

# Calculating Risk for Food Crises in the Middle East: The Role of Social Network Analysis

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## Executive Summary

### Introduction

Net food-importing countries face unique challenges in food security. Traditional value chain analysis and food security assessments do not consider a country's international trade network when calculating the food security levels of a country. This project focuses on wheat trade in the Middle East and North Africa (MENA) region.<sup>1</sup> Wheat is highly consumed in the region, which is overall a net importer of the commodity. In addition, wheat has a cultural importance in the region—riots and civil unrest have often been tied to the rise in bread prices, and the existence of various subsidies of wheat and wheat products demonstrate the importance of making this commodity available to the population. However, the region as a whole is a net-importer of this commodity. Because of this, traditional mechanisms of food security assessments, which generally focus on domestic production, do not give a full picture of a country's food security risks. Instead, assessments of the security of the wheat supply in most MENA countries should consider international trade indicators.

### Methodology

This research uses social network analysis methodology, and analyzes the global trade network in terms of the following indicators: *number of links*, *network density*, *average clustering coefficient*, and *average betweenness centrality*. Then, the top ranking countries are reported in two node-level indicators, *eigenvector centrality*, which detects major players overall, and *authority centrality*, which detects the most well connected importing countries. Finally, the analysis looks at 4 major export bans that affected the MENA region between 2005 and 2010, and notes several reactionary steps that MENA countries used to maintain supplies of wheat in the face of these bans. Reasons for failure to maintain supplies were also noted.

### Policy Question

This research attempts to add to the understanding of the global wheat trade network from 1990-2012, with a particular focus on the MENA region. As several export bans between 2005 and 2010 provide exogenous shocks to the markets, another section of the analysis addresses MENA countries' reactions to these sudden barriers to trade. As a preliminary look at the wheat trade network over time, this research addresses the question: *How has the international trade network of grain in the MENA region reacted to economic shocks since 1990? How can analyzing the evolution of this trade network inform food security measures for the region?*

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<sup>1</sup> Algeria, Bahrain, Djibouti, Egypt, Iran, Iraq, Jordan, Kuwait, Lebanon, Libya, Malta, Morocco, Oman, Qatar, Saudi Arabia, Sudan, Syria, Tunisia, United Arab Emirates, West Bank and Gaza, and Yemen.

## Results

Overall, the network is becoming more dense but less divided into clusters as countries are diversifying their trade and instigating partnerships outside of their previous clusters. On an individual country level, centrality measures can demonstrate when a country has succeeded or failed in forming new partnerships or increasing trade with important partners, often to overcome a barrier to trade such as an export ban. Finally, countries take different steps to overcome trade bans—forming new partnerships, increasing trade with existing partners, or increasing production. It seems that countries with some political clout or purchasing power from their size are able to accomplish this.

## Conclusion

Social network analysis indicators are accurately descriptive in the actions of a country takes overcome a ban. Depending on changes in the rest of the network, if a country increases its partnerships or increases quantity traded from important partners in order to overcome a ban, this action increases the country's centrality scores. While this analysis did not test a theory of correlation between a certain indicator and ability to maintain supplies, data from this project could be used to do so. It is recommended that further research explore what indicators would be useful to predict risk, and what indicators (if any), could be useful to predict resilience in the face of that risk.

## Overview

Net food-importing countries face unique challenges in food security. Traditional value chain analysis and food security assessments do not consider a country's international trade network when calculating the food security levels of a country. This project focuses on wheat trade in the Middle East and North Africa (MENA) region.<sup>2</sup> Wheat is highly consumed in the region, which is overall a net importer of the commodity. In addition, wheat has a cultural importance in the region—riots and civil unrest have often been tied to the rise in bread prices, and the existence of various subsidies of wheat and wheat products demonstrate the importance of making this commodity available to the population. However, the region as a whole is a net-importer of this commodity. Because of this, we cannot use traditional mechanisms of food security assessments, which generally focus on domestic production. Instead, assessments of the security of the wheat supply in most MENA countries should consider international trade indicators.

This project gives an overview of existing international trade indicators used by food security organizations, and then adds to this body of knowledge by assessing the global wheat network using new tools developed in the field of Social Network Analysis. Finally, the project will focus on export bans that affected the global availability and price of wheat during the period of 2005-2010. Extra attention will be paid to MENA countries' reactions to these bans, to understand how some net-importing countries were able to maintain supplies but others were not.

