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Two Effective Solutions from Matching Theory to Solve the Syrian Refugee Crisis in Europe

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Abstract: *The European Union has proved to be unable to efficiently deal with the refugee crisis that is devastating Middle East since 2011. The problem grew bigger in 2014 and 2015, when Syrian migrants illegally entered some frontier Member States, forcing the European Union to introduce a new relocation mechanism that is far from being more effective than previous solutions. To address this distributional problem, I resort to matching theory, which provides some mechanisms that can improve the current policies. In this research I use two well-known algorithms that are adjusted to allow for some specific characteristics of the refugee crisis, the You Request My House - I Get Your Turn, which I studied in previous research, and the Deferred Acceptance. Both mechanisms are faced against each other in a pilot experiment that sheds some results supporting the use of the former algorithm.*

Key words: *Refugee; Matching; House allocation; Existing tenants; You request my house I get your turn; Deferred Acceptance; Quotas; Preferences, Families; Efficiency; Stability*

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1 Introduction

"Syria is the biggest humanitarian and refugee crisis of our time, a continuing cause of suffering for millions which should be garnering a groundswell of support around the world", United Nations Refugee Agency (UNHCR).

According to the UNHCR statistics, there are about 5.6 million Syrian refugees spread around the world, but especially concetrated in frontier countries as Turkey[1], Lebanon and Jordan. This figure suppose more than 32% of total refugees in the world. Although Europe is only dealing with a tiny part of the problem, the distribution of refugees is totally unbalance since, for instance, in just three countries, namely Gerany, Hungary, and Sweden, took place 73% of the total requests for international protection in the European Union. Furthermore, Italy and Greece are dealing with a massive inflow of illegal immigrants entering from their shores. Consequently, these five countries have to bear with a disproportionate burden that has become so difficult to manage that further measures including a relocation of asylum seekers from Italy and Greece has been introduced in the last years.

Up until now, diverse real-life problems where different agents need to get a pair of either the same or different characteristics has been addressed by the use mtaching theory. This theory offers an algebraic framework that provides several algorithms to face, in the most efficient manner, a certain distributional problem. Nevertheless, although the Nobel awarded Alvin E. Roth stated in 2015 that *"refugee relocation is what economists call a matching problem, in the sense that different refugees will thrive differently in different countries. Determining who should go where, and not just how many go to each country, should be a major goal of relocation policy",* the European Commission has not considered this literature yet.

[1]Only in Turkey there are more than 3 million refugees.

Thus, the European Commission has just tried to find the fastest possible solution to the distribution of Syrian refugees, ignoring other necessary properties of the distribution such as efficiency and fairness. Consequently, some European countries are now facing an uneven scenario where just few Member States are accepting their responsibility, while the rest of European countries are not even covering the quotas they agreed. Neither emergency relocation plans, which failed be a fast solution to the Syrian crisis since just 34,689 out of 120,000[2] applicants has been relocated, nor other common procedures such as resettlement schemes, have efficiently solved the current situation that Europe is witnessing. Actually, all these policies have the same deficiency, they do not take into account the preferences of neither refugees nor countries, which ultimately affects the efficiency of the final allocation. The fact that preferences are disregarded is a direct consequence of the application of the criticized[3] *Dublin regulation,* which[4] obliges the country of refugees' first arrival to assume the application procedure when a request for international protection is made. Additionally, movements across European Member States have publicly been prohibited in order to avoid that refugees can choose their preferred country where ask for international protection, which is another measure that diminishes importance to refugee preferences. With the inclusion of preferences in the model, the final allocation can improve towards efficiency, allowing refugees to be matched to their best pos-

[2]Data from relocation's State of Play as of 19 Mayl 2018.

[3]In their work, Teytelboym, et al. (2016) claim that *"given the unprecedented current scale of refugee arrival, existing policies designed to manage refugee flows have effectively collapsed"*. In addition, Fernández-Huertas Moraga and Rapoport (2014) state that *"for one thing, the so-called "Dublin System" whereby an asylum seeker is mainly under the responsibility of the country of first-entry, is more and more regarded as ill-conceived"*.

[4]Regulation (EU) no 604/2013 of the European Parliament and of the Council of 26 June 2013 establishing the criteria and mechanisms for determining the Member State responsible for examining an application for international protection lodged in one of the Member States by a third-country national or a stateless person set out an ordered hierarchic criteria based on minors, family reunification, previous residence documents or visas, and finally and the more common, the first country in which the asylum seeker enters.

sible choice. As an example, imagine a situation in which some refugees are allocated to their most preferred option, but the rest get their worst preferred country, which is a possible outcome if we suppose that those refugees that are considered at risk can select destination, whereas the rest of them are assigned a random[5] country. Example 1[6] shows how the this final assignment can easily improve towards efficiency by just considering refugee preferences when the randomness above described negatively affects them.

This response to the allocation of migrants harms refugees because they cannot choose their country of destinations, as well as countries since the dissatisfaction of refugees is the mirror of the social hostilities between races within European countries. In this sense, the Syrian crisis has given raise to extreme responses, for instance, some extreme right-wind characters has gained votes in these last years due to this problem, as it is the case of Marine Le Pen, leader of the *Front national pour l'unité française*. Moreover, Great Britain decided to leave the European Union in part because of the disagreement with migration policies[7]. Additionally, some Eastern countries like Poland, Hungary and Czech Republic has directly refused to accept more refugees, contradicting the Dublin Convention.

In order to obtain a realistic setting to cover the existing crisis, refugees that have already been sheltered throughout these years under inefficient mechanisms should be given the opportunity to get better assignments. This concept can be easily introduce by using the House Allocation with Existing Tenants model from one-sided matching. To tackle this model, I first used in previous research the *You Request My House - I Get Your Turn* (YRMH -

[5]Here I mean with random assignment the fact that applicants can only request international protection in the country of first arrival, which they cannot self-select in most of the cases given the necessity to leave their country and the absence of means to travel to one or another country. Thus, the lack of self-selected choices from migrants in the case of this refugee crisis can be considered as a random fact.

[6]See part A in the Appendix.

[7]In line with this,Crawley et al. (2013) document that "o*verall, the British public appear to have become less tolerant towards refugees*".

IGYT) algorithm from Abdulkadiroglu & Sönmez (1999), in which one agent side, refugees in this case, reveal their preferences over the other side, which define its components as objects. Additionally, there exist a priority order to assign refugees according to some characteristics, and a fixed capability restriction imposed from the European Commission[8]. Once this mechanism is reviewed, I turn to a more complex literature where also countries have preferences and the dynamic environment generated by the presence of existing tenants is harder to obtain. Thus, I use a dynamic version of *Deferred Acceptance* (DA) algorithm provided by Kennes et al. (2014), with which fit the refugee problem in a similar way as the YRMH - IGYT does.

Because both mechanisms were originally created to address a specific context, similar but not exactly equal as the refugee problem, I introduce some adjustments[9] in order to take into account all the facts and features of the Syrian crisis. The first modification is the introduction of a *system of quotas* inside the model that allow me to run both algorithms when refugees are allocated to quotas instead of being assigned to countries. This forces the introduction of a quota counter[10]. Second, I provide countries with the possibility to state which refugees are acceptable and which are not by the introduction of a list of *binary preferences* for them. This modification is absent in the original House Allocation model and is quite relevant for the purpose of this study since countries are who eventually decide if an applicant is given the condition of refugee in the case of relocation schemes and also which refugees are sheltered by means of resettlement policies. Because the Deferred Acceptance mechanism already considers preferences from both sides of the markets, the discussion about acceptability only makes sense in the YRMH - IGYT mechanism since preferences implicitly assumes accept-

[8]Even though the fairness and capacity of the magnitude of quotas is also an interesting issue directly related to the refugee crisis, is beyond the scope of this research

[9]These adjustments modify both the way in which the model is defined and also the algorithms, which I re-write so as to allow for their correct functioning.

[10]This idea is first introduced in Abdulkadiroglu & Sönmez (2003).

ability. Third, I introduce groups of refugees that I called *families* and that should be assigned together in the same way as the European Union is struggling to do. Finally, I introduce *type-specific quotas* that can only be filled up by refugees at risk or special refugees so as to provide the model with a realistic feature of resettlement schemes. This inclusion is very aggressive in the sense that it hinders the efficiency and stability of final outcomes.

Even though I am the first to use this adjust setting and the House Allocation model with Existing Tenants to address the Syrian crisis, I am not the first to use matching literature to provide an efficient solution to the distributional issues that has already been commented. Fernández-Huertas Moraga and Rapoport (2014) are the first authors who decided to implement the simplest versions of the Deferred Acceptance and the Top Trading Cycles mechanisms to address, with two different perspectives, the reality of the refugee problem. My work in this study is similar in the sense that I also use these same two mechanisms, yet my versions are integrated into the reality of the Syrian crisis to a bigger extent thanks to the adjustments. For their part, Anderson & Ehlers (2016) suggest the use of a specific algorithm designed by themselves that generates stable and maximal matchings for a very specific environment of private housing in Sweden. Although their mechanism is quite sophisticated, it is a solution for a concrete context that might not be likely to happen in other less refugee-friendly countries. Finally, the finest example of matching application in refugee crises is the research from Teytelboym, et al. (2016), which provide a wide array of mechanisms that address the refugee problem in different manners, granting different properties for the final outcome in each situation. However, although these mechanisms are modifications of well-known mechanisms, they are quite difficult to understand, which might back out the European Commissioner when consider the implementation of matching theory to address the Syrian crisis. The difficulty arise from the use of multidimensional constraints to distribute refugees ,which in my opinion imposes a very restrictive context that could

be better suited by the use of the system of quotas that I introduce in this research since it is supposed that the quotas imposed from the European Union already consider these multidimensional constraints in each country.

The rest of the paper is organized as follows. Section 2 is devoted to discuss the economic impact of the prevalence of Syrian refugees in host countries in order to call for the aim of development economics. In section 3 I describe the modified version of the House Allocation with Existing Tenants model and the most important facts and properties of the final matching. In section 4 I discuss why and which are the best mechanisms that adapt better to the previously specified model. In sections 5 and 6, for the YRMH - IGYT and Deferred Acceptance algorithm respectively, I present, one by one, all the modifications to the mechanisms described before. Section 7 describes and discusses some insights of the pilot experiment I carried out to understand which of the two mechanisms is better to fit the refugee problem. Finally, in section 8 I state the main conclusions of this study.

2 Why refugees are important for development economics?

In this background section I review the key insights of migratory movements and their effects on several economic indicators of recipient countries with the aim to show that the economic science, and more specifically, development economics is necessary to address this problem[11].

The way in which refugee movements affect the economic and social performance of recipient countries is not properly identified yet. In line with this, Akgündüz, et al. (2015), stated: *"the impact of immigration on the labor*

[11]It is obvious that the economic and social effect of displaced migrants in the native country is negative because of various reasons, mainly those regarding the decrease in the labour force, which deeply undermine the economic outcome of these countries. Additionally, there exist other effects that are relative to social conflict and family division.

market for natives has long been difficult to pin down for economists".

On the one hand, the standard model suggests that migration inflows increase labour supply and therefore the degree of competitiveness in local labour markets, leading to both lower employment rates and lower wages for natives. This view is shared among those who think of migrants as substitutes for the native labour force, which is a valid argument given the self-selection to migrate that induce people with resources, either economic or intellectual, to look for new job opportunities in foreign markets. This situation is likely to takes place at least in the short-run, until the capital stock equalizes, though it might not hold for refugee movements since they are not as high-skilled as ordinary and self-selected immigrants.

On the other hand, many studies find little or no effect from immigration on several labour market indicators. Foged & Peri (2015) use the Danish Dispersal Policy, which split refugees into different clusters of the same ethnicity, to identify the true impact of external migration on native workers. They find that an increase of immigrants obliges the low-skill native workers to abandon manual-intensive occupations, which ultimately means that these workers can obtain a higher wage moving to other jobs. In addition, there is no evidence of higher unemployment rates in this context.

Clemens & Hunt (2017) try to find explanation to conflicting results on this topic. They find that several negative results can be explained either by methodological errors or by sudden changes that the dataset could not cover. For instance, according to these authors, *"the discrepancy between Card's (1990), Borja's (2017), and Peri &Yasenov's (2016) analyses of the Mariel Boatlift can be fully explained by a large, simultaneous, and hitherto unreported change in the composition of the survey subsamples"*. The change consisted in a sudden increase in the fraction of non-Hispanic blacks without high school in Borja's sample that was not taken into account in the samples of the other aforementioned studies, and that entirely explains the conflicting results. Additionally, they find that the instrument used in Borjas &

Monras (2017) and other papers gives rise to the same results than other placebo tests where the information contained in the instrument is replaced by a white noise.

According to Borjas (2006), one possible cause for the absence of impacts is that immigration leads to higher rates of internal movements, which in fact leads to a sort of compensation on labour market conditions.

Now that it has been shown that negative evidence of immigration on native workers is hard to find, it is time to shift the focus to the recent and rather scarce work on the Syrian refugee movement. Most of the research has been done on Turkey, though there exists additional evidence on other affected regions.

Regarding the labour market consequences of the refugee movement, the existing literature on the Syrian crisis is, in line with immigration results, controversial. To my knowledge, there only has been written three papers addressing this issue: Del Carpio & Wagner (2015), Akgündüz, et al. (2015), and Ceritoglu, et al. (2017). The two latter studies share a similar design since they both use the difference-in-difference methodology to estimate the causal effect of the proportion of Syrians on different labour market indicators, whereas the former opted for the use of an instrumental variable approach. This different methodology can be at the root of the discrepancies[12],though it cannot be the only cause since those papers that use the dif-in-dif approach also find different results. The persistence of conflicting views can be therefore explained by the use of different data sources. There are four main data sources: The Turkish Statistical Institute (TUIK), The Household Income and Consumption Expenditure Survey (HICES), the Survey of Income and Living Conditions (SILC), and the Labour Force Survey. Although the first three databases are better to measure poverty, they lack

[12]The use of a dif-in-dif approach in this setup has been criticised because it would only be valid for the period when refugees did not move from border regions. However, after the year 2013 refugees moved around the country, so that estimations of this year onward may lead to wrong results.

of variables identifying migration movements. Therefore, authors have to resort to the LFS, which does not measure further living standards than the labour income, but on the contrary, contains information about geography identification, i.e. regions within Turkey, and also an identification for migrants.

