 countries in each). This model is calibrated with parameters of the literature, and simulates different types of agreements. On the basis of simulations the signs of the effects are identified and then contrasted with observed data. It is a consistent methodology that seeks to set the micro foundation of the applied analysis. However the simplification of the theoretical reference model fails to consider many other effects.

In the first place, the political economy of PTA creation is not considered. For example the theoretical approach as it is developed by Grossman and Helpman, (1995) and Baldwin (1995). Secondly the complex relationships of networks cannot be included given the stylized geography of the proposed simulation model. The estimation method does not allow capturing these other network interrelations either.

In the case of MPS the argumentation is less ambitious. They describe the mechanisms through which the PTA generate gain for trade through the effect on prices and trade volume. The theoretical reference is Baldwin (1995) despite the fact that the argument of this article is restrictive in terms of the dynamics of the domino effect. In fact, what is modeled in Baldwin (1995) is a country that wants to join a pre-existing agreement and the balance of the decision of the country entering into the agreement depends on the number of members of the agreement considering gain in market access and domestic resistance to preferential trade liberalization. It is an example that stylized the announcement of the European common market and the effect on enlargement in the membership of the EU. However, this is not the typical case of the international economy. The typical case is linked to a bilateral PTA that assesses whether they subscribe or not an agreement. To do so they consider own pre-existing agreements as well as the PTAs of the eventual partner.

In our case, the main idea is that the creation of PTA is always a reciprocal exchange of market access. There are two types of effects. First, if a country gives access to its own market has a negative effect on the government value function that it seeks to maximize (see equation 1).
Import substitutive sectors will be worse with a new PTA which would lead them to persuade government to drop the integration proposal. In Baldwin (1995) terms this is the resistance function of the trade liberalization. This resistance decreases with the number of PTA, ought to the marginally less preference that is given to each new partner. When liberalization is more multilateral the cost associated with domestic production adjustment will be smaller and also the trade diversion cost decreases. Trade preferences are diluted among many partners and the government value function increases.

Then gains depend on the size of the market that can be accessed and the degree of preference in the market of the partner. The higher gain would be associated to accessing large markets in a preferential way. Incentives for export sectors are associated to having preferential access or to be less discriminated in the greatest possible number of markets, since this widens the size of market access that is gained (prices and trading volume). In addition, the interest of exporters becomes predominant as liberalization evolves and the number of agreements grow. Getting access to a new country’s market is always understood as beneficial and will be more so as this access is not shared with others.

If the potential partner with whom there is an opportunity to sign an agreement already has a PTA with other countries then, for exporters, the agreement will have the benefit of reducing discrimination. Minimizing discrimination from a specific market can further impact the value function when the country that already has access is a rival in terms of specialization, i.e. if it specializes in exporting the same products.

The interdependence variables previously referred are related to the complex form of the interaction of the PTAs with others and its influence in the probability that a certain bilateral relationship could lead to a new PTA.

The other variables that are used in the function of government preferences are linked to the natural costs of trade. All the variables that imply more proximity and similarity (i.e. which reduce natural trade cost) increase the incentives to reduce non-natural trade costs which are associated with the particular trade policy established by each government. Gains for trade for reducing non-natural trade cost will be higher for those countries in which 'natural' trade costs are smaller. This is the well-known case of natural blocks pointed out by Krugman (1991 and 1992).

In equation (1) we present a possible reduced form of the preferences of political government of country $i$ who try to balance offensive (exporters) and defensive (import substitution sectors) interest.
\[ F_i = G_i(MA_{i1}, ..., MA_{ip}) \cdot L_i(MA_{i1}, ..., MA_{ip}) \]  

Where: \( G_i(MA_{i1}, ..., MA_{ip}) \) is the gain function that depends on the market access that each country \( j = 1, ..., P \) gives to country \( i \) \( (MA_{ij}) \); \( L_i(MA_{i1}, ..., MA_{ip}) \).

In diagram 2 a simple presentation of our argument is presented. Losses are a decreasing function of own PTA associated with a decreasing in marginal preferences given to each new partner and the gradual reducing in trade diversion. Then gain could have different levels and are specific to each partner. When gains increases associated with size of the market and/or less natural trade cost, the possibility to have more benefits associated with a particular agreements increase, and as we are going to show in the next sub section, also the probability to have an agreement.