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<sup>2</sup> Algeria, Bahrain, Djibouti, Egypt, Iran, Iraq, Jordan, Kuwait, Lebanon, Libya, Malta, Morocco, Oman, Qatar, Saudi Arabia, Sudan, Syria, Tunisia, United Arab Emirates, West Bank and Gaza, and Yemen.

Policy makers will find this analysis most useful for improving understanding of food security assessment methodology for food-importing countries. The portion of this project which analyzes the results of the export bans on importing countries' wheat supplies are also relevant to understanding the effects of barriers to trade, such as export taxes or embargoes, on net-importing countries' supply levels.

In the background statement, Section A gives an overview of global wheat trade, including state-trading enterprises, major transnational companies, and global price transmission. This section also gives an overview of export restrictions and their effects on net-importing countries. Next, Section B focuses on wheat trade in the MENA region, noting both specific vulnerabilities and risks, as well as attempts to address these risks through subsidies and trade agreements. Finally, Sections C and D take a look at food security analysis in the MENA region and existing food security indicators that consider international trade.

In the data and methodology section, Social Network Analysis methods are presented as potential additional methods relevant to food security analysis for net-importing countries. Specific indicators that are most relevant to trade analysis are described. The findings section presents first an overview of the global wheat network in general, noting trends in certain relevant indicators. This is followed by an analysis of the key players of the network in terms of node-specific indicators, with a focus on the movements of MENA countries in the rankings. Finally, the last section takes an in-depth

look at changes in supply, trading partners, and centrality measures in the MENA region as a response to trade bans in the years 2005-2010. Conclusions summarize findings and point out further opportunities for research.

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## Section 1: Background

### A. Global Wheat Trade

This section gives an overview of the big players in global wheat trade both in the government and in the private sector. This section also speculates about the transmission of global price to local price in the wheat market, and finally addresses export bans—why exporting countries implement them and their effects on importing countries.

#### I. State-Trading Enterprises

The Uruguay Roundtable defines State-Trading Enterprises (STE's) as:

*“Governmental and non-governmental enterprises, including marketing boards, which have been granted exclusive or special rights or privileges, including statutory or constitutional powers, in the exercise of which they influence through their purchases or sales the level or direction of imports or exports.”<sup>3</sup>*

In the agriculture industry, these are typically statutory marketing boards. Goals of these boards include protection for domestic producers and price stabilization for consumers.<sup>4</sup> In the 1970s, STE's controlled 90% of wheat imports. In 1996, the number was down to 73% of imports and 40% of exports.<sup>5,6</sup> Reforms of many of these markets were tied to World Bank loans or political intervention from developed countries. STEs in Canada and Australia control all their grain exports, accounting for 24% of the world exports of wheat.

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<sup>3</sup> World Trade Organization, *The Results of the Uruguay Round of Multilateral Trade Negotiations: The Legal Texts*, 1994, pp. 509-511.

<sup>4</sup> Ackerman, Karen Z, and M Dixit Praveen. “An Introduction to Trading in Agriculture.” *USDA Market and Trade Economics Division, Economic Research Service* 783 (2014): 141.

<sup>5</sup> Young, Linda M. “Prevalence and Reform of State Trading Importers in World Grain Markets.” *Trade Research Center, Montana State University* 32 (1999): n. pag. Print.

<sup>6</sup> Ackerman, Karen Z, and M Dixit Praveen. “An Introduction to State Trading in Agriculture.” *USDA Market and Trade Economics Division, Economic Research Service* 783 (2014): 141.



The level of monopolistic control, the range of products controlled, the market for the commodity, distance from the government, trade orientation and the policies the STE uses can all affect the amount of influence the STE has. For example, export oriented STE's can use their rights and privileges to cross subsidize export sales, use domestic price pooling, or create discriminatory long-term agreements with importing countries. Importing STE's can set import amounts and can discriminate on the allocation of tariff rate quotas, grades and standards.<sup>7</sup> Various market failures in the industry can justify the monopolistic behaviors of STEs.