Thus, Akgündüz, et al. (2015), which uses the TUIK to obtain the main indicators and variables for the model and several UNHCR reports to have a proper estimation of refugee movements, do not find significant effects on employment levels. In contrast, Ceritoglu, et al. (2017) show that that is less likely to be employed in the informal sector[13], yet this effect seems to be relevant only for women and low-skilled natives. Actually, it seems that men benefit from the refugee movement since they are more likely to get employment in the formal sector. This can be due to the fact that men remain available in the job market looking for new employment or even for improvements if they belonged to the informal labour force, while women do not enjoy as much opportunities as men so they abandon the job market. Finally, Del Carpio & Wagner (2015), who use IV regression and the LFS dataset complemented with information from the Disaster and Emergency Management Presidency of Turkey (AFAD) also find a decrease in the likelihood of being employed in the informal sector and also in part-time jobs that is only true for women and low-skilled workers. Authors also reported a drop in unemployment that may be explained by the increase in the school attendance. Hence, evidence from these three papers shed light on the substitution that exists between refugees and low-skilled workers. For them, the refugee inflow is harmful since refugees are cheaper workforce than natives, though positive results are also found in the formal sector where those natives who lost their job can move and even achieve improvements.

Significant research has also addressed the effect of Syrian refugees on the

[13]The fact that these effects are only visible in the informal sector are a direct consequence of the strict behavior of Turkish laws, which did not allow Syrian refugees to obtain a job permit at the beginning of the crisis.

poverty rates in the host country. Azevedo, et al. (2016) use linear regressions to evaluate the effects of the refugee crisis on several welfare indicators of Turkish natives. In their paper, the authors face a very important caveat regarding the database they used since they cannot properly separate refugees from other sources of migration. Therefore, authors comment that their results can be seen as an upper bound estimation. According to them, poverty measures are larger in the regions near the Syrian border for both host communities and migrants. Near the border, recent migrant households saw their poverty increased from 15.6% in 2009 to 46.7% in 2013, while a parallel increase can also be observed for recent migrants in the rest of the regions, in this case from 7.3% to 16.1%.

With respect to internal movements, Del Carpio & Wagner (2015) and Akgündüz, et al. (2015), also find different results. Again, the discrepancies can be the result of the different approaches used, IV regression and dif-in-dif estimation, respectively. On the one hand, Del Carpio & Wagner (2015) find statistical evidence in the native relocation of the workforce. The magnitude of the estimations is consistent with 10 refugees entering a province causing 2.5 natives to leave, being the impact larger for women than for men, which is consistent with previous findings. On the other hand, Akgündüz, et al. (2015) show small and insignificant results on exit rates, showing that Turkish inhabitants do not move away due to the refugee inflow, thus contradicting the previous findings.

Some other studies place the focus on other indicators. For instance, Binnur & Semih (2016) use a dif-in-dif approach with CPI data from Turkey to estimate the impact of the refugee inflow on prices. According to them, prices dropped 2.5 percent on average. Akgündüz, et al. (2018) study the impact of the Syrian crisis on firm creation. The result is a positive effect driven by both the creation of new foreign firms and the fact that business can benefit from the use of low-skill employment from refugees.

On the social side, some other papers have found little or no evidence of

change in voting behavior. Altindag & Kaushal (2017) find that only a slight decrease in support for the Justice and Development Party of Turkey, and statistically insignificant effects on election outcomes. According to the authors, this absence of effects can be explained as a demand for stability from Turkish people in response to the civil war in Syria.

As it has been reviewed, refugees negatively affects native labour markets only slightly. Furthermore, some positive effects have also been commented such as increase in job opportunities for male natives, or firm creation. Therefore, supranational organizations must provide both support to refugees[14] and information to natives in order to avoid unfounded racist attitudes towards them.

3 The model

Once it has been discussed why economics should play an important role in migrant decisions, this section defines a theoretical framework with which one can operate the current Syrian refugee crisis. The framework presented in this section is directly taken by the House Allocation with Existing Tenants literature.

The model is a six-tuple problem$\{R_E, R_N, Q_O, Q_V, P, \psi\}$, with R_E being the set of already allocated refugees, the so-called existing tenants[15]. R_N is the set of new refugees who do not own any quota, also known as newcomers. Q_O is the set of quotas that are already owned by the existing tenants, while Q_V is the set of vacant quotas, that is, those that have not owner. All already allocated refugees $r_E \epsilon R_E$ are endowed with one occupied quota

[14]Integration reform in Sweden proved to be helpful for refugees since it increased the both their probability of employment and their earnings (Joona, Et Al. (2016)).

[15]Introducing these tenants violates the Dublin Convention since they can change their asylum country. However, this feature of the model contributes to end other future secondary movements since it directly helps get the better assignment for each refugee. Additionally, there are efficiency gains in allowing these movements at least once, as it is shown in example 2 (see appendix).

$q_r \epsilon Q_O$. Quotas are defined as the total number of indivisible and indifferent[16] slots that a country has to shelter refugees. Finally, let $C : \{c_1, c_2, ..., c_c\}$ be the set of all countries.

Let $R = R_E \cup R_N$ be the set of all refugees, with $Q = Q_O \cup Q_V \cup \{\phi\}$ being the set of all quotas plus the null quota, ϕ, which is defined as the absence of assignment, and is supposed to be the worst quota for every refugee[17].

Each refugee $r \epsilon R$ has a strict preference relation P_r over countries, $P = (P_i)_{i \epsilon R_E \cup R_N}$. There exist a priority list for assigning refugees, expressed as $\psi : \{1, 2, ..., |R_E \cup R_N|\} \rightarrow R_E \cup R_N$, which sorts refugees according to certain characteristics. This order can be either randomly chosen or priority-based, and it is assumed to be strict. Priorities are only established in the case of the You Request My House - I Get Your Turn algorithm; in the Deferred Acceptance model, both refugees and countries have preferences over each other. Therefore, in this second case, every country $c \epsilon C$ has a strict preference relation P_c on R, and the problem would turn out to be a five-tuple one consisting of $\{R_E, R_N, Q_O, Q_V, P\}$.

Even though refugees have preferences over the set of countries, they are assigned to quotas within that countries, and therefore, it is necessary to introduce in the model a counter that registers the quotas that remain unassigned at every moment. As long as the unfilled quotas get filled, the counter reaches its maximum capacity. When the limit is achieved, the country cannot accept more refugees because there are no more quotas left within that country.

Referred to this model, a matching μ is an allocation of refugees to quotas that meets these three conditions:

1. $\mu(r) \leq 1$ for each $r \epsilon R$, which means that refugees can only be assigned

[16] Refugees are indifferent between one or another quota as long as these quotas belong to the same country. This is a realistic assumption since refugees can freely move within the borders of the country that provide them shelter.

[17] None of the results rely on this assumption.

to one quota.

2. $\mu(q) \leq 1$ for each $q \epsilon Q$, that is, every quota can only be the matching of one refugee, except the null quota, which might be the matching of more than one refugee.

3. $\mu(c) \leq q_c$ for each $c \epsilon C$, which means that countries cannot be matched to more refugees than the maximum capacity they have.

For any refugee, I will refer to $\mu(r)$ as the assignment of refugee r under μ. Similarly, $\mu(c)$ describes the assignment of any country under μ, and $\mu(q)$ is the assignment of any quota. According to the preference relation of refugees, refugee r prefers matching μ to matching ν if and only if she prefers $\mu(r)$ to $\nu(r)$. Similarly, given the preference list for countries, country c prefers matching μ to matching ν if and only if it prefers $\mu(c)$ to $v(c)$.

To conclude, a mechanism φ is a systematic procedure that selects a matching for each problem. In the present study, I formalize two different mechanism, the YRMH - IGYT algorithm and a dynamic version of the DA, which will be explained in the next sections.

All mechanisms generate matchings with different properties. These properties are crucial for the improvement of the current distributional mechanism.

- A final matching is *Pareto-efficient* if that matching cannot be improved by making at least one refugee strictly better off without making any other refugee worse off. This is the most important characteristics of the refugee context, since the problem that is being addressed in this research is about the inefficiency of the current distributional mechanism.

- A final matching is *individually rational* if no existing tenant strictly prefers her owned quota to her new allocation, and if newcomers are always assigned quotas that they prefer over remaining unmatched,

which cannot happen given that the null quota is the last choice for all refugee. Individual rationality is also needed in this context in order to guarantee the existence and participation of existing tenants.

- A final matching is *strategy-proof* if truth-telling is the best strategy for refugees. This condition is important to avoid manipulation from both sides of the market. However, both theoretically, and especially in practice, this property is very difficult to fulfill.

- A final matching is *fair* if it always respects the priority order. As it will be commented below, this condition is the less restrictive one in the context of the refugee crisis since the model includes tenants that must be granted a quota at least as good as their endowment, which might suppose a problem for the presence of fairness.

Similarly, in the Deferred Acceptance mechanism, the concepts of fairness and individual rationality are combined if the matching is not blocked by any student or country[18].

- A matching is *blocked by a student* if she prefers to remain unmatched rather than her current matching.

- Similarly, a matching is *blocked by a country* if that country prefers to have unfilled quotas than at least one of its current matchings.

- A given matching is *blocked by a pair* $(c, r) \epsilon C \, x \, R$ if

1. $c \succ_r \mu(r)$, which means that a refugee prefers other country different than the one to which has been assigned, and

2. Either there exists $j \epsilon \mu(c)$ such that $\{r\} \succ_c \{j\}$, or $|\mu(c)| < q_c$ and $\{r\} \succ_c \phi$, which means that there exists a refugee assigned to a country

[18]This same notion that was absent in the previous case for countries has to be included now that countries also have preferences.

that is less preferred than a second refugee r, or that r is not assigned to c even though that country has unfilled quotas and prefers the refugee more than keeping unfilled that quota.

- Given the definition of a matching that is blocked by a pair, we can say that a matching is *stable* if it is not blocked by any agent or pair.[19]

4 Matching approach

As mentioned in the introduction, matching theory is an algebraic tool that can be applied to several environments where two different sides of one same market try to get a mutual benefit. The most important feature of these markets is that money is often irrelevant, as it is the case of the model studied in this paper. Conversely, the information that is available for each side of the market and their decisions are the crucial components of every model. Its first application took place in 1962, when Gale and Shapley developed the Marriage model, where men and women should get a marriage agreement, and the College Admission model, where the application of students to university campus depend on the preferences of both agents. This same work continued in other areas such as School Choice, Kidney exchange, or House Allocation.

Two different branches of matching theory will be reviewed below. On the one hand, the one-sided solution to the House Allocation problem, which consists in the application of the YRMH - IGYT algorithm, which definitively assigns one refugee at a time. This first solution only allow refugees to have preferences, whereas the two-sided solutions admit markets where preferences come from both sides, thus giving the problem a new dimension

[19]This notion of stability substitutes Pareto-efficiency. Because we are now considering two sides with preferences, there is no Pareto-efficient matching for both sides, and therefore a notion of equilibrium is needed to know which final allocation is the best possible matching.

that cannot be solved by the use of the previous mechanism. Therefore, I need to resort to the Deferred Acceptance given the two-sided nature of the matching, which tentatively assigns all refugees simultaneously until someone with higher preference demands the same place than other tentatively matched refugee.

4.1 One-sided matchings[20]

One-sided matching is a very specific branch of matching theory literature. It defines only one of the sides of the market as the agent side, whereas the other side defines its components as objects. The difference between objects and agents reside in the fact that only agents have preferences. Overall, there are four mechanisms that could fit the model above specified from this literature. They all yield matchings with different properties and shortcommings, though the best mechanism for this specific context is the YRMH - IGYT algorithm.

The You Request my House - I Get Your Turn algorithm was firstly stated by Abdulkadiroglu & Sönmez (1999) as an alternative mechanism for the house allocation problem. It proceed as follows:

1. *For any given ordering ψ, assign the first refugee her top choice, the second refugee her top choice among the remaining countries, and so on, until someone demands the quota of an existing tenant.*

2. *If at that point the existing tenant whose quota is demanded is already assigned a quota, then do not disturb the procedure. Otherwise modify the remainder of the ordering by inserting her at the top and proceed with the procedure.*

3. *Similarly, insert any existing tenant who is not already served at the top of the line once her quota is demanded.*

[20]This subsection belongs to my previous work Álvarez (2017).

4. *If at any point a loop forms, it is formed by exclusively existing tenants and each of them demands the quota of the tenant next in the loop. (A loop is an ordered list of refugees* $(r_1, r_2, ..., r_k)$ *where refugee* r_1 *demands the quota of refugee* r_2*, refugee* r_2 *demands the quota of refugee* r_3*, ..., refugee* r_k *demands the quota of refugee* r_1*). In such cases remove all refugees in the loop by assigning them the quotas they demand and proceed with the procedure.*

YRMH - IGYT algorithm always generates the same outcome as the TTC, whichever is the ordering , as theorem 3 from Abdulkadiroglu & Sönmez (1999) states: "*For a given ordering* ψ*, the YRMH - IGYT algorithm yields the same outcome as the top trading cycles algorithm*[21]". Because the outcome of the TTC is always individually rational, strategy-proofness and Pareto-efficient, the only property that we need to give up in order to use this algorithm is fairness, which is implicitly ignored by construction of the model because of the presence of exiting tenants[22].

4.2 Two-sided matchings

The other possible solution to the model specified in section 3 can be found in the two-sided literature about matching theory. In this case, the solution is not as obvious as in the previous case because the existence of tenants allowed for the mechanism to have a temporal dimension even though the mechanism is static. This occurs in the YRMH - IGYT mechanism because the assignments are definitive and the mechanism establishes that when it is the turn of a newcomer who demands the quota of an existing tenant, this existing tenant takes the turn of the newcomer. However, in the case of the deferred acceptance, this fact does not make any sense since assignments are tentative and simultaneous given the absence of priorities and thus, one

[21] TTC.

[22] Further discussion in section B of the appendix.

refugee can always displace other previously, tentatively assigned refugee from her assignment in the case that the country prefers the former.

In consequence, the temporal dimension that is present in the previous mechanism cannot be found in the original literature of two-sided matching theory. Fortunately, more recent research that will be discussed in section 5 has successfully addressed this issue bringing in the dynamic version of different mechanisms.

The widespread use of the Deferred Acceptance algorithm, where different agents propose and accept different matchings, has evolved in a dynamic version whose main characteristic is the fact that previous preferences and matchings determine future outcomes. The Deferred Acceptance was first stated in Gale & Shapley (1962) as the solution to a problem where boys and girls have preferences for each other and seek to be matched with the other gender. Later on, Roth (1984) show that the algorithm used by the National Resident Matching Program to match hospitals and medical residents was equivalent to the Deferred Acceptance. The study of this algorithm shifted from matchings where only single agents were assigned to matchings where single agents were assigned to groups of other agents. It is this second case which is relevant for this research since I want to match a group of refugees to single countries. Therefore, the focus of this section is on the review of the many-to-one matchings.