**Diagram 2**

Gains (G) and Losses (L) of country i by number of PTA_i
3.2 SANO Model

Our methodology follows MPS approach which uses the modification for stochastic actor in non-directed network (SANO) as it is developed by Snijders and Steglich (2009). In this type of models the adjacency matrix of the network is always symmetric (if i is tied to j, then j is tied to i) this is the case in the set of reciprocal trade agreements we study.

The dependent variable is a sequence of temporal networks \(X_t\) represented by a binary adjacency matrix which take value of one \((x_{tij} = 1)\) if there is a PTA between country i and j and zero otherwise \((x_{tij} = 0)\). Time is continuous but we only observed the network in different moments. Then \(t_1, t_2 \ldots t_M\) with \(M \geq 2\) are subsequent moments for which there is an observation of the network status.

\[
X_{t_m} = [x_{t_m ij}] \text{ with } t_m = t_1, t_2 \ldots t_M
\]  

(2)

The matrix \(X_{t_m}\) is a square \(C \times C\) matrix, where \(C\) is the number of actors (countries) at that moment. By construction the diagonal of the adjacency matrix is zero \((x_{tti} = 0)\). It is assumed that from an initial observed \(X_0\), an unobservable continuous-time Markov process causes shift towards \(X_{t_1} \ldots X_{t_M}\). At each time \(t\), only one country has the possibility to make a change in the network (create a new link with another country). The probability of change at each time \(t\) depends on the current state of the network.

The likelihood of change in the network depends on the time and on the countries’ options. In every moment of time in which a country has the chance to make a change, it can choose to do it or not, and if it does make a new link proposal it needs to decide to whom.

In a time \(t\), in a State of the network \(x = X_t\) each player \(i\) has a rate of change \(\lambda_i(x, \delta)\). The probability that the next opportunity to change is for the actor \(i\) is:

\[
\frac{\lambda_i(x, \delta)}{\lambda_+(x, \delta)}
\]  

(3)

Where: \(\lambda_+(x, \delta) = \sum_i \lambda_i(x, \delta)\)

In every moment of time when it has the chance to choose, the actor \(i\) observes the network status \(x\) and evaluates the gain that gives him to move to a new state \(x'\), evaluating the

\(^{10}\) The definition of PTA is similar to BBM and MPS.
networking functions $s_{ki}()$. So the satisfaction function of the change in status is presented in the following equation:

$$f_i(x, x'; \beta) = \sum_k \beta_k s_{ki}(x, x')$$

(4)

Where $k = 1, \ldots, K$ is the index of effects.

The evaluation function enters the probability calculations of both a country initiating a tie and of a country confirming a tie. It is defined, as usual in generalized linear models, as a linear combination.

$$\hat{p}_{ij}(x, x^{\pm ij}; \beta) = \frac{\exp(\sum_k \beta_k s_{ki}(x, x^{\pm ij}))}{\sum_h \exp(\sum_k \beta_k s_{ki}(x, x^{\pm ih}))}$$

(5)

There are different alternatives to coordinate the will of both actors in the process of connecting. As in MPS we choose the unilateral initiative with reciprocal confirmation of the partner\textsuperscript{11}. In this modeling one partner takes the initiative proposing a new tie or dissolving an existing one; the other actor has to confirm, otherwise the tie is not created; for dissolution, confirmation is not required. According with Snijders and Steglich (2009): “one-sided initiative with reciprocal confirmation is in general the most appealing simple representation of the coordination required to create and maintain non-directed ties”. Once $i$ had the initiative of inviting $j$ to join in a PTA, the probability that country $j$ accepts the PTA offer is:

$$p_j(x, x^{+ij}; \beta) = \frac{\exp(\sum_k \beta_k s_{kj}(x, x^{\pm ij}))}{\exp(\sum_k \beta_k s_{kj}(x, x)) + \exp(\sum_k \beta_k s_{kj}(x, x^{\pm ij}))}$$

(6)

