REVOLUTIONS AND CONTAGION

by

Dániel Pass

Submitted to

Central European University

Department of Economics

In partial fulfilment of the requirements for the degree Master of Arts

Supervisor: Professor Ádám Szeidl

Budapest, Hungary

2016

ABSTRACT

Revolutionary waves occur time after time in the history, two obvious examples are the Spring of Nations in the 19th century or the Arab Spring started in 2010. In my thesis, I build a model of contagion to study the conditions which can explain the evolution of these revolutionary chains among countries of similar characteristics. First, I introduce the Barberà-Jackson model which is the building block of my framework. Next, I present my own model and show the necessary constraints which must be satisfied to the development of revolutionary contagion among two and three countries. I show that observing a successful revolution in a country can induce people in other countries to revolt, too. Furthermore, I also point out that people in some countries need to learn the action of more predecessor countries to change their mind and take the streets. This result is also in line with patterns emerged in historical cases. Lastly, a graphical solution is also presented to illustrate my findings, i.e. the existence of the equilibria in which contagion of revolution in every country happens.

ACKNOWLEDGEMENTS

First of all, I would like to thank to my supervisor, Professor Ádám Szeidl, for his guiding comments and feedbacks during the whole thesis writing process. I am also grateful to Professor Matthew O. Jackson for inspiring me with his papers and seminars in Budapest to choose this topic as the subject of my thesis. I thank to my family who supported me during my master studies. Lastly, I also say thanks to all of my friends who helped me in the last months.

TABLE OF CONTENTS

1. INTRODUCTION

In tense political situations, it is a common phenomenon that mass demonstrations or even revolutions in a country or in certain geographical regions occur one after another within a very short time. These serial events are presumably not independent from each other, since there are numerous historical examples when a revolution in a country had a true trigger effect on other countries' decision to revolt. Two historical examples can be the Spring of Nations in the first months of 1848 and the Arab Spring began at the end of 2010, where these chains of revolutions are thoroughly identifiable.

The Spring of Nations was a revolutionary wave throughout Europe during the first few months of 1848. The first rebellions were in France, but in a very short time, in chronological order, there were also riots in the Italian and German states, in Denmark and in the Habsburg Empire. We can make two interesting observation from this historical case. First, in most cases, the rumours and news of the riots in an adjacent country or region triggered the next rebellion, for example, the revolution in Vienna on 13th March 1848 clearly induced the revolution in Budapest two days later. On the other hand, the revolutionary wave swept throughout Europe in a few months, while there were riots in almost every country and region from the West to the East, except one: the authoritarian and closed Russian Empire. Hence, the story of the Tzarist Empire during the Spring of Nations suggests that revolutionary contagions rather only happen among countries of similar characteristics.

The Arab Spring was a sequence of violent and non-violent riots and demonstrations in the Arab world that began at the end of 2010. The first protests occurred in Tunisia, but spread very fast among the similar countries in North Africa and the Middle East (Campante & Chor, 2012). The relevant aspect part of Arab Spring to us is that there is a well-to-follow series of rebellions (Brummitt, Barnett, & D'Souza, 2015) and revolutions after the Tunisian events did not happened simultaneously but one after another. Therefore, we can suppose that the predecessor countries' actions and especially the number of predecessor countires are probably also an important factor.

According to these historical anecdotes, we can suppose that so-called information cascades (Banerjee, 1992; Bikhchandani, Hirshleifer, & Welch, 1992) might occur in the evolution of the revolutionary waves. There is already a remarkable amount of literature about waves of revolutions and mass demonstrations that are using information cascade and collective action models (Angeletos, Hellwig, & Pavan, 2007; Barbera & Jackson, 2016; Kricheli, Livne, & Magaloni, 2011; Kuran, 1991; Lohmann, 1994). These papers are all very similar to my approach, since they modelled the decision of people whether to take part in a revolution or not and discussed the necessary conditions of the equilibria in which revolution can happen.

In my thesis, I build a model based on the framework of Barberà & Jackson (2016) to make an inquiry into the conditions which can induce the development of revolutionary waves through countries. The main idea of my thesis is that there are countries where the citizens are certainly unhappy with the ruling regime, but they may do not believe that there are enough people of their kind and they can make a successful revolution. However, if these people could observe an adjacent or similar country where people revolt, then they may think that their chances of a successful revolution is similar and they might decide to revolt, too.

I begin my thesis by introducing the benchmark model of Barberà & Jackson (2016). I show that this recently published framework can be used as a highly useful and straightforward building block to my model. The main strength of the Barberà-Jackson model is that this is a discrete model, therefore the equilibria and results are significantly easier to interpret and do comparative statics with compared to earlier, continuous models (e.g. Angeletos et al., 2007).

However, Barberà & Jackson (2016) only studies revolutionary contagion from one country to another and miss to expand it to more countries, while my aim is to give a formal interpretation on the evolution of longer chains and the differences between observing one or two countries before taking an action.

Therefore, in the second half of my thesis, I build an own model of contagion which analysis of two- and three-country long chains of revolutionary waves are also possible with. The benchmark of my framework is the Barberà-Jackson model, although I make some modifications and simplifications to make comparative statics more straightforward without losing the virtues of the original framework.

The starting point of my thesis is as follows. Let us consider a world in which there are three countries of similar characteristics. The countries correlates in the chance of having a successful revolution if they decide to revolt, while they only differ in the degree of people's dissatisfaction over the regime. We assume that people in country 1 are unhappy and determined to revolt, but citizens of country 2 and 3 are not convinced enough of the existence of critical mass to have a successful revolution. However, my findings show that observing one or more other countries' action can change the equilibrium in these countries and ultimately, people may decide to revolt.