The problem introduced in Gale & Shapley (1962) consists of a four-tuple $\{C, I, q, \succeq\}$ where C stands for a finite set of colleges, I is a finite set of students, q is a the college capacity, and $\succeq$defines the preferences of both agents, $\succeq = (\succeq_l)_{l \epsilon C \cup I}$. In this sense, the problem can be directly applicable to the refugee problem if we substitute countries for colleges and refugees for students.

The Deferred Acceptance in many-to-one settings proceeds as follows:

- *Step 1. Each refugee proposes to her first choice. Each school tentatively assigns its quotas to its proposers one at a time following their*

preferences. Any remaining proposers are rejected. In general at,

- *Step k. Each refugee who has been rejected in the previous step proposes to her next choice. Each country considers the refugees it has been holding together with its new proposers and tentatively assigns its quotas to these refugees one at a time following their preferences. Any remaining proposers are rejected.*

This definition of the Deferred Acceptance algorithm corresponds to the Refugee-proposing deferred acceptance algorithm. Since both sides of the market are agents with the preferences, another definition can be found in the Country-proposing deferred acceptance algorithm. I will not discuss this definition because the first way has better properties. The refugee-optimal stable matching μ^r that every refugee likes at least as much as any other stable matching is the result of the refugee-proposing deferred acceptance, whereas the county-optimal stable matching μ^c that every country prefers at least as much as any other stable matching is the result of the country-proposing deferred acceptance. The refugee-optimal stable matching is the least preferred stable matching for countries, and the same is true in the case of the country-optimal stable matching for refugees. However, given the nature of many-to-one matchings, in the case of refugees, there is no individually rational matching v where $v(r) \succ_r \mu^r(r)$ for all $r \epsilon R$, whereas in the case of countries such property is absent as theorem 4 in Roth & Sotomayor (1989) demonstrates. According to them, there can exist an individually rational matching in which each country gets a strictly better assignment than under the country-optimal stable matching, which leads to capacity manipulation from countries. Therefore, countries have an incentive to lie, which will break the strategy-proofness of the final matching. However, as Theorem 5 in Roth (1986) states, *"truth-telling is a weakly dominant strategy for all students under the student-optimal stable mechanism"*. In addition, it might be argued that giving the chance to get the better assignment for

refugees is more fair or ethical than giving this same opportunity to countries. These are the reasons why I prefer to focus on the refugee-proposing deferred acceptance. Still, countries can always manipulate the matching by reducing the number of quotas that they want to fill[23]. Sönmez (1997) finds that if there are at least two colleges and three students, there exists no stable mechanism that is immune to manipulation via capacities. Fortunately, Konoshi & Ünver (2006) show that if preferences are strongly monotonic, which means that colleges prefer larger groups of students to smaller groups, the student-optimal stable mechanism is immune to manipulation via capacities. However, this is not an assumption that can be applied to the context of the Syrian crisis since countries view refugees as a burden.

5 Fitting the You Request My House - I Get Your Turn algorithm to the reality of the Syrian crisis[24]

In this section I introduced the four contributions to the original YRMH - IGYT algorithm that adjust it to the real context of the refugee crisis. In so doing, I described the modifications and their implications to the final outcome. In some cases, I need to add some new information to the algorithm and state several assumptions to ensure its correct functioning in this modified environment. Nevertheless, these modifications may disturb the efficiency of the final matching, so that some examples are added to the description in order to shed light on the efficiency loses that are generated by this new version of the algorithm[25].

[23]This cannot happen in the model for refugee since quotas are endogenously established.

[24]This section belongs to my previous work, Álvarez (2017).

[25]For more information about the modifications go to section C of the appendix, where one can find examples, propositions and proofs supporting the introduction of the adjustments in both the model and the algorithm.

5.1 Refugees are assigned to quotas

All the countries state the set of places that can offer to shelter refugees. These places (quotas) are indivisible and unitary slots within a country that are eventually allocated to just one refugee. In addition, they are equally preferred by refugees, that is, refugees have preferences over countries, but not over quotas. Therefore, a refugee can be effectively matched to the quota of a given country only if there is, at least, one uninhabited quota within that country, so that a quota counter is needed to keep track of the available quotas.

Assumption 1 *Refugees are indifferent between one or another quota as long as they belong to the same country.*

In order to ensure the effective way to run the algorithm with this specific characteristic, I need to specify a rule to assign the indifferent quotas within a country:

Whenever a refugee points to a country that has free quotas, the algorithm will always select first the vacant quotas Q_V, except for the case of the existing tenants, which should be matched to their endowment even if there are vacant quotas within the country. If there are no vacant quotas, the algorithm will then select occupied quotas Q_O.

1. Vacant quotas within a country will be assigned randomly since refugees are indifferent between them.

2. Occupied quotas will be assigned following the priority order ψ. That is, the first occupied quota that can be assigned to a refugee that points to the country where this quota exists will be the quota of the existing tenant that has the highest rank in the priority list, the second occupied quota that can be assigned will be the quota owned by the refugee that has the second highest rank in the priority list, and so on.

5.2 Acceptability

Although the YRMH - IGYT algorithm can fit matching theory to the refugee problem, so far I have treated countries as mere objects that cannot state preferences. In line with this topic, many people may argue that countries should host as many refugees as they can, independently of any kind of acceptability over the latter. However, politicians do not share this viewpoint, and some governments have stated that they will not take refugees other than those who meet certain requirements[26]. Therefore, it would be necessary to allow countries to state preferences over refugees in order to avoid individually irrational allocations for the former, which would be a problem for the previous algorithm.

Acceptability is the condition by which countries are allowed to have binary preference relations over refugees. That is, countries can state who are the refugees that they are willing to accept and who are those that under no circumstances will they host. This condition is very realistic since countries are who finally decide either if an applicant is deserving of the refugee status, in the case of relocation, or if a refugee meet their requirements to provide her shelter by means of resettlement policies.

Assumption 2 *Previous assignments under other mechanisms different than the one I provide in this research were also individually rational.*

This assumption is needed in order to ensure that existing tenants cannot be rejected by the countries where they were initially assigned. Imagine that the country that have hosted a refugee assigned under the current regulation, now states that she is no longer acceptable. Then, this existing tenant may end up assigned to a quota that is less preferred than their current one, and therefore, the algorithm would violate individual rationality.

[26]There is a growing concern in East European countries to reject the relocation quota imposed by the European Parliament, especially with those refugees that are Muslims.

5.3 Families

One important feature of the refugee problem is the presence of families as well as single individuals. Let $F = \{f_1, f_2, .., f_f\}$ be the set of all families. A given family $f_i = \{r_{1,i}, r_{2,i}, ..., r_{f,i}\}$ is a group of f individuals who have exactly the same priority and preferences. These two conditions fit the reality of the problem, and are needed to guarantee that the whole family is matched within the same country. In addition, if one member of the family is acceptable in a given country, all the family members are also acceptable. On the contrary, if one family member is unacceptable, the other members are unacceptable too.

Assumption 3 *All the family members have the same preferences over countries and the same priority order. In addition, they all must be allocated within the same country, otherwise, the allocation will not proceed.*

Assumption 4 *All the family members are acceptable for a country if just one of them is acceptable. The same happens if one member is unacceptable for a country.*

Thanks to these assumptions, families can be introduced in the model with acceptability. However, the YRMH - IGYT needs to be slightly modified to allow for this characteristic.

Whenever it is the turn of a family, the set of remaining quotas that accept the family is constrained to the set of acceptable countries plus the set of countries for which there exist, at least, enough quotas to host all family members. At that point:

- If there exists, at least, one country with enough quotas, the family is assigned to that country (in order of preference according to the preference relation of the family over countries).

- If there are no countries with enough vacant quotas to host the whole family, that family remains unmatched and the procedure jumps to the next family or individual, following the priority order.

Whenever the quotas of an existing family are demanded, proceed in the same way as YRMH - IGYT proceed with individuals. That is, all the family members go to the top of the line.

5.4 Type-specific quotas

If politicians want to give different ranks to different groups, these groups may be simply ordered first in the priority list ψ. However, another plausible way to implement this characteristic in the model is by the use of type-specific quotas[27]. That is, countries can reserve a determined amount of quotas for specific groups of refugees. This context seems to be similar to the resettlement scheme, since acceptable refugees for resettlement processes are only those considered at risk[28].

Let Q_S be the set of type-specific quotas, so that the new set of quotas is given by $Q = Q_O \cup Q_V \cup \phi \cup Q_S$.

In order to ensure the correct functioning of the algorithm, I need to introduce the following three conditions:

1. If a non-specific refugee is pointing to a reserved quota, this refugee cannot be assigned to that quota. On the contrary, if a priority refugee points to an unreserved quota, she can be assigned to it.

2. Occupied quotas cannot be part of the set of type-specific quotas.

[27]This sort of quotas are typical from Controlled School Choice models (see Abdulkadiroglu & Sönmez, (2010), and Echenique & Yenmez (2015)).

[28]For instance, Denmark leaves 75 places free for those refugees who are at immediate risk of refoulement, Norway leaves 60% of their quota for women and girls at risk, and Sweden leaves 250 quotas for a non-targeted pool of people as a way to respond to unforeseen crisis.

3. Reserved quotas should always respect the binary preferences of a given country.

The first condition is needed to guarantee that reserved quotas achieve its purpose. For instance, imagine that priority refugees can just be assigned to reserved quotas and that these reserved quotas are the least preferred to them. Then, priority refugees will end up with an assignment that is worse than the assignment that would be achieved if this first condition holds.

The second condition is important to ensure the individual rationality of the final matching. If occupied quotas could be granted to type-specific refugees, existing tenants may be eventually assigned to a quota that is worse than their endowment.

The third condition is necessary to ensure that both acceptability and type-specific quotas can be added simultaneously to the model.

Because the only condition to assign families to a country is that all of their members are in the same country, type-specific quotas may be implemented with families without further assumptions.

6 Fitting the Dynamic Deferred Acceptance to the reality of the Syrian crisis

I discuss in this section the assumptions and modifications that are needed to ensure the correct functioning of the Dynamic Deferred Acceptance. As it will be reviewed, all the modifications introduced in the YRMH - IGYT algorithm can now be introduced in the new mechanism, ,with exception of the binary preference relations, which is implicitly defined in the case of two-sided matching mechanisms.

6.1 The temporal dimension

As it has been already discussed, the refugee problem is inherently a dynamic one, and therefore, the original Deferred Acceptance does not fit its reality. This problem arises because refugees that has already been assigned under other mechanisms should be provided with the possibility to achieve a better matching, according to a sense of fairness. Thus, preferences for both refugees and countries depend on previous assignments. For instance, it is easy to see that countries would prefer a refugee that has already been hosted rather than a newcomer because already assigned refugees are more likely to have a job, to have created social links, or even to know the language. The same can also be true for refugees. This situation does not fit the static environment of the Deferred Acceptance, which could be appropriate for dynamic contexts where preferences are independent so that the only temporal component comes from the repetition of the same algorithm for different periods of time.

Given this situation, it is necessary to specify a rule for the property rights since, as Kennes et al. (2016) comment: *"in markets in which priorities of one side depend on previous allocations, there might be opportunities for manipulation that do not exist in static matching problems"*. In line with this, Pereyra (2013), Kennes et al. (2014) and Dur (2011) show that the period-by-period Deferred Acceptance mechanism generates stable matchings. Nevertheless, it seems that the final matching is also manipulable because of the opportunities that arose given the history-dependence of past assignments. Another kind of history-dependence is given by the "Danish priorities". Under this scenario, an agent that was eligible to participate in previous allocation but did not participate has now higher priority than those agents that were eligible and participated in the assignment process[29].

Fortunately, Kennes et al. (2016) demonstrate that the incentives to lie for the Deferred Acceptance mechanism in dynamic settings vanish as the

[29]For more information about how manipulable is the Deferred Acceptance in this dynamic scenario see example 1 and 2 from Kennes el at. (2016).

market size increases if preferences are only based on property rights. On the contrary, if preferences depend on previous allocations following other rules different than respecting incumbents, for instance the Danish priorities discussed above, the Deferred Acceptance in dynamic environments remains manipulable even in large markets.

In order to allow for the temporal dimension I provide a new definition of matching for each of the t periods following Kennes et al. (2016).

A period-t matching at any $t \geq 0$, μ_t exists if

1. For all $r \epsilon R_{t-1} \cup R_t$, $|\mu_t(r)| = 1$ and $\mu_t(r) \subset C$, which means that refugees in any period of time can only be allocated to one quota.

2. For all $c \epsilon C$, $|\mu_t(c)| \leq q^c$ and $\mu_t(c) \subset R_{t-1} \cup R_t$, which means that countries cannot exceed their capacity.

3. For all $r \epsilon R_{t-1} \cup R_t$, $r \epsilon \mu_t(c)$ iff $c \epsilon \mu_t(r)$, which means that the matching of one side can only be possible if they coincide with the matching of the other side.

A matching μ is a collection of period matchings: $\mu = (\mu_t)_{t=1}^{\infty}$.

Additionally, I need to state as (c_i, c_j), where $i, j \epsilon \{1,...,N\}$, the final allocation for a refugee that has a matching in two different periods. Preferences are such that all the refugees have an underlying ranking over countries that is stable over time. I also assume, in line with Kennes et al. (2016), that there might be complementarities from being assigned to the same country consecutively. Thus, being assigned to c_2 two different periods would be better than being assigned to c_1 and c_3 if refugee's best second choice is c_2. However, in order to allow for the stability of the final matching, as it will be discussed below, complementarities must be avoided. This condition is formalized in assumptions 4 and 5.

Assumption 5 *Rankability (Assumption 1 in Kennes et al. (2016)). If* $(c_1, c_1) \succ_r (c_2, c_2)$ *for some* r, c_1 *and* c_2, *then* $(c_1, c_3) \succ_r (c_2, c_3)$ *and* $(c_3, c_1) \succ_r (c_3, c_2)$ *for any* $c_3 \neq c_2$.

There are two main aspects covered by the definition of rankability. First, each refugee ranks single countries, not pairs. Second, there exist switching costs that refugees care about. According to this previous assumption, refugees prefer to be assigned to a superior country for at least one period than being assigned to an inferior country for two consecutive periods. Consequently, complementarities are not a best choice unless the pair is formed by the best possible country for the two consecutive periods[30].