There is movement to make STEs more open and cooperative with the private sector. Several MENA countries reformed their STE's in order to receive World Bank funding. However, even after reform, Egypt's STE, the General Authority for Supplies and Commodities, still controls 70% of its wheat imports. Depending on the market, private firms may step in when an STE is reformed. In Africa, a lack of available credit inhibited private enterprises' ability to take the place of STE's. However, in Asia private firms did move in when STE's were reformed, and this allowed greater return to investors.<sup>8</sup>

## **II. Transnational Companies**

The other big players in the grain industry are transnational companies. The biggest ones are known as the ABCD's: Archer Daniels Midland (ADM), Bunge, Cargill, and Louis Dreyfus. In 2013, Louis Dreyfus handled 15% of global grain exports, while Cargill exported 35% of US grain and 25% of Argentina's grain. Unlike STEs, which are not

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<sup>7</sup> "Agricultural State Trading Enterprises and Developing Countries: Some Issues in the Context of the WTO Negotiations." *FAO Papers on Selected Issues Relating to the WTO Negotiations on Agriculture* (2002): 89-115. Print.

<sup>8</sup> *ibid.*

vertically integrated and only deal with the trade component of the commodity, these firms are vertically integrated and often deal with: production, storage (in both importing and exporting countries), shipping, and financing. The ABCDs have also assumed the role of banks by becoming involved in futures trading.

Scoppola (2007) presents a game theory model of what would cause the switch between STE to private firm dominated exports for a country—changes in transaction costs or fixed costs, differentiation of the commodity, or competition by price instead of quantity.<sup>9</sup>

### III. Global Price Transmission

The global price of a commodity can affect its local price in varying degrees, depending on the commodity. Minot (2011) found that transmission from global to domestic prices occurs more often when (a) the commodity is more highly trade-able and (b) the country is more import-dependent on this commodity.<sup>10</sup> For example, in Africa domestic prices of plantains and maize are less correlated with global prices because they less often internationally traded and more often domestically produced. However, rice, which is more often internationally traded, exhibits a higher correlation between domestic and local prices. In the MENA region, domestic prices of wheat are transmitted from global prices because with it is a highly tradable good. In addition, domestic wheat prices will be more highly correlated with global prices in the countries that produce less wheat. Minot also finds that local prices change more than the global price in countries where domestic

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<sup>9</sup> Scoppola, Margherita. "Economies of Scale and Market Structure in International Grain Trade." *Agricultural Economics* 37 (2007): 277–291. Print.

<sup>10</sup> Minot, Nicholas. "Transmission of World Food Price Changes to Markets in Sub-Saharan Africa." *IFPRI Discussion Paper* 01059 (2011): n. pag. Print.

policies or production fluctuations could play a role. Middle Eastern countries, which have a high level of government-created market distortions, fall into this category.

#### **IV. Export Restrictions and Net-Importing Countries**

Governments in net-exporting countries enact export restrictions to keep domestic prices low. For example, in 2007 a political justification for India's export ban was that it would maintain low and stable domestic food prices.<sup>11</sup> Another justification for export bans is that they allow a country to maintain adequate buffer stocks to protect against future shocks. For example, during the 2008 food crisis, Russia increased export taxes to combat a rapidly falling stocks-to-use ratio.<sup>12</sup> Usually these restrictions benefit net-exporting countries.<sup>13</sup>

For net-importing countries, however, these bans can be detrimental and cause a government to take drastic steps to maintain the necessary food supply. First, a period of "panic purchasing" may occur in the months before the ban is enacted. For example, prior to an export ban on rice cut the Philippines from several of their trading partners, the government imported 1.3 million metric tons of rice in 2008, surpassing their total imports from 2007.<sup>14</sup>

After panic purchasing, most countries either find new trading partners or rely more heavily on current partners. Often, countries respond by relaxing certain restrictions

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<sup>11</sup> Dorosh, Paul A.; Shahidur Rashid. (2013). Trade subsidies, export bans and price stabilization: Lessons of bangladesh-india rice trade in the 2000s. *Food Policy*, 41, 103.

<sup>12</sup> Dollive, K. (2008). The impact of export restraints on rising grain prices No. 2008-09-A). Washington, DC: United States International Trade Commission.