My two key findings are as follows. First, a contagion of revolution from country 1 to country 2 can happen if the correlation between the two countries is high enough. Second, even if people in country 3 are more undetermined that in country 2, i.e. they would not take the streets after observing the successful revolution in country 1, then there is still a possible equilibrium in which country 3 will ultimately have a revolution. This happens due to the additional signal that country 3 learns by also observing the revolutionary contagion from country 1 to country 2.

Since the algebraic comparison of the results would be too difficult to interpret, I offer a graphical solution in Chapter 4 based on my model framework. By drawing the solutions, I show in a hypothetic world that an equilibrium exists in which contagion of revolution to country 3 can also happen.

The structure of my thesis is as follows. In the next chapter, I introduce the Barberà-Jackson model which is the building block of my framework. In Chapter 3, I discuss my main model about revolutionary contagion and present the two- and three-country version of my model. In the fourth part of my thesis, I draw the graphical solution of my framework using predetermined parameters. Lastly, I make some concluding remarks.

2. THE BARBERÀ-JACKSON MODEL

My main model is strongly based on the framework constructed by Barberà and Jackson (2016). Therefore, in this part of my thesis, I start by introducing their core model, while I only present my model of contagion in the next chapter.

2.1. Set-up

The framework of Barberà and Jackson (2016) is a basic, static, so-called "private values" model of collective action, where the members of a population decide simultaneously whether they *revolt*[1], not considering the other agents' type and action.

The model is built up as follows. There is a continuum of citizens of mass 1 indexed by $i \in [0,1]$. Every citizen has two possible actions, namely to participate or not to participate in a revolution. The revolution is successful if at least a fraction $q \in (0,1]$ of people participates, otherwise it fails. Every agent has a type denoted by $\theta_i \in \mathbb{R}$ which is the agent's private information about her level of dissatisfaction with the regime.

If the agent participates, she gains some additional (positive) value or (negative) cost depending on the outcome of the revolution (i.e. it succeeds or fails), respectively. The additional gain of a successful participation is denoted by the type of the agent (θ_i), while the "punishment" for participating in an unsuccessful revolution is denoted by C and is equal for all i. The payoffs of an agent depending on the outcome of the revolution and the agent's action are summarized in Table 2.1.

[1] Using the terms 'revolt' and 'revolution', as Barberà and Jackson (2016) also mention it, is rather a simplification, since the model framework is more general and can be applied in many other situations.

	$\boldsymbol{Success}$	$\boldsymbol{Failure}$
$\boldsymbol{Participate}$	θ_i	$-C$
$\boldsymbol{Not\ participate}$	0	0

Table 2.1. *Pay-off matrix of agent i in the Barberà-Jackson model.*

In the rest of the thesis, I will consider a simplified, discrete version of the model, also used by Barberà and Jackson (2016). In this set-up, agents can be either high type (θ_H) or low type (θ_L), where $\theta_H > 0$ and $\theta_L < 0$. Furthermore, let us assume that there are two states in the world: a 'High' state with probability π and a 'Low' state with probability $(1 - \pi)$ in which the proportion of agents with type θ_H or θ_L is represented in Table 2.2.

	$\boldsymbol{\theta_H}$	$\boldsymbol{\theta_L}$
$\boldsymbol{'High'\ state}$	$z > q \geq \frac{1}{2}$	$1 - z < q$
$\boldsymbol{'Low'\ state}$	$1 - z < q$	$z > q \geq \frac{1}{2}$

Table 2.2. *Proportion of agents by type in 'High' and 'Low' states.*

2.2. Strategies and equilibria

Since an agent cannot directly influence other agent's action, let $p(\theta_i)$ be agent i's belief that enough people (i.e. at least a fraction of q of the population) will show up on the streets. Considering this probability, the expected payoff of agent i if she participates is

$$p(\theta_i)\theta_i - \big(1 - p(\theta_i)\big)C$$

Therefore, agent i's best response is to participate in the revolution if and only if

$$p(\theta_i)\theta_i - \big(1 - p(\theta_i)\big)C \geq 0 \Leftrightarrow$$

$$\frac{\theta_i}{C} \geq \frac{1 - p(\theta_i)}{p(\theta_i)}$$

Otherwise, agent i's optimal strategy is to stay at home.

2.3. Solution

Applying the condition above to the discrete model, it is evident that agents of low type will never participate in any revolution, because $\theta_L < 0$, so from now on, I will only focus on agents of high type (θ_H) throughout the thesis. Regarding high type agents, the constraint to the equilibrium in which all of them take the streets can be calculated by using appropriate formula of conditional probability on the 'High' state. The main findings are summarized in Proposition 1.

Proposition 1. *In the discrete Barberà-Jackson model:*

1. *An equilibrium exists in which all high types show up if and only if* $z > q$ *and*
$$\frac{\theta_H}{C} \geq \frac{(1-\pi)(1-z)}{\pi z}.$$
2. *There exists always an equilibrium in which nobody participates.*