In addition to rankability, it is necessary to introduce the concept of "Isolated preferences".

Assumption 6 *Isolated Preferences (Definition 3 in Kennes et al. (2016)). For any given period* $t \geq 1$, *and for a given matching* μ_{t-1}, *the isolated preference relation of period* t, $P_r(\mu_{t-1})$ *is a binary relation satisfying*

1. $\forall r \epsilon R_t : c_1 P_r(\mu_{t-1}) c_2$ *if and only if* $(c_1, c_1) \succ_r (c_2, c_2)$ *for any* $c_1 \neq c_2 \, \epsilon C$.
2. $\forall r \epsilon R_{t-1} : c_1 P_r(\mu_{t-1}) c_2$ *if and only if* $(\mu_{t-1}(r), c_1) \succ_r (\mu_{t-1}(r), c_2)$ *for any* $c_1 \neq c_2 \, \epsilon C$.

The basic idea behind these two assumptions is to restrict refugees' preferences to the period in which the matching is taking place.

Finally, it would be required to define countries' preferences in such a way that Danish priorities are not considered. Before going through this assumption, I will provide some notation: if at period t refugee r_1 is preferred by a country c than refugee r_2 given the previous assignment in $t-1$, then $r_1 \succ_c^t (\mu_{t-1}) r_2$.

[30] The absence of complementarities between inferior countries is a necessary condition for the Dynamic Deferred Acceptance to find stable matchings, though it is not a reality of the refugee problem and in that sense matching theory does not perfectly fit the problem.

Assumption 7 *Independence of Past Attendance (Definition 2 in Kennes et al. (2014)). Countries' priorities satisfy the Independence of Past Attendance assumption if the following conditions are satisfied.*

1. *Consistency of different period rankings. If* $r_1 \succ_c^{t-1} (\mu_{t-2})r_2$ *for some* r_1, $r_2 \epsilon R$, $c \epsilon C$ *and* μ, *then* $r_1 \succ_c^t (\mu_{t-1})r_2$ *if either* $\mu^{t-1}(r_1) = \mu^{t-1}(r_2) = c$ *or* $\mu^{t-1}(r_2) \neq c$.

2. *Irrelevance of previous assignments. If* $r_1 \succ_c^t (\mu^{t-1})r_2$ *for some* r_1, $r_2 \epsilon R$, $c \epsilon C$ *and* μ *with* $\mu^{t-1}(r_1) \neq c$ *and* $\mu^{t-1}(r_2) \neq c$, *then* $r_1 \succ_c^t (\nu^{t-1})r_2$ *for any* ν *satisfying either* $\nu^{t-1}(r_1) = \nu^{t-1}(r_2) = c$, *or* $\nu^{t-1}(r_2) \neq c$.

3. *Irrelevance of different age. If* $r_1 \succ_c^t (\mu^{t-1})r_2$ *for some* $r_1 \epsilon R_{t-1}$, $r_2 \epsilon R_t$, $c \epsilon C$ *and* μ *with* $\mu^{t-1} \neq c$, *then* $r_1 \succ_c^t (\nu^{t-1})r_2$ *for all* ν. *In addition, if* $r_2 \succ_c^t (\mu^{t-1})r_1$ *for some* $r_1 \epsilon R_{t-1}$, $r_2 \epsilon R_t$, $c \epsilon C$ *and* μ *with* $\mu^{t-1}(r_1) \neq c$, *then* $r_2 \succ_c^t (\nu^{t-1})r_1$*for all* ν *with* $\nu^{t-1}(r_1) \neq c$.

According to the first condition, a refugee who is preferred for a given country than other in a previous period will still be preferred in future periods if either the former was assigned to this same country or if the latter was not matched to that country in the previous period. The second condition states that a refugee that is more preferred than other will still be preferred regardless of previous matchings. The third condition means that the age of the refugees does not matter in any way to determine the final assignment. Additionally, it states that the only possibility for a younger refugee to be preferred by a country than other older refugee is when the latter was not assigned to that country so that there are no property rights.

The Dynamic Deferred Acceptance mechanism described in Kennes et al. (2016) -Deferred Acceptance using Isolated Preferences, proceeds as follows:

Period-0 *assignment. Set the isolated preferences for each refugee in this period.*

- *Round 1. Each refugee of period 0 applies to her most preferred country according to her isolated preferences. Each country then holds the maximum pool of applicants possible given its capacity and reject all others.*

- *Round k. Each refugee whose application was rejected in the previous round applies to her most preferred country that has not rejected her. Each country considers the pool of applicants composed of the new applicants and the refugees whose application has been held in the previous round. Each country then holds the maximum most preferred refugees of the pool and reject all others.*

The algorithm terminates when no proposal is rejected and each refugee is assigned a final matching..

Period-t *assignment. Set the isolated preferences for each refugee in this period. Now use the same algorithm used in period-0 to determine the final outcome.*

Once I have stated the way in which the DA-IP proceeds, it is necessary to introduce the dynamic concept of stability in dynamic settings, which is the most important feature of two-sided matchings. As a first notion, Kennes et al. (2014) introduce the concept of "autarkic stability", which refers to a situation where there exists at least one blocking pair. Added to this definition, the concept of stability in a dynamic environment exists whenever autarkic stability holds together with the following condition based on definition 8 from Kennes et al. (2014):

Definition 1 *Matching μ is stable if it satisfies autarkic stability and at any period $t \geq 1$, there does not exist a triplet (c_1, c_2, r_1) such that $(c_1, c_2) \succ_{r_1} (\mu^t(r_1), \mu^{t+1}(r_1))$, for $c_1 \neq \mu^t(r_1)$, $c_2 \neq \mu^{t+1}(r_1)$ and one of the following condition holds:*

1. $|\mu^t(c_1)| < q_{c_1}$ *and* $|\mu^{t+1}(c_2)| < q_{c_2}$,

2. $|\mu^t(c_1)| < q_{c_1}$, $|\mu^{t+1}(c_2)| = q_{c_2}$ *and, for some* $r_3 \epsilon \mu^{t+1}(c_2)$, $r_1 \succ_{c_2}^{t+1} (\mu^t) r_3$,

3. $|\mu^t(c_1)| = q_{c_1}$, $|\mu^{t+1}(c_2)| < q_{c_2}$ *and, for some* $r_2 \epsilon \mu^t(c_1)$, $r_1 \succ_{c_1}^{t} (\mu^{t-1}) r_2$,

4. $|\mu^t(c_1)| = q_{c_1}$, $|\mu^{t+1}(c_2)| = q_{c_2}$ *and, for some* $r_2 \epsilon \mu^t(c_1)$, $r_3 \epsilon \mu^{t+1}(c_2)$, $\left| r_1 \succ_{c_1}^{t} (\mu^{t-1}) r_2 \right|$ *and* $r_1 \succ_{c_2}^{t+1} (\mu^t) r_3$.

As it can be noticed, stability in a dynamic context is a more complete version of autarkic stability, where both matchings can be improved for a given refugee given a situation where there exist blocking pairs in some or both period.

Insofar as the Independence of Past Attendance assumption is respected, the matching yielded by the dynamic version of the Deferred Acceptance is stable. Unlike the YRMH - IGYT mechanism, the Dynamic Deferred Acceptance is not strategy-proof in its original setting. The impossibility of truth-telling is demonstrated in Kennes et al. (2014) and illustrated in the following example.

Example 8 ***Strategy-proofness is not always possible in dynamic settings of the Deferred Acceptance algorithm.***

Let r_1 *and* r_2 *be refugees born in* $t = 1$ *and refugee* r_3 *be a refugee born in the next period* $t = 2$. *Additionally, there exist two countries in* $t = 1$, c_2 *and* c_3; *in* $t = 2$ *one more country is added,* c_1. *Preferences are described below:*

$r_1 \succ$: c_1, c_2, c_3

$r_2 \succ$: c_3, c_1, c_2

$r_3 \succ$: c_3, c_1, c_2

$c_1 \succ$: r_3, r_1, r_2

$c_2 \succ$: r_1, r_3, r_2

$c_3 \succ$: r_1, r_3, r_2

According to these preferences, the matching for both periods is obtained following these steps:

Period 1 (round 1):

- r_1 *points to* c_2*, which also prefer this refugee.*
- r_2 *demands a quota in* c_3*, and since* r_1 *can be assigned in* c_2*, the assignment proceeds.*

Period 2 (round 1):

- r_1 *demands a quota in* c_1*, but this country prefers* r_3*, so the assignment is held.*
- r_2 *wants a matching in* c_3*, where she has her endowment.*
- r_3*wants a matching in* c_3*, but is rejected since that country prefers* r_2*.*

Period 2 (round 2):

- r_3*wants a matching in* c_1*, where she is the most preferred choice. Therefore,* r_1 *is displaced from this country.*

Period 2 (round 3):

- r_1 *points to* c_2*, where she has her endowment.*

Therefore, the final matchings for both periods are:
$\mu_{t=1} = \begin{pmatrix} r_1 & r_2 \\ c_2 & c_3 \end{pmatrix}$; $\mu_{t=2} = \begin{pmatrix} r_1 & r_2 & r_3 \\ c_2 & c_3 & c_1 \end{pmatrix}$.
Nevertheless, if r_1 *changes her preferences to* $r_1 \succ: c_1, c_3, c_2$*, the new matching for both periods would be different:*

Period 1 (round 1):

- r_1 *points to* c_3*, which also prefer this refugee.*

- *r_2 demands a quota in c_3, but this country prefers r_1.*

Period 1 (round 2):

- *r_2 demands a quota in c_2, where she is assigned.*

Period 2 (round 1):

- *r_1 demands a quota in c_1, but this country prefers r_3, so the assignment is held.*
- *r_2 wants a matching in c_3, but this country prefers r_1.*
- *$r_3$wants a matching in c_3, but this country prefers r_1. Nevertheless, the matching is held since for c_3, r_3 is more preferred than r_2.*

Period 2 (round 2):

- *r_2 now points to c_1, but the country prefers to keep held r_1.*

Period 2 (round 3):

- *$r_2$demands a quota in c_2, where she has her endowment.*

Period 2 (round 4):

- *Because both r_1 and r_3 are held by the countries that prefer the other refugee, the matching is released so that each refugee gets her most preferred country.*

$\mu_{t=1}^{'} = \begin{pmatrix} r_1 & r_2 \\ c_3 & c_2 \end{pmatrix}$; $\mu_{t=2}^{'} = \begin{pmatrix} r_1 & r_2 & r_3 \\ c_1 & c_2 & c_3 \end{pmatrix}$.

Thus, $\mu^{'}(r_1) = (c_3, c_1) \succ_{r_1} \mu(r_1) = (c_2, c_2)$. This way, placing a less preferred country as best preference can trigger a sequence by which a refugee can obtain a better matching in future periods.

Fortunately, the previous example was describing a situation where agents were to be matched to schools, not to European countries. Therefore, the situation where new countries join to the setting in future periods is not as likely as in the case of schools. Consequently, it is realistic not to get this rupture of the strategy-proofness when using the Dynamic Deferred Acceptance in the context of the Syrian refugee crisis.

Proposition 1 *If no countries are added to the mechanism once it was started, the final matching is strategy-proof.*

6.2 Refugees are assigned to quotas

As in the case of the previous mechanism, the introduction of quotas significantly alters how the mechanism works. Thus, I need to modify the algorithm in order to allow for the existence of these quotas:

Each country definitively accepts as many refugees as they can admit given their quota limit. If a refugee points to a country where she is at least as preferred as the last refugee that it can admit, this refugee is definitively assigned to that country even if there exist other refugees that are more preferred that are not assigned yet. Additionally, each country will hold the next most preferred refugee that exceeds its quota limit whenever there still exist unfilled slots within that country.

This statement is true since given the deferred nature of the assignments under this mechanism, every refugee that is most preferred for a country than a refugee that is already matched can be always matched in following rounds because there always be remaining quotas granted for them. In case these most preferred refugees are definitively matched to other countries, the quotas that are still free in other countries can still be matched to other new refugees that will now be the most preferred ones.

Because tenants choose to participate only if they are willing to give up their quota[31], the differences between types of quotas does not exist when the algorithm starts to work. Therefore, all the quotas will be assigned randomly as though they all were vacant quotas.

Example 9 below shows how the Dynamic Deferred Acceptance works with the introduction of quotas.

Example 9 ***Introduction of quotas in the Dynamic Deferred Acceptance.***

There exist two existing tenants, $R^E : \{r_1^e, r_2^e\}$*, and two newcomers,* $R^N : \{r_3^n, r_4^n\}$ *in the first period. There are two countries with two quotas each,* $C : \{c_1, c_2\}$*. Preferences are the following:*

$$\begin{aligned} r_1^e &\succ: c_1, c_2 \\ r_2^e &\succ: c_2, c_1 \\ r_3^n &\succ: c_2, c_1 \\ r_4^n &\succ: c_2, c_2 \\ c_1 &\succ: r_1^e, r_3^n, r_4^n, r_2^e \\ c_2 &\succ: r_2^e, r_1^e, r_4^n, r_3^n \end{aligned}$$

In the second period there are two more refugees, r_5^n*, who prefers* c_2 *over* c_1*, and* r_6^n*, who prefers* c_1 *over* c_2*. In addition, countries add one more quota to their capacity. Country preferences are now:*

$$\begin{aligned} c_1 &\succ: r_1^e, r_3^n, r_5^n, r_6^n, r_4^n, r_2^e \\ c_2 &\succ: r_2^e, r_1^e, r_6^n, r_5^n, r_4^n, r_3^n \end{aligned}$$

Period 1 (round 1):

[31]The reason why property rights need to be included for tenants is because they have to give up their quota at the beginning of the process, and therefore, they can get an assignment that is worst than their previous endowment, violating individually rationality and making it more difficult for tenants to participate in the mechanism.