Summarizing both results the probability that a tie is proposed and confirmed, sustained or eliminated is:

$$p_{ij}(x, x^{\pm ij}; \beta) = \left(\frac{\exp(\sum_k \beta_k s_{ki}(x, x^{\pm ij}))}{\sum_h \exp(\sum_k \beta_k s_{ki}(x, x^{\pm ih}))}\right) \left(\frac{\exp(\sum_k \beta_k s_{kj}(x, x^{\pm ij}))}{\exp(\sum_k \beta_k s_{kj}(x, x)) + \exp(\sum_k \beta_k s_{kj}(x, x^{\pm ij}))}\right)^{1-x_{ij}}$$

(7)

For estimation purposes, we use the longitudinal analysis package Simulation Investigation for Empirical Network Analysis (SIENA; Ripley, Snijders, and Preciado López, 2011) in statistic program R\textsuperscript{12}. Given the relative size of the sample (140 nodes) we performed the estimation

\textsuperscript{11} According to Snijders and Steglich (2009)

with the conditional method of moment estimation, where conditioning variable is the total number of observed changes ("distance") in the network PTA variable.

SIENA\textsuperscript{13} uses certain statistics that reflect the parameter values for the function. The final parameters should be such that the expected values of the statistics are equal to the observed values. Expected values are approximated as the averages over a lot of simulated networks.

Observed values are calculated from the data set. To find these parameter values, an iterative stochastic simulation algorithm is applied, in which (a) the sensitivity of the statistics to the parameters is roughly determined; (b) provisional parameter values are updated iteratively by simulating a network according to the provisional parameter values, calculating the statistics and the deviations between these simulated statistics and the target values, and making marginal updates; (c) the final result of that procedure is used and it is checked if the average statistics of many simulated networks are indeed close to the target values.

Then, the SIENA algorithm is based on repeated simulation of the evolution process of the network. The method of moments estimation algorithm is based on comparing the observed network (obtained from the data files) to the hypothetical networks generated in the simulations. Standard errors are estimated with the likelihood ratio method.

\textsuperscript{13} Manual of RSIENA (Ripley et al, 2017)
4. RESULTS

Following the theoretical background explained in previous sections, we suppose countries have three main set of motives to sign an agreement. The first two of them are the domino effect and trade cost effects. Both groups of effects have been used in previous models and were discussed in section 3. Second we include network interaction effects that have a theoretical rationale. Third, we include in our model trade specialization variables under the hypothesis that they have a role in explaining motivations to sign PTA.

We focus in the period where the proliferation of agreements started: after 1994. The time spans for the analysis are related to countries entering the European Union, between 1994 and 2012. The first period -from 1994 to 2004- represents a world with 141 countries. The second period -from 2004 to 2007- represents one with 134 countries.

For each period we build the dependent variable: an array of subsequent binary networks representing the evolution of PTAs between all countries. The observed networks represent annual sequence except for those periods where only few new links were created, in which cases we introduce a jump of one or two years. We use Bergstrand (2017) database on PTA, selecting only the agreements classified as Free Trade agreements, Customs Union, Common Market or Economic Union.

The independent co-variables used to explain the dynamics of PTAs are built from trade, distance and political databases. We introduce the domino effects in the evaluation function through structural network effects. In particular for the period 1994-2004 we test three basic effects:

i. **transitive ties effect**: measures the number of countries to which a country $i$ is connected both directly and indirectly. A positive coefficient of this variable can be interpreted as a higher probability of countries to sign agreements to those countries with which its partners already have an agreement.

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14 In this period there are three waves of countries entering the EU: 1995, 2004 and 2007. For simplicity, and because period 2004-2007 is short we make the fiction that all changes in the EU composition in 2007 took place three years before, in 2004. In practice this means that instead of having two separated models with 136 countries in 2004-2007 and 134 countries in 2007-2012, there were 134 countries from 2004 to 2012. All independent variables were properly suited to this simplified setting.

15 The introduction of this jumps in observed periods should have no impact in the results given that the same jump is forced in the independent variables.