Proof. The first condition, i.e. $z > q$ is always satisfied in 'High' state according to Table 2.2. First, the conditional probability of a high type agent on the 'High' and 'Low' states must be calculated by using Table 2.2 and Bayes' Rule:

$$Pr_{\theta_H}('High') = \frac{\pi z}{\pi z + (1-\pi)(1-z)}$$

$$Pr_{\theta_H}('Low') = \frac{(1-\pi)(1-z)}{\pi z + (1-\pi)(1-z)}$$

Hence, by plugging back the chance of the 'High' and 'Low' states to the condition derived in the last section, the constraint for an equilibrium in which a high type agent will show up can be calculated as follows:

$$\frac{\pi z}{\pi z + (1-\pi)(1-z)}\theta_H - \frac{(1-\pi)(1-z)}{\pi z + (1-\pi)(1-z)}C \geq 0 \Rightarrow$$

$$\frac{\theta_H}{C} \geq \frac{(1-\pi)(1-z)}{\pi z}$$

This also means, that if this constraint is satisfied, then all high type agent will participate in the revolution, while if not, then all high types will stay at home. ■

3. THE MODEL OF CONTAGION

In this chapter, I introduce my main model of contagion. This is already a dynamic model in which there are countries instead of individuals. I present two versions of this expanded framework: a model with two countries deciding sequentially, and then a model with three countries also deciding to revolt one after another. These two models also use the framework of Barberà and Jackson (2016) as a building block, but I make some key modifications and simplifications which are also discussed in the this part of the thesis.

3.1. Model with two countries

3.1.1. Set-up

There are two countries, 1 and 2, that differ only in the additional value of high type agents, such that $\theta_{H1} > \theta_{H2}$. This means that agents of high type in country 1 (θ_{H1}) are more unhappy with the regime than high types in country 2 (θ_{H2}). Agents in the countries have the same cost related to participation in a revolution $(C_1 = C_2 = C)$. Furthermore, the types' correlation with the state $(z_1 = z_2 = z)$ and the "threshold-to-success" $(q_1 = q_2 = q)$ are also identical.

To sum up, using the same notations as before, the characteristics of the three countries are: (θ_{H1}, C, z, q_1) for country 1 and (θ_{H2}, C, z, q_2) for country 2. Also suppose that $z \geq q$ for both countries, which means that there is the opportunity for a successful revolution within both country 1 and country 2, in the case of 'High' state.

Whether a country is in 'High' or 'Low' state is determined by the following way. Let us assume that there is a common shock (denoted by s), which can be considered as an external regional shock. Countries having this common shock s are in the 'High' state with a probability of π, while they are in 'Low' state with a probability of $1 - \pi$. A country i (denoted by c_i) has the common shock with a probability of r or, alternatively, it has an idiosyncratic shock (denoted by

v_i) with a probability of $1 - r$. If a country i has this country-specific shock v_i, then its chance of being in 'High state' is also π, while the chance of being in 'Low' state is also $1 - \pi$.

Hence, we can easily calculate the probability that country i is being in 'High' state (H), i.e.

$$\Pr(c_i = H) = \Pr(c_i = s) \cdot \Pr(s = H) + \Pr(c_i = v_i) \cdot \Pr(v_i = H) = r\pi + (1 - r)\pi = \pi$$

Therefore, the initial probability of a country being in 'High' state is π, while the square of probability of the common shock, i.e. r^2, can be treated as the correlation term between the state in countries.

Furthermore, based on the constraint derived in Section 2.3, let us assume that

$$\frac{\theta_{H1}}{C_1} \geq \frac{(1 - \pi)(1 - z_1)}{\pi z_1}$$

but

$$\frac{\theta_{H2}}{C_2} \leq \frac{(1 - \pi)(1 - z_2)}{\pi z_2}$$

This means that in country 1, agents of high type believe that there are enough similarly unhappy people to have a successful revolution, but in country 2, high type agents are not convinced enough about the 'High' state to take the streets.

However, as Barberà and Jackson (2016) also showed it in their study, a contagion from a predecessor country toward another country is possible to happen if correlation between the states within the two countries is high enough. This means that if there is a revolution in country 1 which is observed by country 2, then people of country 2 could learn their state, update their beliefs and might decide to revolt, too.

3.1.2. Solution

To calculate the threshold value of correlation when a contagion between countries happens, the appropriate formula of conditional probabilities must be plugged back to the participation constraint. The conditions for a successful contagion of revolution are summarized in Proposition 2.

Proposition 2. *In the dynamic model of contagion with two countries (country 1 and 2), there is an equilibrium in which contagion of revolution from country 1 to country 2 takes place if and only if* $z \geq q$ *and*

$$r^2 \geq \frac{\frac{(1-z)C}{z\theta_{H2}} + \frac{\pi}{1-\pi}}{\frac{(1-z)C}{z\theta_{H2}} + 1}.$$

Proof. First, we have to calculate the conditional probability of the 'High' state in country 2 given that there is a 'High' state in country 1. By using the event and joint probabilities (see in Appendix A.1), the conditional probability can be derived (see Appendix A.2 for complete derivation):

$$\Pr\left(c_j = H \middle| c_i = H\right) = \pi + r^2(1-\pi)$$

Secondly, by plugging back the conditional probability to the appropriate formula of the constraint of Proposition 1, I get the constraint of the equilibrium when contagion happens (the detailed derivation can be found in Appendix A.2):

$$\frac{\theta_{H2}}{C} \geq \frac{[1-\pi-r^2(1-\pi)](1-z)}{[\pi+r^2(1-\pi)]z} \Leftrightarrow$$

$$r^2 \geq \frac{\frac{(1-z)C}{z\theta_{H2}} + \frac{\pi}{1-\pi}}{\frac{(1-z)C}{z\theta_{H2}} + 1}$$

Therefore, if r^2 is high enough, then a contagion from country 1 toward country 2 could happen, i.e. high type people in country 2 will revolt after observing a successful revolution in country 1 and learning their own state from it. ■

3.2. Model with three countries

3.2.1. Set-up

The three countries version of my model is built-up by the same logic as the framework with two countries. There are three countries, 1, 2 and 3, which all have the same probability (denoted by π)

of 'High' state. The countries differ only in the additional value of high type agents, such that $\theta_{H1} > \theta_{H2} > \theta_{H2}$, while they have the same cost related to participation in a revolution $(C_1 = C_2 = C_3 = C)$. Furthermore, the types' correlation with the state $(z_1 = z_2 = z_3 = z)$ and the "threshold-to-success" $(q_1 = q_2 = q_3 = q)$ are also identical in every country. Hence, using again the conventional notation, the characteristics of the three countries are as follows: (θ_{H1}, C, z, q) for country 1, (θ_{H2}, C, z, q) for country 2 and (θ_{H3}, C, z, q) for country 3.