- *r_1^e points to c_1, where she has her endowment.*
- *r_2^e demands a quota in c_2, where she has her endowment.*
- *r_3^n wants a quota in c_2, which has only one available slot. Because r_4^n is more preferred, c_2 holds r_3^n.*
- *r_4^n wants a quota in c_2, which has one held position. Because r_4^n is more preferred, c_2 displaces r_3^n in favour of r_4^n.*

Period 1 (round 2):

- *r_3^n is assigned to c_1, which is the only country with available quotas. All previous assignments that were tentative become definitive now that all refugees have an assignment.*

The final matching in period 1 is:

$$\mu_{t=1}^{DDA} = \begin{pmatrix} r_1^e & r_2^e & r_3^n & r_4^n \\ c_1 & c_2 & c_1 & c_2 \end{pmatrix}$$

Period 2 (round 1):

- *All previously assigned refugees are now existing tenants in the countries where they have now their owned quota. Therefore, country preferences change accordingly:*

$$c_1 \succ: r_1^e, r_3^n, r_5^n, r_6^n, r_4^n, r_2^e$$
$$c_2 \succ: r_2^e, r_4^n, r_1^e, r_6^n, r_5^n, r_3^n$$

- *r_1^e points to c_1, where she has her endowment.*
- *r_2^e demands a quota in c_2, where she has her endowment.*
- *r_3^e wants a quota in c_2. Because there are only two quotas left in that country and r_3^e is the fourth preference, c_2 holds the assignment tentatively.*

- *r_4^e wants a quota in c_2, where she has her endowment. r_3^e remains tentatively held in c_2 since there still exist one more uninhabited quota in that country.*

- *r_5^n wants a quota in c_2, where she has more preference than r_3^e. Therefore, the former is now tentatively held in this country (because c_2 prefers r_6^n over r_5^n), while r_3^e is rejected.*

- *r_6^n wants a quota in c_1, where there are still two unassigned quotas. Because r_3^e and r_5^n do not have a final matching yet and are preferred in c_1 over r_6^n, this country tentatively holds r_6^n.*

Period 2 (round 2):

- *r_3^e demands a quota in c_1, where she has her endowment. r_6^n remains tentatively held by c_1 since there is still one more quota left in that country.*

- *Because both r_5^n and r_6^n are tentatively held in their most preferred countries, this tentative assignments become definitive.*

Therefore, the final matching in period 2 is:

$$\mu_{t=2}^{DDA} = \begin{pmatrix} r_1^e & r_2^e & r_3^e & r_4^e & r_5^n & r_6^n \\ c_1 & c_2 & c_1 & c_2 & c_2 & c_1 \end{pmatrix}$$

Proposition 2 *The final matching generated by the dynamic Deferred Acceptance algorithm when refugees are assigned to quotas rather than to countries is stable and strategy-proof in large markets.*

Proof. A refugee will be matched to a given quota within a country only if that refugee could also be assigned to that country if there would not exist quotas. Therefore, neither the introduction of the quota counter, nor the fact that refugees are assigned to indifferent quotas disturb in any sense the final outcome provided by this setup. ■

6.3 Families

A family $f_i = \{r_{1,i}, r_{2,i}, ..., r_{f,i}\}$ is a group of f individuals who have exactly the same priority and preferences, as commented above. These two conditions are still necessary in order to ensure the correct functioning of the matching mechanism, in this case the dynamic deferred acceptance.

Assumption 8 *All the family members have the same preferences over countries and all countries have the same preference over each refugee that belongs to the same family*[32]*. In addition, they all must be allocated within the same country, otherwise, the allocation will not proceed.*

Assumption 9 *All the family members are acceptable for a country if just one of them is acceptable. The same happens if one member is unacceptable for a country.*

Assumption 10 *Every country is acceptable for a given family if just one of the members accepts that country.*

Assumption 11 *Families are never preferred over existing tenants for those countries that host these tenants.*

Thanks to these four assumptions, families can be introduced in the Dynamic Deferred Acceptance mechanism. Nevertheless, the algorithm needs to be modified in order to allow for this new feature.

Whenever it is the turn of a family, the set of remaining quotas that accept the family is constrained to the set of countries for which there exist, at least, enough quotas to host all family members. At that point:

[32]According to this, I define a new type of preference relation that is "vertical" in the sense that all the family members have the same rank and cannot be ordered. For instance, let $c_1 \succ r_1, r_2, \underset{r_5}{\overset{r_3}{r_4}}, r_6$ be the preferences of country 1 over six refugees, where r_3, r_4, r_5 belong to the same family.

- If there exists, at least, one country with enough quotas, the family is assigned to that country (in order of preference according to the preference relation of the family over countries).
- If there are no countries with enough vacant quotas to host the whole family, that family remains unmatched and the procedure jumps to the next family or individual, following the priority order.

Example 10 shows how the the Dynamic Deferred Acceptance works with the introduction of families.

Example 10 ***Introduction of families in the Dynamic Deferred Acceptance setup.***

The setup of this exercise is exactly the same as in the previous example but with the introduction of a family of two newcomers in period 2, $F : \{r_7^n, r_8^n\}$ *that prefers* c_2 *over* c_1*. Each country has now four quotas.*

As in the previous setting, he final matching in period 1 is:

$$\mu_{t=1}^{DDA} = \begin{pmatrix} r_1^e & r_2^e & r_3^n & r_4^n \\ c_1 & c_2 & c_1 & c_2 \end{pmatrix}$$

Country preferences in period 2 are now:

$$c_1 \succ: \ r_1^e, r_3^n, r_5^n, r_6^n, r_4^n, r_2^e, \begin{matrix} r_7^n \\ r_8^n \end{matrix}$$

$$c_2 \succ: \ r_2^e, r_4^n, \begin{matrix} r_7^n \\ r_8^n \end{matrix}, r_1^e, r_6^n, r_5^n, r_3^n$$

Period 2 (round 1):

- r_1^e *points to* c_1*, where she has her endowment.*
- r_2^e *demands a quota in* c_2*, where she has her endowment.*

- *r_3^e wants a quota in c_2. Because there are only three quotas left in that country and r_3^e is the seventh preference, c_2 holds the assignment tentatively.*

- *r_4^e wants a quota in c_2, where she has her endowment. r_3^e remains tentatively held in c_2 since there still exist two more uninhabited quotas in that country.*

- *r_5^n wants a quota in c_2, where she has more preference than r_3^e. Therefore, the former is now tentatively held to this country (because c_2 prefers r_6^n over r_5^n), while r_3^e is rejected.*

- *r_6^n wants a quota in c_1, where there are still two unassigned quotas. Because r_3^e and r_5^n do not have a final matching yet and are preferred in c_1 over r_6^n, this country tentatively holds r_6^n.*

- *r_7^n demands a quota in c_2, where there are still two uninhabited quotas. Because both r_7^n and r_8^n are more preferred than r_5^n, r_7^n is tentatively assigned to c_2 until her relative is also assigned a quota in that country.*

- *r_8^n demands a quota in c_2. Thus, the family is assigned to that country, displacing r_5^n.*

Period 2 (round 2):

- *r_3^e, who was rejected by c_2 in the previous round, now demands a quota in c_1, where she has her endowment.*

- *r_5^n demands a quota in c_1. Because c_1 has still two unfilled quotas, r_5^n is assigned to that country.*

- *Similarly, r_6^n, who had a tentative assignment in c_1, is assigned to that country because there is still one available quota.*

The final matching of this setup with families in period 2 is:

$$\mu_{t=2}^{DDA} = \begin{pmatrix} r_1^e & r_2^e & r_3^e & r_4^e & r_5^n & r_6^n & r_7^n & r_8^n \\ c_1 & c_2 & c_1 & c_2 & c_1 & c_1 & c_2 & c_2 \end{pmatrix}$$

Proposition 3 *The final outcome generated by the Dynamic Deferred Acceptance algorithm when families are included in the setup is stable.*

Proof. The only possible scenario where families cannot be included in a certain country is when that country has not enough quotas to host the hold family even when some of their members could have been matched. Therefore stability can never be broken by families because one pre-condition for stability stated before is that countries should have enough quotas after the algorithm has concluded. ■

Proposition 4 *The final outcome generated by the Dynamic Deferred Acceptance algorithm when families are included in the model is strategy proof if no countries are added to the mechanism once it was started.*

Proof. Because families always respect the property rights of the existing tenants, they cannot create a situation where they displace the latter from being the most preferred refugees for the country that host them. ■

6.4 Type-specific quotas

Type-specific quotas are defined in exactly the same way as did before. In order to introduce them in the algorithm of the Dynamic Deferred Acceptance, I need to state the following conditions:

1. If a non-specific refugee is pointing to a reserved quota, this refugee cannot be assigned to that quota. On the contrary, if a priority refugee points to an unreserved quota, she can be assigned to it.

2. Although there are not occupied quotas when the algorithm starts because tenants give them up at the beginning, special refugees can never have a higher preference than existing tenants in countries where the latter had their quota in previous rounds.

3. Reserved quotas should always respect the binary preferences of a given country.

Because the only condition to assign families to a country is that all of their members are in the same country, type-specific quotas might be implemented with families without further assumptions.

The following example shows how the Dynamic Deferred Acceptance works when type-specific quotas are introduced.

Example 11 ***Introducing type-specific quotas in the Dynamic Deferred Acceptance model.***

In the case of this example, the setup is exactly the same as in example 11, but we add a new special refugee in period 2, r_9^s, who is a newcomer and is the least preferred refugee for each country. Additionally, she prefers the first country over the second. Finally, the second country has now one more quota, which is type-specific.

As in the previous setting, he final matching in period 1 is:

$$\mu_{t=1}^{DDA} = \begin{pmatrix} r_1^e & r_2^e & r_3^n & r_4^n \\ c_1 & c_2 & c_1 & c_2 \end{pmatrix}$$

Country preferences in period 2 are now:

$$c_1 \succ: r_1^e, r_3^n, r_5^n, r_6^n, r_4^n, r_2^e, \begin{matrix} r_7^n \\ r_8^n \end{matrix}, r_9^s$$

$$c_2 \succ: r_2^e, r_4^n, \begin{matrix} r_7^n \\ r_8^n \end{matrix}, r_1^e, r_6^n, r_5^n, r_3^n, r_9^s$$

Period 2 (round 1):

- *All previous steps from example 10 remains the same.*
- r_9^s *demands a quota in* c_1*, where she is rejected since this country has already one held refugee which is more preferred.*

Period 2 (round 2):

- r_3^e*, who was rejected by* c_2 *in the previous round, now demands a quota in* c_1*, where she has her endowment.*
- r_5^n *demands a quota in* c_1*. Because* c_1 *has still two unfilled quotas,* r_5^n *is assigned to that country.*
- *Similarly,* r_6^n*, who had a tentative assignment in* c_1*, is assigned to that country because there is still one available quota.*
- r_9^s *demands a quota in* c_2*, where there exists a type-specific quota.*

The final matching of this setup with type-specific quotas is:

$$\mu_{t=2}^{DDA} = \begin{pmatrix} r_1^e & r_2^e & r_3^e & r_4^e & r_5^n & r_6^n & r_7^n & r_8^n & r_9^s \\ c_1 & c_2 & c_1 & c_2 & c_1 & c_1 & c_2 & c_2 & c_2 \end{pmatrix}$$

Proposition 5 *The final outcome generated by the Dynamic Deferred Acceptance type-specific quotas is not stable*[33]*.*

[33] A possible way to force the mechanism to be stable is by giving the special refugees the maximum preference in every country, with the exception of tenants in the countries where they have their owned quota. This way, it could never be the case that a special refugee less preferred by a given country is occupying the quota that this same country would have used to shelter another ordinary refugee that is more preferred. However, this situation where countries are forced to prefer type-specific refugees violates the definition of a preference relation with which countries can individually decide an order to assign refugees. As a possible solution to this, it could be possible to create a setup where countries have tenants as their first preference, then they have an imposed priority order for all type-specific refugees, and finally a preference relation for all ordinary refugees.

Proof. It could be the case that a special refugee takes the place of a normal refugee who was rejected by a country where she was more preferred but that had only special quotas unfilled, as it is shown in the following example. ■

Example 12 ***Instability when type-specific quotas are added to the mechanism.***

There exist three refugees $R : \{r_1, r_2, r_3^s\}$ *and three countries* $C : \{c_1, c_2, c_3\}$ *with one quota each. Country* c_2 *has a type-specific quota. Preferences are the following:*

$$r_1 :\succ c_1, c_2, c_3$$
$$r_2 :\succ c_2, c_1, c_3$$
$$r_3 :\succ c_2, c_1, c_3$$
$$c_1 :\succ r_1, r_2, r_3^s$$
$$c_2 :\succ r_2, r_1, r_3^s$$
$$c_3 :\succ r_1, r_3^s, r_2$$

When r_2 *demands a position in* c_2*, this country must reject her because it only has a type-specific quota available. In consequence,* r_2 *is displaced to other less preferred country, while the special refugee is assigned to a country that prefers the other refugee. Therefore, the final unstable matching would be:*

$$\mu = \begin{pmatrix} r_1 & r_2 & r_3^s \\ c_1 & c_3 & c_2 \end{pmatrix}$$

Proposition 6 *The final outcome generated by the Dynamic Deferred Acceptance with families and type-specific quotas is not stable.*

Proof. As it was shown before, if at the end of the mechanism one special refugee is occupying a quota that is more preferred by any other refugee who is more preferred by that country than the special refugee, the final matching does not meet all the requirements to be stable. Additionally, as example 13 shows below, families facilitate the presence of this kind of instability. ■

Example 13 ***Instability when type-specific quotas alongside with families are added to the Dynamic Deferred Acceptance setup.***

There exist five refugees and two countries with three quotas each of which one is reserved to special refugees. The three first refugees are a family, and the fourth refugee is a special refugee. Preferences are as follow:

$$\begin{array}{rc} r_1 \succ: & c_1, c_2 \\ r_2 \succ: & c_1, c_2 \\ r_3 \succ: & c_{1,2} \\ r_4 \succ: & c_1, c_2 \\ r_5 \succ: & c_1, c_2 \end{array}$$

$$c_1 \succ: \begin{array}{c} r_1 \\ r_2 \ , r_5, r_4 \\ r_3 \end{array}$$

$$c_2 \succ: \begin{array}{c} r_1 \\ r_4, r_5 r_2 \ . \\ r_3 \end{array}$$

Because r_4 has her quota granted by her condition of special refugee, she displaces the family to other less preferred country. Thus, the final matching is:

$$\mu_1^{DDA} = \begin{pmatrix} r_1 & r_2 & r_3 & r_4 & r_5 \\ c_2 & c_2 & c_2 & c_1 & c_1 \end{pmatrix}$$

Nevertheless, this matching violates stability because the family could have been hosted in the first country, which actually prefers to host the family than its current assignment. In the absence of type-specific quotas, the final and stable matching would be:

$$\mu_2^{DDA} = \begin{pmatrix} r_1 & r_2 & r_3 & r_4 & r_5 \\ c_1 & c_1 & c_1 & c_2 & c_2 \end{pmatrix}$$

which is also preferred by the countries.