<sup>13</sup> Laborde Debucquet, D., & Bouët, A. (2012). Food crisis and export taxation: The cost of non-cooperative trade policies. *Review of World Economics*, 148(1), 209-233. doi:10.1007/s10290-011-0108-8

<sup>14</sup> Headey, D. (2011). Rethinking the global food crisis: The role of trade shocks. *Food Policy*, 36(2), 136-146. doi:10.1016/j.foodpol.2010.10.003

such as quotas, regulations, and tariffs.<sup>15,16</sup> For example, after Argentina's export ban of wheat in 2007, Brazil replaced its 85% market share of imports from Argentina by increasing imports from other nations in MERCOSUR (the Latin American customs group), Canada and the US. To achieve this, Brazil reduced import tariffs on non-Mercosur imports, and relaxed import quotas.<sup>17</sup> South Korea was also affected by an export ban, on Chinese maize. The government diversified by starting a new trading relationship with Indonesia and increasing US imports drastically.<sup>18</sup> A final strategy for importing countries is to tap into their buffer stocks. This short-term strategy is typically coupled with other coping mechanisms. For example, Bangladesh released 702,000 metric tons of rice to local markets to maintain adequate supply and low prices during the crisis of 2008.<sup>19</sup>

Export restrictions serve their purpose in keeping supplies high and domestic prices low for net-exporting countries, but they greatly impact net-importing countries' prices and supplies. For example, after export bans put in place by Russia and the Ukraine in 2007, demand for US wheat increased drastically. The US price increased by 70% in 3 months and US exports nearly doubled.<sup>20</sup> Export bans also adversely effect total global supply of the commodity, and often impact real national income of net-importing countries.

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<sup>15</sup> Laborde Debucquet, D., & Bouët, A. (2012). Food crisis and export taxation: The cost of non-cooperative trade policies. *Review of World Economics*, 148(1), 209-233. doi:10.1007/s10290-011-0108-8

<sup>16</sup> Dollive, K. (2008). The impact of export restraints on rising grain prices No. 2008-09-A). Washington, DC: United States International Trade Commission.

<sup>17</sup> Ibid

<sup>18</sup> Ibid

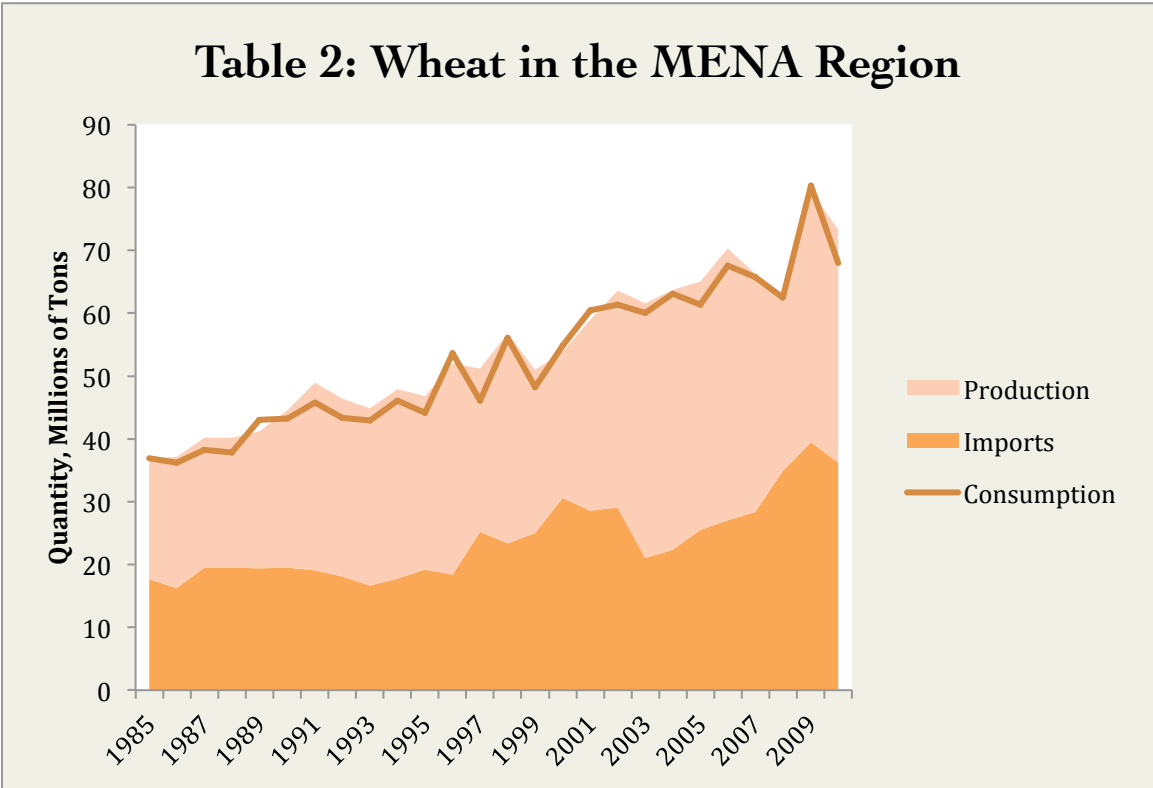
<sup>19</sup> Dorosh, Paul A.; Shahidur Rashid. (2013). Trade subsidies, export bans and price stabilization: Lessons of bangladesh-india rice trade in the 2000s. *Food Policy*, 41, 103.