The possible shocks a country can have are the same as in the two-country case, therefore a country's probability of being in 'High' state is also π.

This time, let us assume that

$$\frac{\theta_{H1}}{C} \geq \frac{(1-\pi)(1-z)}{\pi z}$$

but

$$\frac{\theta_{H2}}{C} \leq \frac{(1-\pi)(1-z)}{\pi z}$$

$$\frac{\theta_{H3}}{C} \leq \frac{(1-\pi)(1-z)}{\pi z}$$

This means that initially, only high type agents in country 1 would revolt, while people of high type in country 2 and 3 would stay at home, since they do not believe in the existence of a critical mass within their country to have a successful revolution.

Furthermore, let us also assume that

$$r^2 \geq \frac{\frac{(1-z)C}{z\theta_{H2}} + \frac{\pi}{1-\pi}}{\frac{(1-z)C}{z\theta_{H2}} + 1}$$

but

$$r^2 < \frac{\frac{(1-z)C}{z\theta_{H3}} + \frac{\pi}{1-\pi}}{\frac{(1-z)C}{z\theta_{H3}} + 1}$$

This means that contagion from country 1 to country 2 happens, but if people in country 3 can only observe country 1 (Note: this is also the two-country version of the model I covered above with country 1 and 3), then there is no direct contagion from country 1 toward country 3 and the latter will not revolt despite the additional information. It happens due to the lower additional value of high type agents compared to agents of high types within country 2.

However, a revolution might still happen in country 3, if people living there could observe people revolting in country 1 and also observe a successful contagion to country 2. If high type agents in country 3 could learn their type due to a high enough correlation with both predecessor countries having a successful revolution, then an information cascade might evolve and cause a revolution also in the third country.

3.2.2. Solution

To find the threshold value of correlation when the information cascade and contagion among the three countries happens, I have to take the same steps of calculation as in Section 3.1.2. The conditions for a successful contagion in the three-country case are summarized in Proposition 3.

Proposition 3. *In the dynamic model of contagion with three countries (country 1, 2 and 3), there is an equilibrium in which contagion of revolution from country 1and country 2 toward country 3 takes place if and only if* $z \geq q$ *and*

$$\frac{\theta_{H3}}{C} > \frac{\left[1 - \frac{\pi^2 + r^2 3\pi(1-\pi) + r^3(1-2\pi)(1-\pi)}{\pi + r^2(1-\pi)}\right](1-z)}{\frac{\pi^2 + r^2 3\pi(1-\pi) + r^3(1-2\pi)(1-\pi)}{\pi + r^2(1-\pi)} z}.$$

Proof. First, the conditional probability of the 'High' state in country 3 given that there is a 'High' state in country 1 and 2 must be derived (see Appendix A.2 for more detailed steps):

$$\Pr\left(s_k = 1 \middle| s_i = 1, s_j = 1\right) = \frac{\pi^2 + r^2 3\pi(1-\pi) + r^3(1-2\pi)(1-\pi)}{\pi + r^2(1-\pi)}$$

Thereafter, plugging back this conditional probability to the participation constraint of Proposition 1, I get the necessary constraint for the equilibrium with contagion in country 3 (for detailed derivation, see Appendix A.3):

$$\frac{\theta_{H3}}{C} > \frac{\left[1 - \frac{\pi^2 + r^2 3\pi(1-\pi) + r^3(1-2\pi)(1-\pi)}{\pi + r^2(1-\pi)}\right](1-z)}{\frac{\pi^2 + r^2 3\pi(1-\pi) + r^3(1-2\pi)(1-\pi)}{\pi + r^2(1-\pi)} z} \Leftrightarrow$$

$$r^2 3\pi[z\theta_{H3} + (1-z)C] - r^2(1-z)C + r^3(1-2\pi)[z\theta_{H3} + (1-z)C]$$

$$> \frac{\pi}{1-\pi}(1-z)C - \frac{\pi^2}{1-\pi}[z\theta_{H3} + (1-z)C]$$

Unfortunately, this constraint cannot be reordered to express the necessary threshold of correlation r^2 needed for contagion. However, if this constraint is satisfied, then there is an equilibrium in which a revolution in country 3 happens after observing the revolutions in country 1 and country 2. ■

4. GRAPHICAL SOLUTION OF THE MODEL

As I noted at the end of the last chapter, the three-country version of the constraint for a successful contagion has no closed form which r^2 could be expressed with. It makes any algebraic comparison more complex and hard to interpret. However, if we define values to the parameters then some intuitive and relevant comparative statics could be made and the equilibria in which contagion takes place become identifiable.

Therefore, in this section, I present a theoretical case of country 2 and country 3 with predefined parameters to show that if country 3 can learn the action of one more country (here: country 1 & 2 instead of only country 1) where revolution has happened, then a revolution in its own country will be more likely to take place, too.