16 https://www3.nd.edu/~jbergstr/

17 Sources are described in table 1 in statistical annex
ii. actor pairs at dist 2 effect: measures the number of countries to which $i$ is only indirectly tied (through at least one intermediary). A positive coefficient in this variable would mean that countries are satisfied by keeping indirect ties to other countries (i.e. when it has a chance to sign a new agreement it will not be to some country to which its partners are connected).

iii. network isolate: measures the isolation of $i$, this means the chances that the new ties in the PTA network are signed for countries that have no previous agreements to any other.

The second group of variables is associated to the costs of trade, either natural or political and the bilateral trade relations. In the SAOM model, these variables are called actor-dependent covariates ($v_i$) that enter the evaluation function through the value they have for either $i$ or $j$ when considering monadic covariates (for instance democracy), or as attributes of pairs of actors $v_{ij}$ when considering dyadic covariates (for instance geographic distance, trade).

Natural costs:

i. Geographical distance, different languages and alike are related to higher costs to trade and so indirectly they can inhibit the need open markets. But also the cost of going through the negotiation process may be not equally necessary when countries receive migrants from one another for being close, having similar cultures or speaking same languages, than when labor migration is not usual. For this reasons, we expect that that natural trade costs impact negatively the probability of signing a new agreement between two countries. We use static binary matrices to account for these effects, except for distance matrix which is expressed in logs. We also build a monadic variable (resistmult) which accounts for how far each country is from all the rest of the world (the mean of the distance to every country). Additionally we create a dyadic variable equal to one if two countries belong to the same subcontinent\(^\text{18}\).

ii. On the opposite direction we would expect that the previous commercial relations, measured by a sequence of networks of logs of total trade (with a lag of two years), would positively impact the probability of signing a new agreement. This means, given that a country $i$ already gave access to its market to a country $j$ it would be expected that she can have gains in further facilitating trade (lowering costs of imports) and also having better access to the j’s market.

\(^{18}\) The subcontinents are: Caribbean, Central Asia, Channel Islands, Eastern Europe, Northern Africa, Northern America, Oceania, South America, South-eastern Asia, Southern Europe, Sub-Saharan Africa, Western Asia, Western Europe.
iii. We can also think on the size of the country or its wealth as relative costs to engage in trade agreements from own country perspective but also in a dyadic perspective. For instance, when country it is turn for country i to decide whether to engage in a new PTA, she would evaluate the gains according with its own size (big countries might have less gains from opening their markets) but also might chose the potential partner according to j’s size. The same reasoning is valid for wealth, measured through log of GDP per capita. Both monadic variables are dynamic and considered with two years lag with respect to the dependent variable.

**Political costs:**

i. We use two proxies for political cost, following previous literature on the matter. First we use a monadic variable democracy, which we suppose following MPS (2012) that acts in two complementary ways: the greater level of democracy diminishes the probabilities of making new agreements, but on the other hand when a democracy signs an agreement it will be more probably with another democracy. Democracy is a monadic dynamic variable that ranges from -10 to 10 with only a bunch of countries positioned as full democracies (for instance, United States is punctuated as 6 in this range).

ii. Conflict is the second proxy for political frictions. We use a dynamic dyadic variable that ranges from -10 to 11, where negative values account for official cooperation or dismantling of conflict declarations or actions.

Finally, we introduce in our model a set of determinants that have not been properly accounted for in previous approaches to the dynamics of PTA, as far as we know.

Dyadic **trade specialization** variables: complementarity and rivalry. The complementarity considers for every pair of countries the extent to which the products that one of them exports with comparative advantage are imported by the other country with comparative advantage. The construction of this variable is well documented in Flores (2017), but it mainly iterates the product of a RCAX matrix times RCAM matrix. The concept of rivalry is analogous but it measures the extent to which two countries are specialized in exporting to the same markets or in importing with specialization from the same markets (this means they compete either for

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19 We performed a log transformation of a variable that accounts for the sum of events of conflict (or dismantling of cooperation among dyads of countries) according to official declarations, which are given positive values. We used a database provided by Manuel Flores, who built it from GDELT events database.

20 RCAX: Relative Comparative Advantages in exports, RCAM is the same concept for imports.
client countries or for supplier countries. Both matrices’ elements range from 0 to 1 as they actually measure distances between specializations.