<sup>20</sup> According to Bouet (2011), wheat markets are especially vulnerable to export restrictions. He estimates that export restrictions on wheat can lead to additional world price increases of 16.8%. When net importers react by reducing import tariffs, the price increases by an additional 28.3%. Both export restrictions and import tariff reductions combined can increase wheat prices by up to 41.1%.

Bouet (2011) estimated that, Egypt and East Africa’s real national incomes were reduced by .85% and .37%, respectively, because of export restrictions.

**B. The Wheat Market in the MENA Region**

This section provides an overview of wheat trade in the MENA region: market distortions such as subsidies and tariffs, vulnerabilities and risks in the region, and attempts to mitigate this risk through bilateral trade agreements as well as technology development to increase production.



Source: UN ComTrade: sum of reported exports. Djibouti excluded because of incomplete data.

The Middle East is the largest net importing region of cereals, purchasing approximately 27% of all globally traded wheat.<sup>21 22</sup> On average, the region imports 40% of the wheat it consumes, with some countries such as Libya importing up to 90%.<sup>23</sup> Top ten exporters of wheat to the MENA region are: Argentina, Australia, Canada, France, Germany, Kazakhstan, Russia, Turkey, Ukraine and USA. As the average cost of wheat increases, global price volatility is also rising. The increase in price volatility is due to several factors, including an increasing demand for biofuels, fluctuation in oil prices, depreciation of the US dollar relative to other currencies, and rising commodity speculation.<sup>24</sup>

## I. Market Distortions

Wheat has a cultural importance in the region, where 37% of daily caloric consumption is wheat products. Because of this, government involvement in both the domestic production industry and the price of the imported commodity is strong, distorting the market through price controls or subsidies. Overall, the MENA region is considered highly protective of agricultural activities, scoring higher than the global average on several indicators for agricultural protection.<sup>25</sup> Some examples of protectionist production policies utilized in the region include procurement price floors, guaranteed

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<sup>21</sup> Wright, Brian, and Carlo Cafiero. 2011. "Grain Reserves and Food Security in the Middle East and North Africa." *Food Security* 3 (S1) (February 12): 61–76. doi:10.1007/s12571-010-0094-z. <http://link.springer.com/10.1007/s12571-010-0094-z>.

<sup>22</sup> FAO, 2013. FAOSTAT Database on Agriculture. Food and Agriculture Organization of the United Nations (FAO). Rome, Italy.

<sup>23</sup> Larson, Donald F. 2012. "Food Security and Storage in the Middle East and North Africa." World Bank Policy Paper (April). [http://papers.ssrn.com/sol3/papers.cfm?abstract\\_id=2035787](http://papers.ssrn.com/sol3/papers.cfm?abstract_id=2035787).

<sup>24</sup> The World Bank and FAO (2012). *The Grain Chain: Food Security and Managing Wheat Imports in Arab Countries*. Washington DC, The World Bank and Food and Agriculture Organization of the United Nations.

<sup>25</sup> *ibid*, 10.

purchase prices, import tariffs reflecting the Cost, Insurance and Freight (CIF) price, and value-added taxes (VAT) which are dependent on end use.<sup>26</sup>

In addition, intra-country trade in the region is more costly than trade between the MENA region and Europe. The reasons for these high costs include: non-tariff restrictions between MENA regions; underperforming and disrupted logistics services between countries; and a lack of coordination in intraregional infrastructure. Fragmented coordination stems from a lack of trust of the standards or origin of products, particularly because the Pan Arab Free Trade Agreement removes tariffs on goods of Arab origin.<sup>27</sup>

Since most countries in the MENA region are net-importers of wheat, in the face of a shock in the market, governments focus their protectionist measures on demand side dynamics. For example, during the Arab Spring, Jordan revived food subsidies they had recently cut, and initiated tax exemptions on 13 food items.<sup>28</sup> Various subsidies on flour and bread in Egypt, Jordan, and Morocco also keep demand high and prices artificially low.<sup>29</sup> <sup>30</sup> Research shows that many of these subsidies, such as those on retail food in urban markets in Egypt, imported materials for food processing, and fuel for transport and irrigation in Yemen, disproportionately assist those with a higher socio-economic status.<sup>31</sup>

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<sup>26</sup> "Policies for Basic Food Commodities." *Food and Agriculture Organization* (2005): n. pag. Print.