4.1.1. Case A: observing only one country

First, let us consider the case when country 2 and country 3 both can only observe country 1, whether they revolt or not. It was assumed earlier that country 2 and country 3 only differ in the added value of agents of high type, such that $\theta_{H2} > \theta_{H3}$ and these high type agents of both countries are initially not convinced enough about the 'High" state. However, by Proposition 3.1, there is an equilibrium in which contagion of revolution can happen if and only if $z \geq q$ and correlation of the states in the countries is high enough. It was supposed in the last chapter that the condition $z \geq q$ is always satisfied in the 'High' state, so I will not emphasize it hereinafter and I will focus solely on the second condition.

To model a hypothetical world, I determine the key parameters such that $(\theta_{H2} = 0.2, \theta_{H3} = 0.1, C = 1, z = 0.7, \pi = 0.4)$. Hence, the second condition depending on the value of r^2 can be drawn for both countries. The results are pictured in Figure 4.1. By definition, contagion happens only on the interval where the curve is in the positive range, i.e. beyond the horizontal axis.

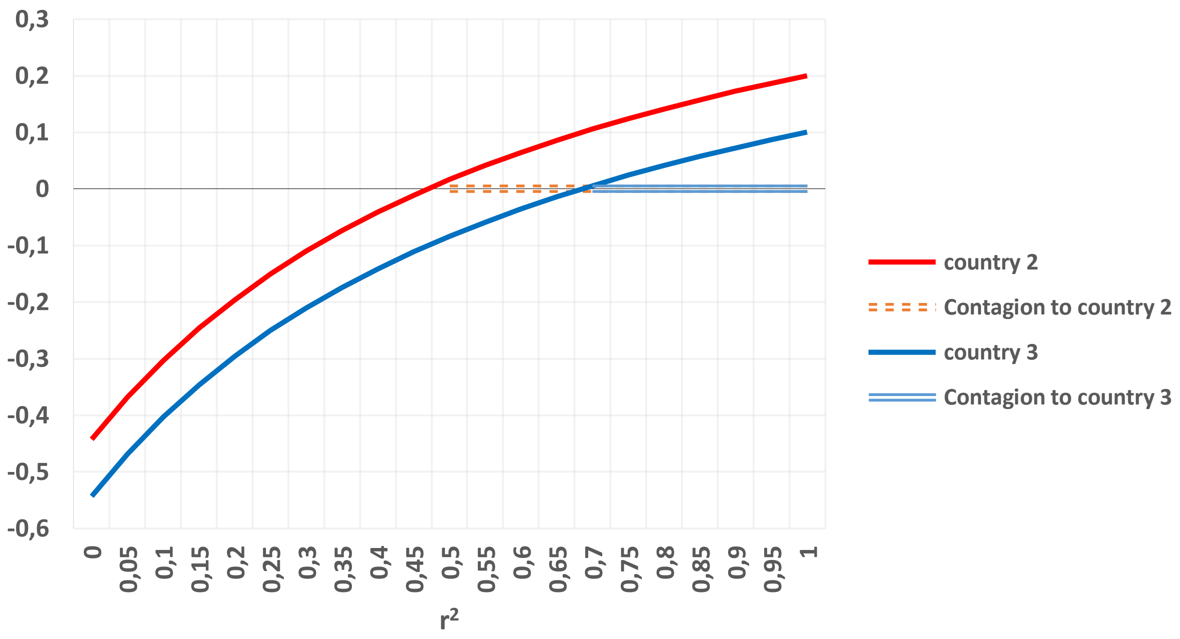

Figure 4.1. *Results for country 2 and 3 after observing country 1.*
($\theta_{H2} = 0.2, \theta_{H3} = 0.1, C = 1, z = 0.7, \pi = 0.4$)

As we can see in Figure 4.1, there is an interval of values of r^2, i.e. $[0.68,1]$ in which contagion from country 1 to country 2 and also to country 3 takes place (marked by the blue line). This means that taking the parameters, there is a contagion of revolution from country 1 to both country 2 and country 3 if and only if the correlation between the states in the countries is at least 0.68.

However, in the interval of $r^2 \in [0.47,0.68]$ (denoted by the dashed orange line), contagion only takes place from country 1 to country 2, while people in country 3 stay at home even after learning the action of a predecessor country. If correlation if less than 0.47, then there is no revolutionary contagion to any country.

4.1.2. Case B: observing two countries

The more interesting case is when we focus on country 3, while the correlation r^2 falls into the interval of $[0.47,0.68]$. Under these circumstances, as it was supposed earlier, this country does not revolt neither on its own nor after observing the action of country 1.

However, keeping the parameters and high types' values unchanged, let us suppose now that country 3 can observe both the action of country 1 and the successful contagion of revolution to country 2, which is indeed happens in this range of correlation (see above). By Proposition 3, there is equilibria in which contagion can happen also to country 3.

Now, the second condition depending on r^2 is pictured in Figure 4.2. The interpretation is the same, i.e. contagion happens only on the interval where the curve is in the positive range, i.e. beyond the horizontal axis.