We would expect that two complementary countries would be willing to open access to mutual markets. Anyhow, considering the costs of signing an agreement, if the complementarity is very intensive then it would be probable that there is no need for a PTA. To give an example, when countries have high specialization in producing a good it will not need a preferential agreement to enter the market of a county that needs to import it anyways. The need would surge because of competitors, which leads us to incorporate the second specialization variable: rivalry.

If we think about rivalry in exports, the fact that two countries i and j compete in the same market h does not necessary mean that i and j would gain (or lose) anything by signing an agreement between them. For this reason, if there is any rivalries effect it would be with signing an agreement with the third country (h) to have preferential access when the other has already preference.

Table 1 presents the parameter estimates. These can be used to calculate the estimated effects of our actor and dyadic covariates, and structural effects on the probability of a tie formation. Simulation work has demonstrated that these distributions are normal (Ripley, Snijders, and Preciado López 2011). This permits the use of the usual methods of statistical inference. We show significance levels based on t-statistics. The estimated parameters for each effect should be interpreted as log-odds ratios.

The coefficients of the network structural effects are in line with the hypothesis of domino effects in regional trade agreements. All three effects are statistically significant (t>2) and with expected signs. It is more probable that countries sign PTA with other countries with which they already have indirect ties: if my partner has an agreement with another country I have incentives to sign with that third country than to any other.

Also, isolated countries have a greater probability to change their neighboring status (make a tie) relative to connected countries. The negative sign in the interaction between network isolate effect and gdp per capita (“int. network-isolate x lnpi bpc” in third block of table 1) shows that if we consider only isolate countries, the wealthiest ones will be more prone to change status in relation with lower gdp per capita countries. Next, the positive coefficient of the interaction between gdp per capita of ego (evaluating node i) and alter (potential partner node j) “gdppc ego x gdppc alter” means that countries will more probably sign agreements
with other countries with a similar wealth (i.e. rich countries will sign agreements with other rich countries). These results taken together are in line with those of MPS (2012).

The natural trade costs effects have the expected sign. In period 1994-2004, only distance and contiguity are statistically significant, indicating that geographical proximity induces more chances of signing a PTA. Also as expected, bigger countries in terms of GDP are less probable to sign PTA with any other country.

Stronger democracies have lower probability to sign PTAs (negative odds ratio) in relation to weaker democracies or autocracies. This result also is in line with that of PSM (2012), although in our case the fact that stronger democracies sign with stronger democracies (and the opposite) has the correct sign but it is not significant.

The negative sign of complementarity matrix means that considering costs and network effects, two countries would have less motivation to sign an agreement if they are strongly specialized in complementary goods.

Rivalry in itself does not help explain the dynamics of PTAs\textsuperscript{21}. Instead, we evaluated a theoretically reasonable effect: “XW=>X closure of Rivalry”. XW=>X refers to the closure of mixed network (x) and covariate (w) two-paths effect. If a country i has a network connection with h and h has a covariate connection with j then i would have greater chances to connect with j than to other country. In this case, the covariate is rivalry matrix, which means that a country i would tend to sign agreements more often with two rival countries, or looking from j’s perspective (because j have also to accept i’s invitation to sign a PTA), it will more often accept i’s invitation when its rival h already has a preferential agreement with i.

The same model was applied to period 2004-2012 (table 2). Most effects have the same sign. A few difference had to be introduced though, in order to get convergence in the estimation (critical to get valid standard error estimates).

\textsuperscript{21}Actually, this variable leads to non-convergence of the algorithm, because of high collinearity with other variables.
Table 1. Estimation results.  
Dependent variable: preferential trade agreements dynamics in period 1994-2004