<sup>27</sup> "Using Trade Policy to Overcome Food Insecurity." *Global Monitoring Report 2012: Food Prices, Nutrition, and the Millennium Development Goals*. World Bank, 2012. 117–134.

<sup>28</sup> *ibid*, 125.

<sup>29</sup> Obeidat, Omar. "Bakery Owners Reject Smart Card Plan to Regulate Bread Subsidy." *The Jordan Times* 28 Aug. 2013.

<sup>30</sup> Wallace, Stuart. "Morocco Buys 160,000 Tons of Local Wheat for Flour Supply." *Bloomberg* 6 Aug. 2013 : n. pag. Print.

<sup>31</sup> Breisinger, Clemens, Claudia Ringler, Catherine Aragon, and Olivier Ecker. 2010. "Food Security and Economic Development in the Middle East and North Africa Current State and Future Perspectives." p42.

## II. Vulnerabilities and Risks

Sadler, et al divide the risks faced by the MENA region grain market into three types, and propose relevant solutions to each.<sup>32</sup> First, physical availability of grain is threatened by global weather patterns or infestations. Declining global stocks and increasing consumption have intensified the impact of this risk. Stockpiling, through the public or private sector, and overseas or domestically, could address this risk but may do so at a high cost. Saudi Arabia is following this track. The country aims to be 100% dependent on wheat imports by 2016 in order to save water. They've signed deals to build new wheat silos and mills at Jazan Port, which will raise storage capacity to three million tons of wheat, meeting annual consumption.<sup>33</sup>

Counterparty risks include the possibility that a trade partner will fail to deliver the agreed-upon quantity at the agreed-upon price. These risks will be impacted by both commercial factors such as a failure to secure freight at the proper rate, and non-commercial factors such as a natural disaster or conflict disrupting the planned transaction. A recent relevant example of this is the Gulf Wars in Iraq, which led to the disruption of both wheat imports and domestic production. These risks can be mitigated through spot purchasing or longer-term contracts.

Finally, grain trade is vulnerable to price risk, as raw prices and volatility continue to increase since 2000. With climate change's adverse effect on production, and as well as

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<sup>32</sup> Sadler, Marc, and Nicholas Magnan. 2011. "Grain Import Dependency in the MENA Region: Risk Management Options." *Food Security* 3 (S1) (February 12): 77-89. doi:10.1007/s12571-010-0095-y. <http://link.springer.com/10.1007/s12571-010-0095-y>.

<sup>33</sup> Khan, Ghazanfar Ali. 2013. "Pioneering Saudi Farm Techniques Bear Fruit." *Arabnews.com*, September 23. <http://www.arabnews.com/news/465523>.



continued growing populations and rising consumption, price risk does not appear to be decreasing. Some options to mitigate price risk include futures and options trading, and forward contracts. More domestic growth or stockpiling will also mitigate this risk. The World Bank advises against increased domestic growth, as it does not consider it the most efficient alternative for the region.<sup>34</sup> Strategic moves such as Saudi Arabia's increased capacity for stockpiling imported grain and Gulf countries' foreign investment in agricultural development in partner countries, seem to indicate that most MENA countries are following this advice.

Export restrictions increase all three types of the risks listed above.<sup>35</sup> For example, in 2008, the following countries instigated exports bans on grain: Argentina, India, Kazakhstan, Pakistan, Ukraine, Russia, and Vietnam. These restrictions limited the availability of grain, led to a temporary loss of trade partners, and raised prices. Potential paths to mitigating this risk is for net-importing countries to form agreements with major exporters to ensure preferential treatment in the case of a food export ban, or to use political pressure to outlaw such export bans in the future.