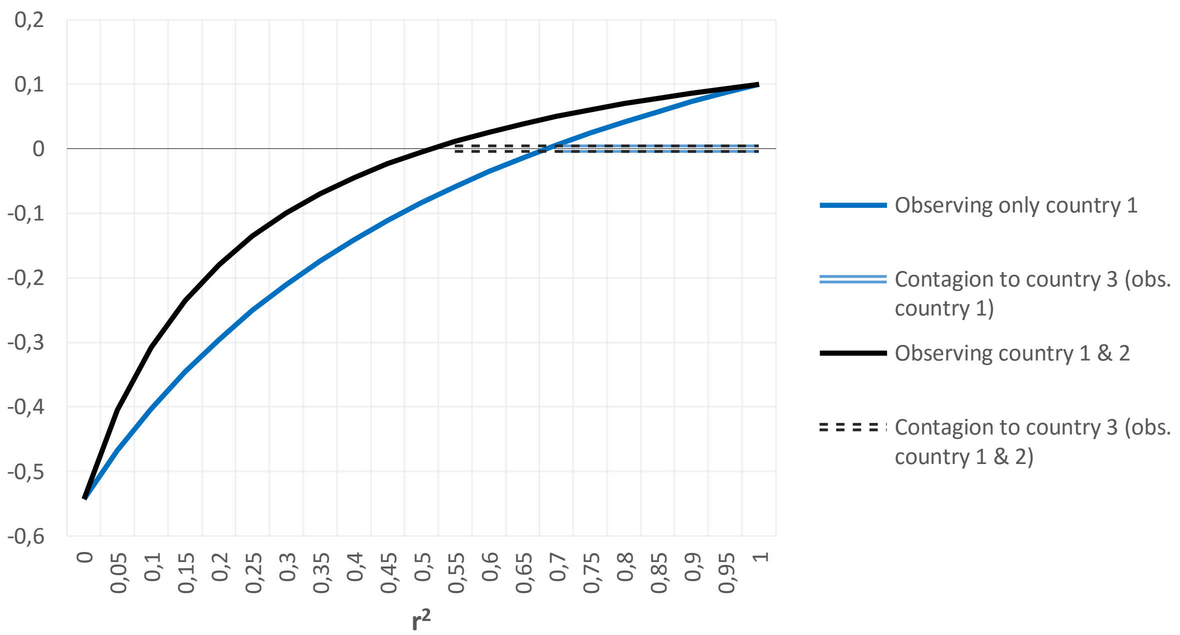

Figure 4.2 *Results for country 3 after observing both country 1 and country 2.*
($\theta_{H2} = 0.2, \theta_{H3} = 0.1, C = 1, z = 0.7, \pi = 0.4$)

As we can see in Figure 4.2, the interval of correlation (denoted by the black dashed line) in which revolutionary contagion also in country 3 takes place has increased to $[0.51, 0.68]$ compared to the previous result (denoted by the blue line). This means that for example, if the correlation of states among countries is initially $r^2 = 0.55$, then we have an equilibrium in which direct contagion from country 1 to country 3 does not happen, but if the action of country 2 is also observable by people in country 3, then they will revolt.

Note that if value of correlation is less than 0.51 than country 3 will not revolt even if they can see the action of both predecessor countries. Furthermore, the findings for the interval $r^2 \in [0.47,0.51]$ and below are the same as in Case A, i.e. revolutionary contagion from country 1 only happens to country 2 or in the latter case, neither of the countries will revolt.

5. Conclusion

Revolutionary waves has occurred from time to time in the world history. Two obvious examples are the Spring of Nations and the Arab Spring. I my thesis, I built a model to give a theoretical interpretation on the development of revolutionary waves. I especially make an inquiry into the conditions and constraints of direct and indirect contagion of revolutions, i.e. scenarios when a country revolts (or not) after learning the action of one or more predecessor countries.

In Chapter 2, I introduced a recent framework, the Barberà-Jackson model which was useful and straightforward to show some interesting characteristics of revolutionary contagion with and made it to an ideal building block of my own model. In Chapter 3, I presented my model of contagion. Based on a two- and three-country version of this framework, I derived the necessary conditions which has to be satisfied to a contagion of revolutions among countries. I also pointed out that there are countries where direct contagion does not take place. However, if the people of that country can observe more prior revolutions in other countries, then equilibria exists in which they take the streets. These findings was not particularly studied in the previous literature.

An evident direction of further research could be the incorporation of the emerging role of information technology and social media (Acemoglu, Hassan, & Tahoun, 2014; Enikolopov, Makarin, & Petrova, 2015; Hussain & Howard, 2013) related to mass demonstrations and revolutions. Furthermore, a closer look and some quantitative analysis on a broader range of historical cases would be also useful to examine the relevance of the findings of my thesis.

APPENDIX

A.1. Calculation of joint probabilities of being in 'High' state

Case of two countries

$$
\begin{aligned}
&\Pr\left(c_i = H, c_j = H\right) \\
&\quad = \Pr\left(c_i = s, c_j = s\right) \cdot \Pr(s = H) + \Pr\left(c_i = v_i, c_j = s\right) \cdot \Pr(s = H) \\
&\quad \cdot \Pr(v_i = H) + \Pr\left(c_i = s, c_j = v_j\right) \cdot \Pr(s = H) \cdot \Pr\left(v_j = H\right) \\
&\quad + \Pr\left(c_i = v_i, c_j = v_j\right) \cdot \Pr\left(v_j = H\right) \cdot \Pr(v_j = H) \\
&\quad = \mathrm{r}^2\pi + \mathrm{r}(1-\mathrm{r})\pi^2 + \mathrm{r}(1-\mathrm{r})\pi^2 + (1-\mathrm{r})^2\pi^2 \\
&\quad = r^2\pi + 2r(1-r)\pi^2 + (1-r)^2\pi^2 \\
&\quad = r^2\pi^2 - r^2\pi^2 + r^2\pi + 2r(1-r)\pi^2 + (1-r)^2\pi^2 \\
&\quad = r^2\pi - r^2\pi^2 + \pi^2[r^2 + 2r(1-r) + (1-r)^2] \\
&\quad = r^2\pi - r^2\pi^2 + \pi^2[r + (1-r)]^2 = r^2\pi - r^2\pi^2 + \pi^2 = \pi^2 + r^2\pi(1-\pi)
\end{aligned}
$$