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>St. Err.</th>
<th>t</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Network structural effects</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>transitive ties*</td>
<td>1.5391</td>
<td>(0.3572)</td>
<td>4,3</td>
</tr>
<tr>
<td>actor pairs at dist 2*</td>
<td>-0.3896</td>
<td>(0.0504)</td>
<td>-7,7</td>
</tr>
<tr>
<td>network-isolate*</td>
<td>6.6861</td>
<td>(0.5698)</td>
<td>11,7</td>
</tr>
<tr>
<td><strong>Trade Cost effects</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Natural trade cost</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>distg*</td>
<td>-1.1243</td>
<td>(0.1333)</td>
<td>-8,4</td>
</tr>
<tr>
<td>continent</td>
<td>0.3749</td>
<td>(0.2131)</td>
<td>1,8</td>
</tr>
<tr>
<td>comlang</td>
<td>0.1128</td>
<td>(0.2096)</td>
<td>0,5</td>
</tr>
<tr>
<td>contig*</td>
<td>0.6970</td>
<td>(0.2615)</td>
<td>2,7</td>
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<tr>
<td>trade*</td>
<td>0.0588</td>
<td>(0.0256)</td>
<td>2,3</td>
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<td>resistmult</td>
<td>0.1627</td>
<td>(0.1272)</td>
<td>1,3</td>
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<tr>
<td>gdp*</td>
<td>-0.5423</td>
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<td>-2,8</td>
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<tr>
<td>gdp similarity</td>
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<td>1,8</td>
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<tr>
<td>Gdp_pc</td>
<td>-0.7929</td>
<td>(0.5522)</td>
<td>-1,4</td>
</tr>
<tr>
<td><strong>Political economy effects</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>conflict</td>
<td>-0.0020</td>
<td>(0.0467)</td>
<td>0,0</td>
</tr>
<tr>
<td>democ*</td>
<td>-0.2983</td>
<td>(0.0984)</td>
<td>-3,0</td>
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<tr>
<td>democ ego x democ alter</td>
<td>0.0033</td>
<td>(0.0023)</td>
<td>1,4</td>
</tr>
<tr>
<td><strong>Specialization and interaction effects</strong></td>
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<td></td>
</tr>
<tr>
<td>complementarity*</td>
<td>-4.3041</td>
<td>(1.3883)</td>
<td>-3,1</td>
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<td>XW=&gt;X closure of Riv*</td>
<td>1.3476</td>
<td>(0.3880)</td>
<td>3,5</td>
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<tr>
<td>int. network-isolate x gdppc*</td>
<td>-1.9499</td>
<td>(0.5061)</td>
<td>-3,9</td>
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<tr>
<td>gdppc ego x gdppc alter *</td>
<td>0.1432</td>
<td>(0.0605)</td>
<td>2,4</td>
</tr>
</tbody>
</table>

Significant estimates in bold

We analyze only the differences. First, for this period the size of the country loses significance.

The second differences relates to the non-significance of rivalry – network interaction (we needed to drop it from the model to improve the goodness of fit).

In this period instead, the covariate that captures the incentive to sign PTAs to similar countries is continent. We need to analyze this interaction together with the value of the covariate itself. The fact that two countries belong to same region (subcontinent) lowers the probability to sign a PTA relative to the alternative case of two countries in different regions. This might respond to the fact that most regional agreement closures happened in previous period. But, the effect: “XW=>X closure of continent” indicates that it was more frequent that countries signed agreements with those that belonged to the same continent to one country with which the first already had an agreement.
Table 2. Estimation results.
Dependent variable: preferential trade agreements dynamics in period 2004-2012