Proposition 7 *The final outcome generated by the Dynamic Deferred Acceptance when type-specific quotas are added to the model is strategy-proof if no countries are added to the mechanism once it was started.*

Proof. Because special refugees always respect the property rights of the existing tenants, they cannot create a situation where they displace tenants from being the most preferred refugees for the country that host them. ■

7 The Experiment

In 2002 Sönmez and Chen proved, by means of an experiment, that the TTC is more efficient and a has higher participation rate than the RSD (78.8% vs. 46.9%), though for both mechanisms the rate of truthful preference revelation is statistically the same. In line with this research, Guillen and Kesten in 2012 decided to study the prevalence of the TTC against the Deferred Acceptance. Although in theory the DA is not Pareto-efficient for the House Allocation with Existing Tenants model, the experiment proved that this mechanism outperformed the TTC in terms of both efficiency and participation rates (77.5% vs. 47.5%).

In the spirit of these two experiments I carried out a very similar one. Unfortunately, I did not get as many answers as it would be necessary to perform the whole task, though I obtained enough to get some insights about the behavior of the YRMH - IGYT and the Dynamic Deferred Acceptance in the Syrian crisis context.

This pilot experiment is designed so that there are groups of 20[34] refugees, of which the first ten are existing tenants and the rest are newcomers. The

[34]In the original experiments, groups were formed by 12 refugees. However, since I need to include families in the setup, I need to use larger groups, which is an additional difficulty in getting a big sample.

existing tenants have their quota in one of the ten countries that exist in this setup, each of them with two available quotas except countries #9 and #10, which have only one slot. This way, refugee r_1 has her quota in c_1, refugee r_2 has her quota in c_2, and so on. Unlike the original experiments, the priority ordering of refugees is predetermined before the start of the experiment and is hidden knowledge for the players. Likewise, in the context of the second mechanism, it is explained that instead of a priority order, there is a group of preference relations for each country that is also hidden knowledge for the players. In consequence, there is one unique outcome with the desirable properties that is achieved only if players respect the induced preferences for each of the refugee that is assigned to them. This induced preferences are based on a monetary payoff[35] that would be delivered to the players depending on their final matching[36]. Refugees only know their induced preferences, which are shown in table 1. The paper with the instructions for the experiment, and an example of the document containing the exercise for the first refugee, is included in section D of the appendix.

Even though I did not restrict the time that players could spend doing the experiment since I was not present conducting sessions, I recommended not to spend much more than half an hour.

The original experiments were conducted in different sessions with university students that were paid accordingly to a payoff scheme similar to what is described above. However, I did not have these means to carry out the experiment so that I needed to distribute the questionnaire via email. I obtained 80 answers out of roughly 120 sent questionnaires. These answers

[35]The most preferred country pays the player $20 if she ends up assigned there. The least preferred country pays $2 if she ends up assigned there. Thus, players lose $2 for each preferred country where they fail to be assigned.

[36]Since I did not have monetary resources to pay money to the players, the experience and incentives of the reported preferences may be different than what would have been in the case that the money was real. One could expect higher rates of risk aversion in order to get at least some money. Nevertheless, the risk aversion in the present experiment turned out to be high.

do not cover more than one full group of 20 refugees. In consequence, I could not get a proper sample[37] to evaluate the efficiency of both mechanisms, though I have enough answers to individually gather some conclusions about the results of the experiment.

Table 1. *Induced preferences for all the players.*

Role	Induced Preferences									
Refugee #1	c_1	c_2	c_3	c_4	c_5	c_6	c_7	c_8	c_9	c_{10}
Refugee #2	c_1	c_2	c_3	c_4	c_5	c_6	c_7	c_8	c_9	c_{10}
Refugee #3	c_3	c_2	c_5	c_8	c_6	c_9	c_7	c_4	c_1	c_{10}
Refugee #4	c_4	c_1	c_5	c_8	c_6	c_9	c_7	c_3	c_2	c_{10}
Refugee #5	c_3	c_6	c_2	c_1	c_7	c_8	c_4	c_9	c_{10}	c_5
Refugee #6	c_2	c_1	c_{10}	c_9	c_8	c_6	c_3	c_5	c_4	c_7
Refugee #7	c_7	c_1	c_{10}	c_9	c_8	c_6	c_3	c_5	c_4	c_2
Refugee #8	c_8	c_7	c_2	c_{10}	c_9	c_3	c_5	c_6	c_1	c_4
Refugee #9	c_5	c_9	c_2	c_{10}	c_1	c_7	c_4	c_6	c_3	c_8
Refugee #10	c_{10}	c_9	c_3	c_1	c_8	c_4	c_6	c_5	c_7	c_2
Refugee #11	c_2	c_3	c_1	c_8	c_9	c_7	c_4	c_{10}	c_5	c_6
Refugee #12	c_9	c_{10}	c_8	c_6	c_2	c_1	c_7	c_4	c_5	c_3
Refugee #13	c_9	c_2	c_1	c_{10}	c_3	c_5	c_6	c_4	c_7	c_8
Refugee #14	c_8	c_2	c_{10}	c_1	c_4	c_9	c_6	c_7	c_3	c_5
Refugee #15	c_5	c_{10}	c_1	c_4	c_9	c_6	c_7	c_3	c_8	c_2
Refugee #16	c_7	c_9	c_6	c_3	c_2	c_8	c_{10}	c_4	c_1	c_5
Refugee #17	c_1	c_2	c_4	c_5	c_6	c_{10}	c_9	c_3	c_8	c_7
Refugee #18	c_1	c_2	c_4	c_5	c_6	c_{10}	c_9	c_3	c_8	c_7
Refugee #19	c_5	c_3	c_8	c_9	c_1	c_4	c_2	c_{10}	c_6	c_7
Refugee #20	c_3	c_7	c_4	c_{10}	c_2	c_1	c_9	c_6	c_4	c_7

Source: *Own author.*

[37]In the small-size experiment carried out by Chen & Sönmez (2002) they tested three different environments where they used a sample of 168 participants, whereas Guillen & Kesten (2012) testing three different environment as well used a sample of 180 participants.

Differently from the other experiments, I propose trivial cases for some existing tenants. These tenants have their owned quota as their first preference. The purpose of this characteristic is to observe the behavior of the players that where given these cases. Besides, it allows for some reality since the case where existing tenants have their quota as their best choice is a very plausible scenario of this model. According to the answers, players seemed to understand trivial cases and they chose not to participate in neither mechanism. Additionally, they tended to state their true preferences. The only trivial case where players participated was in the exercise for the first refugee who forms a family with the second refugee. In that case, people chose to participate in the YRMH - IGYT mechanism, but not in the Deferred Acceptance. However, in the case of refugee #2, players rejected participating in the experiment, which means that either people do not take into account that they have a family member to care about, or that they think that the first refugee would choose country #2 instead of country #1, which is unlikely given that refugee #1 prefers country #1 over #2.

In the case of the rest of existing tenants the answers are diverse. People who played the role of refugee #5 usually participated in the experiment given that their owned quota is the worst choice. However, they only revealed their true preferences in the case of the first mechanism, whereas for the DA they tended to state middle-paid countries as their best choices. The same happened for the rest of existing tenants. They sometimes stated middle-paid countries as best choices, though this tendency was stronger in the DA mechanism, as though people understood that it is easier to end up assigned to the best countries in the first mechanism than in the second. Other observed tendency is to place the owned quota at the beginning of the preferences list and then the rest of induced preferences. Nevertheless, participation rates are low for existing tenants even in the case of refugee #6 whose quota is the 6th best choice.

Newcomers cannot choose not to participate in the experiment. They often

stated their true preferences, but sometimes they placed middle-paid countries as their best choice, especially in the case of the second mechanism.

This said, it seems that players felt as comfortable playing the first mechanism as playing the DA setup since participation rates were the same (28.47% vs. 28.47%).

As long as they report the true preferences, the mechanism will get the most efficient or stable outcome. Therefore, it seems to be more likely to achieve the better possible matching for the YRMH - IGYT case. With respect to truthful preference revelation, players lied in both mechanism, yet for the DA is more likely to get middle-paid countries as best choices, presumably because players understood that is harder to obtain a preferred quota with this mechanism (51.25% vs. 42.5%).

Because players where not given the other refugees' preferences, they did not know if there are countries generally preferred by all refugees. Consequently, there is no advantage whatsoever in misrepresenting the preferences. The result is therefore surprising given the high rates of misrepresentation.

For future research, it might be interesting to provide some information about which countries are most preferred by refugees and which are not in order to see whether players consider the likelihood of having a place in a country that is highly preferred by other refugees as well as their own preferences.

8 Conclusion

As it has been reviewed throughout the paper, crises like the existing one in Syria must be addressed by the use of economic techniques, especially when the dimension of the problems is so huge as in the case of the distributional issues that the European Union is still unable to address. In consequence, I resort to matching theory, and more specifically, to a very concrete model called House Allocation with Existing Tenants, where both already assigned

agents and newcomers must be matched to the different European countries, attending to certain rules. These rules are given by the use of two different mechanisms that generate different final allocations with certain properties that seek the maximum efficiency of the distribution. However, in both cases, some modifications need to be introduced in order to fit the real problem to the model, which was not specifically designed to address refugee crises. In so doing, I break down countries into indifferent and indivisible slots called quotas, so that refugees are eventually assigned to them rather than being directly assigned to countries. In addition to that, I provide countries with the possibility to have either binary or complete preferences over refugees so that, in the worst case, countries can decide which refugees can accept and which cannot. Families are also introduced as a new type of agent formed as a group of refugees with the same preferences and that are equally preferred by countries. Finally, I introduce special agents that can get type-specific quotas whenever they request international protection in a country that has free quotas of this kind.

These modifications are defined and introduced both in the model and in the algorithms that run this model, the You Request My House - I Get Your Time mechanism and a dynamic version of the Deferred Acceptance. However, all these adjustments, with the exception of the introduction of quotas, compromise the Pareto-efficiency of the final allocation in such a way that it might be restored by swapping pairs of either single refugees or families. Nonetheless, these restrictions do not completely break the efficiency of the outcome, they just constrain it so that a final constrained Pareto-efficient matching can be achieved by the use of the YRMH - IGYT algorithm. In addition, the fairness of the mechanism can also be broken whenever there exists a situation of wastefulness where there are uninhabited quotas and unassigned refugees at the end of the mechanism as a consequence of the restrictions imposed by the acceptability and the limit of quotas.

In the case of the second mechanism, the Dynamic Deferred Acceptance

model run by the Deferred Acceptance using Isolated Preferences algorithm, the introduction of family and the implicit acceptability of the mechanism do not suppose a concern for the stability of the final outcome, which also grants efficiency. Nevertheless, when type-specific quotas are introduced, the stability condition of the matching can be broken because less preferred refugees can get access to quotas that would have been preferred by both other refugees and the country that is hosting the special refugee. Therefore, the complete model with all the specifications fails to be stable in a similar way as the previous model failed to be Pareto-efficient.

Hence, as discussed above, the final matching in the case of the first mechanism might always be constrained Pareto-efficient, whereas in the case of the Dynamic Deferred Acceptance, the introduction of preferences forces the matching to establish a priority conditions to some refugees to get stable matchings. For instance, it is assumed that there exist property rights for the existing tenants, that is, they had priority over other refugee in those countries where they had their owned quota. Similarly, the introduction of special refugees forces the model to give more priority to them whenever they demand a quota, independently from the preference order of countries. This condition violates the stability of the matching since it might be the case where special refugees take the quota that would be available for other non-special refugees that had priority in the country. This rupture with stability is stronger than the case of the Pareto-efficiency for the YRMH - IGYT mechanism. This is because of the fact that both sides have preferences make it more difficult to find second best matchings as the constrained efficient ones for the first mechanism. Therefore, it would be more recommendable to use the YRMH - IGYT algorithm over the Dynamic Deferred Acceptance. Theoretically, the only advantage of the DA model is that it allows for the countries to have complete preferences, but since acceptability is introduced in the case of the YRMH - IGYT mechanism, this drawback is softened.

Additionally, it appears to be the case that the deferred acceptance is more difficult to understand than the other mechanism. In the pilot experiment I carried out it seems that players preferred to state their true preferences in the YRMH - IGYT algorithm, though they participate the same in both mechanism. However, this contradicts the results observed in Guillen & Kesten (2012), which suggest that participation rates are higher in the case of the deferred acceptance setup. Moreover, even though this mechanism is not Pareto-efficient in the context of House Allocation, this last experiment proved the opposite.

Evidently, my pilot experiment is not conclusive enough to unseat previous findings, though it is true that results may not be comparable since the mechanisms that are being tested are different and are also modified versions of the original ones. Thus, it would be good to check these findings in a future experiment with the methodology I explain in this study and the feedback I received about how to improve it.

Although both mechanisms described in this study has their own drawbacks, they can be used to address a sufficiently complex and detailed version of the current Syrian crisis that Europe is facing. These two models can easily improve the final allocation of refugees given that they take into account both refugee and country preferences. Moreover, because the Syrian refugee problem is not a different scenario than other refugee movements, these same mechanisms can properly addressed the distribution of other future crises of the same kind.

Appendix

A. Examples

Example 1 ***Improving the allocation upon refugees***[38]**.**

[38]This example was introduced in Álvarez (2017).

The set of refugees is $R = \{r_1, r_2, r_3, r_4\}$, where the two first refugees have priority over the other two. Refugee preferences are just taken into account for those refugees that have higher priority. Let C be the set of all countries, so that $C = \{c_1, c_2, c_3, c_4\}$. Finally, the preference relations are given by:

$$r_1 \succ: c_1, c_2, c_3, c_4$$

$$r_2 \succ: c_2, c_1, c_3, c_4$$

$$r_3 \succ: c_3, c_1, c_2, c_4$$

$$r_4 \succ: c_4, c_1, c_2, c_3$$

According to this setup, the first two refugees will always be matched to their most preferred countries, while the other two will be assigned to their least preferred countries the 50% of the time. Therefore, one feasible outcome could be given by:

$$\mu = \begin{pmatrix} r_1 & r_2 & r_3 & r_4 \\ c_1 & c_2 & c_4 & c_3 \end{pmatrix}$$

This matching μ can be easily improved by using the Serial Dictatorship Mechanism that assigns the most preferred country to the first ranked refugee, the most preferred country among the remaining objects to the second refugee, and so on. Given the previous setup, four orders can be found:

$$\psi_1 : \{r_1, r_2, r_3, r_4\}$$

$$\psi_2 : \{r_1, r_2, r_4, r_3\}$$

$$\psi_3 : \{r_2, r_1, r_3, r_4\}$$

$$\psi_4 : \{r_2, r_1, r_4, r_3\}$$

Whichever is the order, the matching will remain unchanged if it is generated by the Serial Dictatorship Mechanism. In addition, the resulting matching

is Pareto-superior to the previous one given by the random assignment for non-priority refugees:

$$\mu^{SD-\psi_1} = \mu^{SD-\psi_2} = \mu^{SD-\psi_3} = \mu^{SD-\psi_3} = \begin{pmatrix} r_1 & r_2 & r_3 & r_4 \\ c_1 & c_2 & c_3 & c_4 \end{pmatrix}$$

Therefore, this example proves that even the simplest matching theory can help improve the efficiency of the current allocation.