Case of three countries

$$
\begin{aligned}
&\Pr\left(s_i = 1, s_j = 1, s_k = 1\right) \\
&\quad = \Pr\left(s_i = s, s_j = s, s_k = s\right) * \pi + \Pr\left(s_i = v_i, s_j = s, s_k = s\right) * \pi^2 \\
&\quad + \Pr\left(s_i = s, s_j = v_j, s_k = s\right) * \pi^2 + \Pr\left(s_i = s, s_j = s, s_k = v_k\right) * \pi^2 \\
&\quad + \Pr\left(s_i = v_i, s_j = v_j, s_k = s\right) * \pi^3 + \Pr\left(s_i = v_i, s_j = s, s_k = v_k\right) * \pi^3 \\
&\quad + \Pr\left(s_i = s, s_j = v_j, s_k = v_k\right) * \pi^3 + \Pr\left(s_i = v_i, s_j = v_j, s_k = v_k\right) * \pi^3 \\
&\quad = \mathrm{r}^3\pi + \mathrm{r}^2(1-\mathrm{r})\pi^2 + \mathrm{r}^2(1-\mathrm{r})\pi^2 + \mathrm{r}^2(1-\mathrm{r})\pi^2 + \mathrm{r}(1-\mathrm{r})^2\pi^3 \\
&\quad + \mathrm{r}(1-\mathrm{r})^2\pi^3 + \mathrm{r}(1-\mathrm{r})^2\pi^3 + (1-\mathrm{r})^3\pi^3 \\
&\quad = \mathrm{r}^3\pi + 3\mathrm{r}^2(1-\mathrm{r})\pi^2 + 3\mathrm{r}(1-\mathrm{r})^2\pi^3 + (1-\mathrm{r})^3\pi^3 \\
&\quad = r^3\pi^3 - r^3\pi^3 + 3\mathrm{r}^2(1-\mathrm{r})\pi^3 - 3\mathrm{r}^2(1-\mathrm{r})\pi^3 + \mathrm{r}^3\pi + 3\mathrm{r}^2(1-\mathrm{r})\pi^2 \\
&\quad + 3\mathrm{r}(1-\mathrm{r})^2\pi^3 + (1-\mathrm{r})^3\pi^3 \\
&\quad = \mathrm{r}^3\pi - r^3\pi^3 + 3\mathrm{r}^2(1-\mathrm{r})\pi^2 - 3\mathrm{r}^2(1-\mathrm{r})\pi^3 \\
&\quad + \pi^3[r^3 + 3\mathrm{r}^2(1-\mathrm{r}) + 3\mathrm{r}(1-\mathrm{r})^2 + (1-\mathrm{r})^3] \\
&\quad = \mathrm{r}^3\pi - r^3\pi^3 + 3\mathrm{r}^2(1-\mathrm{r})\pi^2 - 3\mathrm{r}^2(1-\mathrm{r})\pi^3 + \pi^3[r + (1-\mathrm{r})]^3 \\
&\quad = \mathrm{r}^3\pi - r^3\pi^3 + 3\mathrm{r}^2\pi^2 - 3\mathrm{r}^3\pi^2 - 3\mathrm{r}^2\pi^3 + 3r^3\pi^3 + \pi^3 \\
&\quad = \pi^3 + 3\mathrm{r}^2\pi^2 - 3\mathrm{r}^2\pi^3 + \mathrm{r}^3\pi - 3\mathrm{r}^3\pi^2 + 2r^3\pi^3 \\
&\quad = \pi^3 + r^2 3\pi^2(1-\pi) + r^3\pi(1-3\pi+2\pi^2) \\
&\quad = \pi^3 + r^2 3\pi^2(1-\pi) + r^3\pi(1-2\pi)(1-\pi)
\end{aligned}
$$

A.2. Calculating the conditional probabilities of being in 'High' state

Observing one country

$$
\Pr\left(c_j = H \middle| c_i = H\right) = \frac{\Pr\left(c_i = H, c_j = H\right)}{\Pr(c_i = H)} = \frac{\pi^2 + r^2\pi(1-\pi)}{\pi} = \pi + r^2(1-\pi)
$$

Observing two countries

$$\begin{aligned}\Pr\left(s_k = 1 \middle| s_i = 1, s_j = 1\right) &= \frac{\Pr\left(s_i = 1, s_j = 1, s_k = 1\right)}{\Pr\left(s_i = 1, s_j = 1\right)} \\ &= \frac{\pi^3 + r^2 3\pi^2(1-\pi) + r^3\pi(1-2\pi)(1-\pi)}{\pi^2 + r^2\pi(1-\pi)} \\ &= \frac{\pi^2 + r^2 3\pi(1-\pi) + r^3(1-2\pi)(1-\pi)}{\pi + r^2(1-\pi)}\end{aligned}$$

A.3. Deriving the constraints for contagion

Observing one country

$$\frac{\theta_{H2}}{C} > \frac{[1-\pi-r^2(1-\pi)](1-z)}{[\pi+r^2(1-\pi)]z} \Leftrightarrow$$

$$[\pi + r^2(1-\pi)]z\theta_{H2} > [1-\pi-r^2(1-\pi)](1-z)C$$

$$\pi z\theta_{H2} + r^2(1-\pi)z\theta_{H2} > (1-\pi)(1-z)C - r^2(1-\pi)(1-z)C$$

$$r^2(1-\pi)z\theta_{H2} + r^2(1-\pi)(1-z)C > (1-\pi)(1-z)C + \pi z\theta_{H2}$$

$$r^2 + r^2\frac{(1-z)C}{z\theta_{H2}} > \frac{(1-z)C}{z\theta_{H2}} + \frac{\pi}{1-\pi}$$

$$r^2 > \frac{\dfrac{(1-z)C}{z\theta_{H2}} + \dfrac{\pi}{1-\pi}}{\dfrac{(1-z)C}{z\theta_{H2}} + 1}$$