<table>
<thead>
<tr>
<th>Variable</th>
<th>coefficient</th>
<th>St. Err.</th>
<th>T</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Network structural effects</strong></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>transitive ties *</td>
<td>0.7248</td>
<td>(0.3047)</td>
<td>2.4</td>
</tr>
<tr>
<td>actor pairs at dist 2*</td>
<td>-0.3431</td>
<td>(0.0328)</td>
<td>-10.5</td>
</tr>
<tr>
<td>network-isolate *</td>
<td>5.3781</td>
<td>(1.0338)</td>
<td>5.2</td>
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<tr>
<td><strong>Trade Cost effects</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Natural trade cost</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>distg</td>
<td>-0.1704</td>
<td>(0.1265)</td>
<td>-1.3</td>
</tr>
<tr>
<td>Comlang*</td>
<td>0.5763</td>
<td>(0.1760)</td>
<td>3.3</td>
</tr>
<tr>
<td>Continent*</td>
<td>-3.0476</td>
<td>(0.9236)</td>
<td>-3.3</td>
</tr>
<tr>
<td>trade*</td>
<td>0.2159</td>
<td>(0.0380)</td>
<td>5.7</td>
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<tr>
<td>conflict*</td>
<td>0.1044</td>
<td>(0.0402)</td>
<td>2.6</td>
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<tr>
<td>gdp</td>
<td>0.2535</td>
<td>(0.2389)</td>
<td>1.1</td>
</tr>
<tr>
<td>gdp similarity</td>
<td>0.7433</td>
<td>(0.4591)</td>
<td>1.6</td>
</tr>
<tr>
<td><strong>Political economy effects</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>democ</td>
<td>-0.4280</td>
<td>(0.1612)</td>
<td>-2.7</td>
</tr>
<tr>
<td>democ ego x democ alter*</td>
<td>0.0017</td>
<td>(0.0021)</td>
<td>0.8</td>
</tr>
<tr>
<td><strong>Specialization and interaction effects</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Complementarity *</td>
<td>-2.3619</td>
<td>(0.9001)</td>
<td>-2.6</td>
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<tr>
<td>XW=&gt;X closure of continent*</td>
<td>0.3086</td>
<td>(0.0813)</td>
<td>3.8</td>
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<td>gdppc ego x gdppc alter*</td>
<td>0.1051</td>
<td>(0.0332)</td>
<td>3.2</td>
</tr>
</tbody>
</table>

5. CONCLUSIONS

Since the 80’s, and most notably since the middle of the 90’s, the PTA formation has grown steadily, starting from a map of agreements where few countries were connected through regional patterns and ending up in a totally connected world. This keeps the regional pattern but other types of connection appear besides the regional ones.

The objective of this study was to analyze the dynamics of the linkages between countries through PTA using a simple theoretical framework based in an extension of Badlwin (1995). The main idea is that the creation of PTA is always a reciprocal exchange of market access. We test a model in which a country would prefer to sign PTA if it maximizes preferential market access and/or diminishes market discrimination. We are interested in including the interdependency between countries as an additional conditioning of the probability of signing a PTA, which can only be properly addressed using networking approaches. Third we test the role of natural costs of trade in determining the probability that two countries engage in agreements. Finally, we introduce as a determinant for PTA formation the role of trade specialization through two proxies: complementarity and rivalry of trade.
Our methodology follows MPS approach which uses the modification for stochastic actor in non-directed network (SANO) as it is developed by Snijders and Steglich (2009). These models assume that at each time one country has the possibility to create a new link with another country, and the probability of change depends only on the current state of the network (follow a Markov process).

We used an array of PTA matrices in annual basis between 1994 and 2012, split according to EU composition change in the period. These are discrete “pictures” of network evolution (dependent variable) used as inputs for SIENA algorithms. The independent variables consist of vector and matrixes aligned to theoretical arguments.

Results show that the network structural effects are in line with the hypothesis of domino effects in regional trade agreements: It is more probable that countries sign PTA with other countries with which they already have indirect ties; isolated countries have a greater probability to change their neighboring status (make a tie) relative to connected countries, and among these, being wealthier increases the probability.

Similar to MPS (2012) we found that countries will more probably tend to engage with other countries with a similar economic level.

Trade complementarity has a negative impact on the probability of two countries signing a PTA. These can respond to multiple factors. First the fact that the high specialization of one country in a certain basket of goods would ease its access to markets that highly demand those goods, even in the absence of PTA. Second, this could be capturing some effect of similarity in natural preconditions which is not capture by usual geographic variables (in fact, in this setting continent is not significant).

In the first period (1995-2004) a particular effect relating rivalry is found: countries will more probably sign an agreement with a partner that already gave access to a rival of the former. This effect is not found in the specification for the next period (2004-2012). Instead, continent plays a significant role: two countries belonging to same continent lowers the probability to sign a PTA relative to the alternative case of two countries in different regions (probably because most regional agreement closures happened in previous period). But, it is more probable that countries sign agreements with those that belong to the same continent to one country with which they already had an agreement (it could be understood as intercontinental closures).
REFERENCES