Example 2 ***Benefits from secondary movements***[39]**.**

There are four refugees $R = \{r_1, r_2, r_3, r_4\}$*, and four countries with unitary capacity* $Q = \{q_1, q_2, q_3, q_4\}$*. The first three refugees are existing tenants that has property rights over one of the first three quotas, that is,* r_1*,* r_2*, and* r_3 *are the owners of* q_1*,* q_2*, and* q_3*, respectively. Preferences are:*

$$r_1 \succ: q_1, q_2, q_3, q_4$$

$$r_2 \succ: q_2, q_1, q_3, q_4$$

$$r_3 \succ: q_4, q_2, q_1, q_4$$

$$r_4 \succ: q_3, q_2, q_1, q_4$$

The priority order is $\psi : \{r_1, r_2, r_3, r_4\}$*. Finally, let* μ^{sm} *and* μ^{nsm} *be the final matchings for the model with, and without secondary movements.*

$$\mu^{nsm} = \begin{pmatrix} r_1 & r_2 & r_3 & r_4 \\ q_1 & q_2 & q_3 & q_4 \end{pmatrix}$$

$$\mu^{sm} = \begin{pmatrix} r_1 & r_2 & r_3 & r_4 \\ q_1 & q_2 & q_4 & q_3 \end{pmatrix}$$

Notice that in the case of the final outcome without secondary movements,

[39]This example was introduced in Álvarez (2017).

r_3 cannot go to q_4 because this quota belongs to a different country. Consequently, r_3 stays in q_3, denying to r_4 the possibility of going to that quota, which is the most preferred for her. Allowing for secondary movements eliminates this inefficiency so that r_3 and r_4 can be assigned to their most preferred quota.

B. Discussion of one-sided matchings[40]

The first one is the *Random Serial Dictatorship with Squatting Rights* (RSD), which has a major drawback since it is not individually rational. The second one is the *New House 4* (NH4) of MIT, which is, in turn, not Pareto efficient. The third and the fourth mechanism yield exactly the same outcome[41], but they proceed in a different manner. They are the *Top Trading Cycles* and the YRMH - IGYT, which are not fair.

As one can observe, there is no mechanism that can meet all the properties at the same time, as it is stated in proposition 1 form Guillen & Kesten (2012): "*No mechanism is individually rational, Pareto efficient, and fair. However, there exist mechanisms satisfying any other three properties simultaneously*".

Individual rationality is a crucial component in this context because it guarantees efficiency gains from trade that, otherwise, would not have been taken into account since those existing tenants that want a new assignment will not enter the market because they might be eventually matched to a less preferred quota than the one they release[42]. Therefore, the first mechanism will not be taken into account because of its inability to ensure the participation of the existing tenants.

The NH4 mechanism has been used at residences of MIT. Surprisingly, this algorithm always yields exactly the same outcome as the Deferred Acceptance

[40]This section belongs to my previous work, Álvarez (2017).

[41]See Abdulkadiroglu & Sönmez (1999) for more details.

[42]Chen & Sönmez (2002) show, by means of an experiment, that the efficiency of the TTC is significantly higher than that of the RSD, in addition to the significant difference in participation rates between this two mechanisms in favour of TTC. No differences are found in the case of truthful revelation of preferences.

(DA) mechanism developed by Gale and Shapley (1962), as theorem 1 from Guillen & Kesten (2012) relates: "*NH4 and DA are equivalent*".

From this theorem it follows that any other equivalent algorithm will yield an outcome with the same properties as the outcomes from the DA. This is the reason why NH4 is individually rational, fair, and strategy-proof. Although this mechanism is not Pareto efficient (see Abdulkadiroglu & Sönmez (1999)), it dominates any other mechanism with the same properties.

Nevertheless, for the case of the Syrian crisis, Pareto-efficiency is necessary to improve the distributional issues that make the current policies inefficient. Besides, the cost of introducing this characteristic is not expensive, since fairness is, in principle, just broken by the existence of incumbents for whom it make sense to provide property rights over their current quota. Therefore, the NH4 will not be taken into account for the purpose of this study.

C. Propositions and examples for Section 5[43]

C.1. Introduction of quotas

Example 3 shows how works the algorithm with the inclusion of both the counter and the assignment to quotas.

Example 3 ***Introducing the quota counter.***

Let $R_E = \{r_1, r_2, r_3\}$ *be the set of all existing tenants and let* $R_N = \{r_4, r_5, r_6, r_7\}$ *be the set of newcomers.* $C = \{c_1, c_2\}$ *is the set of all countries in the setting. Each has three available quotas:* $c_1 = \{q_{1,o}, q_{2,v}, q_{3,v}\}$ *and* $c_2 = \{q_{4,o}, q_{5,0}, q_{6,v}\}$. r_1*,* r_2*, and* r_3 *owns* $q_{1,o}$*,* $q_{4,0}$*, and* $q_{5,0}$*, respectively. The priority order is given by* $\psi : \{r_1, r_7, r_5, r_3, r_4, r_2, r_6\}$*, and refugee preferences are the following:*

$$r_1 \succ: c_1, c_2$$

$$r_2 \succ: c_2, c_1$$

$$r_3 \succ: c_1, c_2$$

[43]This section belongs to my previous work, Álvarez (2017).

$$r_4 \succ: c_2, c_1$$

$$r_5 \succ: c_2, c_1$$

$$r_6 \succ: c_1, c_2$$

$$r_7 \succ: c_2, c_1$$

The final assignment is achieved following these steps:

- r_1 *wants a place in* c_1*, where she has her endowment.*
- r_7*wants a place in* c_2*, so she takes one the only vacant quota available in that country,* $q_{6,v}$*.*
- r_5 *points to* c_2*, but since there are no vacant quotas left, she is tentatively assigned* $q_{5,o}$*. Then,* r_3*, who is the tenant in* c_2 *with the highest priority, takes the turn of* r_5*.*
- r_3 *wants a place in* c_1*, so she takes one vacant quota, for instance* $q_{2,v}$*.*
- *Once* r_3 *has been assigned a quota, her endowment is released so that* r_5*, who has a tentative assignment to* $q_{5,o}$*, is finally assigned to that quota.*
- r_4 *demands a quota in* c_2*. Again, the only quota available is an occupied quota, so she is tentatively assigned to that quota until its owner gets another matching.*
- r_2*, who is the owner of* $q_{4,o}$ *takes the turn of* r_4*. She wants to go to* c_2*, so she gets her endowment.*
- *Now that* r_2 *has been allocated in* $q_{4,o}$*,* r_4 *cannot demand a quota in* c_2 *because there are no more quotas available. Then, she points to* c_1*, where she is given* $q_{3,v}$*.*
- *Finally,* r_6 *cannot be allocated since there are no more quotas available.*

Hence, the final matching is:

$$\mu^1 = \begin{pmatrix} r_1 & r_2 & r_3 & r_4 & r_5 & r_6 & r_7 \\ q_{1,o} & q_{4,0} & q_{2,v} & q_{3,v} & q_{5,o} & \phi & q_{6,v} \end{pmatrix}$$

Proposition 8 *The final matching generated by the YRMH - IGYT algorithm when refugees are assigned to quotas rather than to countries is individually rational, strategy-proof, and Pareto-efficient.*

Proof. A refugee will be matched to a given quota within a country only if that refugee could also be assigned to that country if there would not exist quotas. Therefore, neither the introduction of the quota counter, nor the fact that refugees are assigned to indifferent quotas disturb in any sense the final outcome provided by this setup. ■

C.2 Introducing acceptability

Example 4 shows how the algorithm works with the inclusion of binary preferences.

Example 4 ***Introducing acceptability.***

The setting of this example is the same as in example 3, with the addition of binary preferences of countries over refugees. These preferences are such that all refugees are acceptable in all countries with the exception of r_3, who is unacceptable for c_1.

$$c_1 \succ: r_1, r_2, r_4, r_5, r_6, c_1, r_3, r_7$$

$$c_2 \succ: r_2, r_3, r_4, r_5, r_6, r_7, c_2, r_1$$

Differently from example 3, when r_3 demands a quota in c_1, she finds that she is unacceptable so that she points to her next preference, c_2, where she receives her endowment, $q_{5,o}$. This triggers a sequence where r_5 is forced to demand the following available quota in c_2, which is the endowment of r_4,

who also prefers to be matched to c_2. Because r_4 takes now the turn of r_5, the latter lose all the quotas in c_2. Therefore, she is forced to find a matching in c_1, where she receives $q_{2,v}$.

Thus, the final matching when acceptability is introduced is the following:

$$\mu^2 = \begin{pmatrix} r_1 & r_2 & r_3 & r_4 & r_5 & r_6 & r_7 \\ q_{1,o} & q_{4,0} & q_{5,o} & q_{3,v} & q_{2,v} & \phi & q_{6,v} \end{pmatrix}$$

In this case, r_3 is unacceptable for c_1. Therefore, when this refugee demands a quota, c_1 rejects her proposal. Consequently, r_3 has to resort to her next preferred country.

Proposition 9 *The final outcome generated by the YRMH - IGYT is individually rational and strategy-proof for the refugees*[44]*.*

Proof. Individual rationality will be ensured if assumption 1 holds, because existing tenants will always be able to get, at least, their own quota. In addition, the algorithm will yield strategy-proof outcomes because the best decision for each agent is stating their true preferences, even if refugees know the countries that do not accept them. This is because the algorithm matches one refugee at a time. In other words, the matching is definitive, not tentative. Thus, even if it is the case that the only country that accepts a given refugee is the least preferred for her, it does not make sense to put that country at the top of the preference list, because, eventually, the refugee will be assigned to the quota in that country, and no refugee would take this quota before her since the algorithm does not pass to the next refugee until the decision for the previous one is made. ■

Proposition 10 *The final outcome generated by the YRMH - IGYT algorithm with acceptability is not Pareto-efficient for the refugees.*

[44]I specify that the properties only endure for the refugees, because countries are now agents with preferences, and therefore, individual rationality, strategy-proofness, and Pareto-efficiency are concerns of both sides of the market.

Proof. The assignment would be wasteful if there exist at least one uninhabited quota and one unmatched refugee. This could be the case of those refugees that are unacceptable for the countries where the unmatched quotas exist. Additionally, in some cases, acceptability might disturb the final outcome in such a way that the new matching could improve efficiency by just swapping pairs of refugees, as it can be the case of the previous example if we change the assignments of r_3 and r_5. ■

Proposition 11 *The outcome generated by the YRMH - IGYT algorithm is constrained*[45] *Pareto-efficient for the refugees, in the case of the setup with binary preferences for countries.*

Proof. Because the YRMH - IGYT algorithm always yields Pareto-efficient outcomes, it will also yield Pareto-efficient outcomes for this new particular setup. ■

If unmatched refugees have higher ranks than some other effectively matched refugees, the assignment will not be fair not only due to the existence of incumbents, but also because of the acceptability condition.

Proposition 12 *The YRMH - IGYT algorithm is not fair due to the introduction of binary preference relations, for the refugee side.*

Proof. When a refugee cannot be matched because all of the remaining quotas in which she may be assigned belong to countries that do not accept that refugee, the algorithm will pass to the next refugee in the list, thus violating the priority order. ■

C.3 Introducing families

Example 5 shows how the algorithm works when families are included in the setup.

[45] Constrained stands for the fact that the outcome would not be Pareto-efficient because of both the existence of swapping pairs and the presence of wastefulness.

Example 5 ***Introducing families.***

In the case of this example, the setup is the same as in the example with acceptability, but I introduce now two different families, $f_1 = \{r_1, r_2\}$ *and* $f_2 = \{r_5, r_6, r_7\}$*. Because families need to have the same preference and priority, the following changes are also introduced:* $\psi : \left\{ \begin{array}{c} \\ r_1 \\ r_2 \\ \\ \end{array} , \begin{array}{c} r_5 \\ r_6 \\ \\ r_7 \end{array} , r_3, r_4 \right\}$*, with the vertical positions meaning that all refugees in a given column have the same priority, and preferences are now:*

$$r_1 \succ: c_1, c_2$$

$$r_2 \succ: c_1, c_2$$

$$r_3 \succ: c_1, c_2$$

$$r_4 \succ: c_2, c_1$$

$$r_5 \succ: c_2, c_1$$

$$r_6 \succ: c_2, c_1$$

$$r_7 \succ: c_2, c_1$$

According to this setting, the final matching is achieved in these steps:

- r_1 *demands a quota in* c_1*, where she has her endowment. She is therefore tentatively assigned to that country until her relative is assigned a quota in this same country.*
- r_2 *points also to* c_1*, and is assigned a vacant quota, for instance* $q_{2,v}$*. Hence, the family is definitively assigned to* c_1*.*
- *Now it is the turn of the following family. First,* r_5 *points to* c_2*, where she is assigned the only vacant quota available. Then,* r_4 *points to* $q_{4,o}$*,*

which has been released since r_2 is already allocated. Finally, r_5, demands the last quota in c_2, which belongs to r_3. The family is tentatively assigned until this last tenant gets another matching.