Observing two countries

$$\frac{\theta_{H3}}{C} > \frac{\left[1 - \dfrac{\pi^2 + r^2 3\pi(1-\pi) + r^3(1-2\pi)(1-\pi)}{\pi + r^2(1-\pi)}\right](1-z)}{\dfrac{\pi^2 + r^2 3\pi(1-\pi) + r^3(1-2\pi)(1-\pi)}{\pi + r^2(1-\pi)}z} \Leftrightarrow$$

$$\begin{aligned}&\frac{\pi^2 + r^2 3\pi(1-\pi) + r^3(1-2\pi)(1-\pi)}{\pi + r^2(1-\pi)}z\theta_{H3} \\ &\qquad > \left[1 - \frac{\pi^2 + r^2 3\pi(1-\pi) + r^3(1-2\pi)(1-\pi)}{\pi + r^2(1-\pi)}\right](1-z)C\end{aligned}$$

$$\begin{aligned}&[\pi^2 + r^2 3\pi(1-\pi) + r^3(1-2\pi)(1-\pi)]z\theta_{H3} \\ &\qquad > [\pi + r^2(1-\pi) - \pi^2 - r^2 3\pi(1-\pi) - r^3(1-2\pi)(1-\pi)](1-z)C\end{aligned}$$

$$\begin{aligned}&r^2 3\pi(1-\pi)z\theta_{H3} + r^2 3\pi(1-\pi)(1-z)C - r^2(1-\pi)(1-z)C + r^3(1-2\pi)(1-\pi)z\theta_{H3} \\ &\qquad + r^3(1-2\pi)(1-\pi)(1-z)C > \pi(1-z)C - \pi^2(1-z)C - \pi^2 z\theta_{H3}\end{aligned}$$

$$\begin{aligned}&r^2 3\pi[z\theta_{H3} + (1-z)C] - r^2(1-z)C + r^3(1-2\pi)[z\theta_{H3} + (1-z)C] \\ &\qquad > \frac{\pi}{1-\pi}(1-z)C - \frac{\pi^2}{1-\pi}[z\theta_{H3} + (1-z)C]\end{aligned}$$

REFERENCES

Acemoglu, D., Hassan, T., & Tahoun, A. (2014). *The Power of the Street: Evidence from Egypt's Arab Spring* (No. w20665). Cambridge, MA: National Bureau of Economic Research. Retrieved from http://www.nber.org/papers/w20665.pdf

Angeletos, G.-M., Hellwig, C., & Pavan, A. (2007). Dynamic Global Games of Regime Change: Learning, Multiplicity, and the Timing of Attacks. *Econometrica*, *75*(3), 711–756. http://doi.org/10.1111/j.1468-0262.2007.00766.x

Banerjee, A. V. (1992). A Simple Model of Herd Behavior. *The Quarterly Journal of Economics*, *107*(3), 797–817. http://doi.org/10.2307/2118364

Barbera, S., & Jackson, M. O. (2016). A Model of Protests, Revolution, and Information. *SSRN Electronic Journal*. http://doi.org/10.2139/ssrn.2732864

Barberà, S., & Jackson, M. O. (2016). *A Model of Protests, Revolution, and Information* (SSRN Scholarly Paper No. ID 2732864). Rochester, NY: Social Science Research Network. Retrieved from http://papers.ssrn.com/abstract=2732864

Bikhchandani, S., Hirshleifer, D., & Welch, I. (1992). A Theory of Fads, Fashion, Custom, and Cultural Change as Informational Cascades. *Journal of Political Economy*, *100*(5), 992–1026. http://doi.org/10.1086/261849

Brummitt, C. D., Barnett, G., & D'Souza, R. M. (2015). Coupled catastrophes: sudden shifts cascade and hop among interdependent systems. *Journal of The Royal Society Interface*, *12*(112). http://doi.org/10.1098/rsif.2015.0712

Campante, F. R., & Chor, D. (2012). Why was the Arab World Poised for Revolution? Schooling, Economic Opportunities, and the Arab Spring. *Journal of Economic Perspectives*, *26*(2), 167–188. http://doi.org/10.1257/jep.26.2.167

Enikolopov, R., Makarin, A., & Petrova, M. (2015). Social Media and Protest Participation: Evidence from Russia. *SSRN Electronic Journal*. http://doi.org/10.2139/ssrn.2696236

Hussain, M. M., & Howard, P. N. (2013). What Best Explains Successful Protest Cascades? ICTs and the Fuzzy Causes of the Arab Spring. *International Studies Review*, *15*(1), 48–66. http://doi.org/10.1111/misr.12020

Kricheli, R., Livne, Y., & Magaloni, B. (2011). Taking to the Streets: Theory and Evidence on Protests under Authoritarianism. *APSA 2010 Annual Meeting Paper*. Retrieved from http://ssrn.com/abstract=1642040

Kuran, T. (1991). The East European Revolution of 1989: Is it Surprising that We Were Surprised? *The American Economic Review*, *81*(2), 121–125.

Lohmann, S. (1994). Information Aggregation Through Costly Political Action. *The American Economic Review*, *84*(3), 518–530.