- *r_3 points to c_1, where she is assigned to $q_{3,v}$, which release her endowment, triggering a sequence through which f_2 is definitively assigned to c_2, as stated in the previous step.*

- *Finally, r_4, remains unmatched since there are no available quotas in neither country.*

The final matching is therefore:

$$\mu^3 = \begin{pmatrix} r_1 & r_2 & r_3 & r_4 & r_5 & r_6 & r_7 \\ q_{1,o} & q_{2,v} & q_{3,v} & \phi & q_{6,v} & q_{4,o} & q_{5,o} \end{pmatrix}$$

Proposition 13 *The final outcome generated by the YRMH - IGYT algorithm with families is individually rational and strategy-proof for the refugees.*

Proof. The algorithm will be individually rational because the inclusion of families does not break the condition by which existing tenants, and also existing families, will always be provided with the opportunity to take their endowments when they are requested by other refugees or families. Strategy-proofness will be granted because the algorithm assigns definitive matchings. ■

Proposition 14 *The outcome generated by the YRMH - IGYT algorithm is not Pareto-efficient when families and acceptability are both added to the model, for the refugees.*

Proof. Wastefulness can be a bigger problem now with the introduction of families than just when acceptability was taking into account, because it could be the case that entire families will not have enough quotas within a

country to be hosted. Therefore, several free quotas will remain unmatched at the final outcome[46]. Furthermore, as it was the case for acceptability, for a given setup, the final outcome generated by the YRMH - IGYT algorithm might improve efficiency by swapping places. In this case, the exchange should be made by pairs of families containing the same number of refugees, by a family consisting in the same members as a group of single refugees that want the quotas where that family is hosted, or by a mixture of the two previous cases. ■

Example 6 ***Swapping families and singletons.***

There are six refugees $R = \{r_1, r_2, r_3, r_4, r_5, r_6\}$ *and one family,* $f_1 = \{r_4, r_5\}$ *. There are four countries* $C = \{c_1, c_2, c_3, c_4\}$ *with capacity two. Additionally,* f_1 *is unacceptable for* c_3*. The priority order is* $\psi : \{r_1, f_1, r_2, r_3, r_6\}$ *and refugee preferences are the following:*

$$r_1 \succ: c_1, c_3, c_2, c_4$$

$$r_2 \succ: c_1, c_2, c_3, c_4$$

$$r_3 \succ: c_1, c_2, c_3, c_4$$

$$r_6 \succ: c_1, c_2, c_3, c_4$$

$$f_1 \succ: c_1, c_3, c_2, c_4$$

μ^{o3} *and* μ^{c3} *are the final outcomes for the setup without and with acceptability:*

$$\mu^{o3} = \begin{pmatrix} r_1 & f_1 & r_2 & r_3 & r_6 \\ c_1 & c_3 & c_1 & c_2 & c_2 \end{pmatrix}$$

[46]This is a concern that exists in the context of "hard" quotas. If instead, a flexible mechanism were used, it could marginally increase the number of quotas in order to host the families that the algorithm left unmatched.

$$\mu^{c3} = \begin{pmatrix} r_1 & f_1 & r_2 & r_3 & r_6 \\ c_1 & c_2 & c_1 & c_3 & c_3 \end{pmatrix}$$

Because the family is not acceptable in one country, refugees are forced to go to their next preferred choice, c_2. However, if acceptability is abolished, the Pareto-efficient outcome is achieved by just swapping the quotas of the family and the quotas of the two other refugees who were assigned to c_3.

Proposition 15 *The final matching generated by the YRMH - IGYT algorithm is constrained Pareto-efficient for the refugees, when families are introduced in the setup together with acceptability.*

Proof. Because the YRMH - IGYT algorithm always yields Pareto-efficient outcomes, it will also yield Pareto-efficient outcomes for this new particular setup. ■ The fairness of the mechanism may also be a serious concern due to the introduction of families with a higher global rank than individuals, even when these other individuals may have a higher priority than some of the family members in an underlying priority ranking with just singletons. Therefore, it could be possible that one or more members of a family get a better assignment than a single refugee that ranks higher. In consequence, I need to introduce a new concept of fairness that allows the mechanism to respect this property as long as it is just considered between different priority groups, i.e. in the case of this context, the assignment is fair (regardless of the property rights) within groups (families and individuals) but not across groups.

Proposition 16 *The YRMH - IGYT algorithm with families is fair (regardless of the property rights) only within groups for the refugees.*

Proof. Think, for instance, that a family formed by three individuals is placed at the top of the priority list because just one of them has the highest priority among all the individuals, so that, the other two family members

have now the same priority. However, as individuals, these two family members have a lower rank than the rest of individuals that do not belong to that family, but they end up with a matching that is also preferred by these individuals. Thus, priorities are not respected not only because of the existence of incumbents but also because of the existence of families. ■ ***C.4 Introducing type-specific quotas***

Example 7 shows how the algorithm works when type-specific quotas are included in the model.

Example 7 ***Introducing type-specific quotas.***

In the case of this example, I follow the setup of the example with families and acceptability, but I introduce now a special refugee, r_8^s who has the lowest priority in ψ, and prefers c_1 over c_2 . Additionally, $q_{2,v}$ is now a type-specific quota.

According to this, the assignment for the first family is still the firs country, though r_2 cannot be assigned now to $q_{2,v}^s$, so she is assigned to $q_{3,v}$. For the second family, the algorithm proceeds like follow:

- *r_5 points to $q_{6,v}$. r_6, points to $q_{4,o}$, and finally, r_7, points to $q_{5,o}$. The problem now is that, when requested the endowment of r_3, in her turn, this refugee cannot be assigned to c_1 because the only available quota is the type-specific one. Therefore, r_3 is forced to choose her next preferred choice, which is her endowment. Thus, the whole family is displaced since there are just two available quotas in c_2, after r_3 get her owned quota.*

- *Finally, the special refugee, r_8^s is assigned to the type-specific quota in c_1, $q_{2,v}^s$.*

According to this, the final outcome is:

$$\mu^4 = \begin{pmatrix} r_1 & r_2 & r_3 & r_4 & r_5 & r_6 & r_7 & r_8^s \\ q_{1,o} & q_{3,v} & q_{5,0} & q_{6,v}^r & \phi & \phi & \phi & q_{2,v}^r \end{pmatrix}$$

Proposition 17 *The YRMH - IGYT algorithm with type-specific quotas provides individually rational and strategy-proof final matchings for the refugees.*

Proof. Thanks to the second condition, no existing tenant can eventually be assigned to a quota worse than their endowment. Strategy-proofness holds because assignments are definitive, not tentative. ■

Proposition 18 *The algorithm generated by the YRMH - IGYT algorithm with type-specific quotas is not Pareto-efficient for the refugees.*

Proof. If at the end of the process there are at least one non-priority refugee and one reserved quota without assignment, the final outcome would be wasteful[47]. In addition, as previous examples showed, the final outcome generated when reserved quotas are included might be improved by swapping pairs of refugees, if we exchange the matching of the special refugee when type-specific quotas exist with her matching when there are not such quotas. ■

Proposition 19 *The final matching generated by the YRMH - IGYT algorithm with type-specific quotas is constrained Pareto-efficient for the refugees.*

Proof. Because the YRMH - IGYT algorithm always yields Pareto-efficient outcomes, it will also yield Pareto-efficient outcomes for this new particular setup. ■ Finally, the final outcome might not be fair, not only because of the existence of property rights, but also because unmatched refugees might have higher ranks than other refugees effectively matched because they were granted a reserved quota.

Proposition 20 *The YRMH - IGYT algorithm will not be fair in the context of reserved quotas for the refugees.*

[47] One way to fix this problem is releasing the reserved quotas for unmatched refugees. Therefore, at the end of the mechanism, a new step should be introduced, and the same procedure should be carried out again to match as many refugees as the mechanism can allocate with released quotas. If there are enough refugees to fill all the released quotas, wastefulness will not constitute a problem.

Proof. When an ordinary refugee cannot be matched because all of the remaining quotas in which she may be assigned belong to countries that only have reserved quotas available, the algorithm will pass to the next refugee in the list, thus violating the priority order. ■

D. Instructions for the experiment

In the present document I describe two different mechanisms developed for my master's thesis. In both of them there exists an assigned side (i.e. refugees) and a recipient side (i.e. countries). What I am going to ask you is to play the role of a refugee who wants to be assigned to a country given certain preferences over the possible countries to which the refugee can be assigned.

Before explaining the mechanisms, I will briefly explain why this exercise is necessary. Nowadays, there are 5.5 million people that have escaped from the Syrian border since the onset of the civil war in 2011[48]*. Out of 160,000 refugees who are in charge of the European Union, only 28,242 have been already assigned, although by the end of 2017 the relocation process of refugees from Greece and Italy should have been finished. Moreover, out of 17,337 quotas that Spain should have already filled, only 1,910 are actually covered (11%)*[49]*.*

The mechanisms described below are designed to solve this problem in an efficient way. Thanks to your collaboration, I will obtain an estimation of which of both mechanisms is the most efficient, in which of both people lie more with respect to the individual preferences, and in which of both there is a higher participation rate.

Here I describe some of the main concepts of the mechanisms:

- *There exists a set of refugees with preferences (ordered list that relates*

[48] *http://www.unhcr.org/syria-emergency.html*

[49] *www.eldiario.es/desalambre/Espana-incumplido-cuota-refugiados-paises_0_690481792.html*

how countries value refugees) over countries. This set of refugees is divided into two subsets, those refugees that have already been assigned to a country and want to swap their quota (existing tenants), and those refugees that participate for the first time (newcomers). The difference between them is that exiting tenants already own one of the quotas offered by one country.

- *There exists a set of countries that may or may not have preferences over refugees. In negative case, there would be a priority order for refugees (think of the priority order as a unique order of preferences over refugees which all the countries agree on).*
- *Each country has a set of quotas that needs to be met. Each quota is an individual and indivisible slot within the borders of a given country.*
- *There exists a set of families that always have the same preferences and the same priority. Countries equally prefer every family member. They will be matched only if there exist countries that have enough quotas to host them all. Otherwise, the family will have to look for another country.*
- *There exists a set of special refugees that can be assigned to both type-specific quotas and ordinary quotas.*
- *There is a set of type-specific quotas for special refugees or refugees at risk. These quotas can only be assigned to this kind of refugee, unless they have already been assigned in previous rounds.*

Mechanism #1: YOU REQUEST MY HOUSE – I GET YOUR TURN

In this mechanism, only refugees have preferences. Countries follow a unique priority order to assign refugees.

1. *The refugee with the highest priority is assigned to her most preferred quota. Afterwards, the refugee with the second highest priority is assigned to her most preferred quota among the set of remaining quotas, and so on until someone demands the quota of an existing tenant.*

2. *If the existing tenant has already been assigned to a quota, then the procedure is not disturbed. Otherwise, the previous order is modified by inserting the existing tenant to the top of the priority order, thus restarting the procedure from the previous step, that is, the step where the refugee demanded the quota of the existing tenant. (The incumbent is now the refugee with the higher priority, and if she wants to keep their quota, she will have preference over the refugee that has requested it and had more priority in the previous order).*

3. *Similarly, insert any other existing tenant that has not been assigned yet to the top of the priority order when her quota is demanded.*

4. *Whenever it is the turn of a family, their members will choose individually but always attending to the final assignment of the other members. The set of remaining quotas will be constrained to those countries that have enough quotas to host the whole family. At this point, if there exists at least one county that meets this requirement, the family will be assigned to that country, attending to the preference order of the family. Otherwise, the family will remain unmatched and the algorithm will pass to the following family or individual, following the priority order.*

5. *In case that the quotas of a given family are demanded, the family will be placed on the top of the priority order, in the same way as it was explained with individuals.*

Mechanism #2: DYNAMIC DEFERRED ACCEPTANCE

The main difference between this mechanism and the previous one is that countries have now preferences over refugees instead of following a unique

priority order (remember that preferences may follow different orders).

1. *All refugees, at the same time, demand a quota in her most preferred country. Each country rejects all requests but the most preferred ones that can be included in the quotas of this country. If a country still has unfilled quotas, it will tentatively assign the next most preferred refugee.*

2. *Whenever it is the turn of a family, their members will choose individually but always attending to the final assignment of the other members. The set of remaining quotas will be constrained to those countries that have enough quotas to host the whole family. At this point, if there exists at least one county that meets these requirements, the family will be assigned to that country, attending to the preference order of the family. Otherwise, the family will remain unmatched and the algorithm will pass to the following family or individual, following the priority order.*

3. *Each refugee or family that has been rejected in the previous step proposes to her next preferred country. Each country rejects all requests except the best that do not exceed their quota limit, and additionally, assigns one tentative quota to the next most preferred refugee, as in the case of the first step.*

4. *Repeat this same process until no more refugees are to be assigned.*

Now you have finished your first lecture of how the model and the mechanisms work, read the document again as many times as you find necessary to understand it as well as possible. Concepts are complex, so you should not get alarmed in case any of them is not totally understood. In the attached document you will find four questions that I want you to answer and that can be perfectly answered even if you do not have understood this document perfectly.

Now, you will be assigned a refugee number at random to play her role as refugee. In case you are assigned an existing tenant, first you will need to considerer whether you will participate or not in the exercise, which will leave you with the quota that you already own (notice that the participation decision is, to my research, as important as the allocation process, so there is no problem whatsoever if you decide not to participate). In case you are assigned as a newcomer, there is no participation decision, and you will directly report your preferences over countries. The experiment in which this exercise is based on consisted of an average payoff of $14 per person. Due to lack of funds, neither me nor the university will give any monetary incentive. However, I would really appreciate if you could perform the exercise as though you can actually earn the money. At the end of the paper you can find the refugee that you have been assigned to and her payoff table as a function of the country where you end up. Before proceeding, you should know that you compete against other 19 refugees (a total of 20 individuals), that there are ten countries, each of them with two quotas except the ninth and the tenth, which only have one (notice that two refugees will always remain unmatched at the end of the mechanism due to the lack of space within the countries; who of these refugees will be unmatched will depend on countries' preferences or on the priority order, which will be hidden information). There are two special refugees and two type-specific quotas that will not be revealed either. There are also two families of two individuals. You have been assigned to play the role of refugee #1, an existing tenant whose quota is within country #1 (c1) and who is family of refugee #2. Your payoff table is the following:

Refugee	c_1	c_2	c_3	c_4	c_5	c_6	c_7	c_8	c_9	c_{10}
#1	\$20	\$18	\$16	\$14	\$12	\$10	\$8	\$6	\$4	\$2

Answer to the following question for both the first and the second mechanism.

You request my house – I get your turn

1. *Do you participate in the relocation mechanism? (Answer with "yes" or "no" and write down your answer in red colour in the blank space*

below this question, please)

2. *Even if you decide not to participate, write in the blank space below this question your ordered list of preferences (in an horizontal line starting from the left with the country that you preferred most, ending from the right with the country that you least preferred, in red colour, and separating the countries by ";", please)*

Dynamic Deferred Acceptance

1. *Do you participate in the relocation mechanism? (Answer with "yes" or "no" and write down your answer in red colour in the blank space below this question, please)*

2. *Even if you decide not to participate, write in the blank space below this question your ordered list of preferences (in an horizontal line starting from the left with the country that you preferred most, ending from the right with the country that you least preferred, in red colour, and separating the countries by ";", please)*

Once you have answered the four questions, send this same document to masther.thesis.ignacio.2018@gmail.com.

Thanks for your collaboration.

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