IFPRI notes that reliance on oil exports makes the region's food security more tenuous—fluctuations in the market for oil can affect oil-exporting countries' ability to purchase sufficient wheat.<sup>36</sup> Crude price fluctuations will have diverse effects on countries in the MENA region depending on whether or not they produce oil. For energy-exporters,

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<sup>34</sup> "MENA Region: Agriculture and Rural Development." World Bank Group (2008): n. pag. Web. 7 Nov. 2013.

<sup>35</sup> *ibid.*

<sup>36</sup> Breisinger, Clemens, Claudia Ringler, Catherine Aragon, and Olivier Ecker. 2010. "Food Security and Economic Development in the Middle East and North Africa Current State and Future Perspectives."

rising prices of fuel can balance the rising price of food on the global level. However, those in mineral rich countries who are not a part of the fuel market will disproportionately feel the impacts of rising prices of food. Furthermore, MENA countries that do not produce oil face a doubled risk when rising fuel prices are coupled with rising food prices. This is particularly true in the case of grain, where transportation costs are often higher than actual commodity prices.<sup>37</sup>

### III. Trade Agreements and other Efforts at Increasing Food Security

In recent years, MENA countries have become more active in the global food policy discussion. Qatar's National Food Security Programme has taken the lead in innovative research and development to combat water scarcity, and in the policy arena by creating the Global Dry Land Alliance in 2012, a treaty-based alliance among countries who face extreme dry land challenges.<sup>38</sup> The alliance's goals are to solve common food security problems by sharing knowledge and best practices, provide assistance in times of need, fund technological research and innovation, and plan for food crisis responses.

Bilateral trade agreements are in process in with many of the major exporters of wheat to the region. The EU has signed free trade agreements (FTAs) with Tunisia, Israel,

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<sup>37</sup> Sadler, Marc, and Nicholas Magnan. 2011. "Grain Import Dependency in the MENA Region: Risk Management Options." *Food Security* 3 (S1) (February 12): 77-89. doi:10.1007/s12571-010-0095-y. <http://link.springer.com/10.1007/s12571-010-0095-y>, p86.

<sup>38</sup> "UN Secretary General Ban Ki-Moon Pledges Full Support to Qatar for Establishing the Global Dry Land Alliance (GDLA)." 2012. *Qatar National Food Security Programme*. <http://www.prnewswire.com/news-releases/un-secretary-general-ban-ki-moon-pledges-full-support-to-qatar-for-establishing-the-global-dry-land-alliance-gdla-160124985.html>.

Morocco, Jordan, Egypt, Algeria, Lebanon and the Palestinian Authority.<sup>39</sup> The US has signed FTAs with Morocco, Jordan, Israel, the UAE, Bahrain and Oman. The Bush administration began plans for a comprehensive Middle East FTA (MEFTA), with a deadline of 2013, but this agenda has not been continued by the Obama administration. Currently, Egypt is in negotiations with Russia and Mercosur (a customs union between Latin American countries which include Argentina, a major exporter of wheat). The Gulf Cooperation Council (GCC)<sup>40</sup> is also in negotiations with Australia, Russia, the EU and Mercosur. Regionally, MENA countries are members of the Greater Arab FTA (GAFTA), which began in 1997 and achieved the elimination of tariffs between members. The Agadir Agreement for the Establishment of a Free Trade Zone (2004) connects Mediterranean countries of Egypt, Jordan, Morocco and Tunisia. Egypt and Libya are also members of the Common Market of Eastern and Southern Africa (COMESA). As stated above, these agreements do not necessarily translate to efficient market structures. In addition, the League of Arab States has proposed a monitoring mechanism that would track the global availability of grains and other commodities, as well as locate the needed quantities of assistance in a crisis.

Gulf states have invested in countries not known for their food export capacity but who serve as natural partners due to physical proximity, political connections or cultural similarities. These include Pakistan, Sudan and Ethiopia. While Pakistan now contributes a significant amount of rice to the region, other countries have yet to provide returns on the

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<sup>39</sup> Khouri, R Al. "EU and US Free Trade Agreements in the Middle East and North Africa." *Carnegie Middle East Center* 8 (2008): n. pag. Web. 26 Nov. 2013.

<sup>40</sup> Bahrain, Kuwait, Oman, Qatar, Saudi Arabia, and the United Arab Emirates

investment of agriculture development.<sup>41</sup> Several of these countries currently experience food scarcity themselves. Agro-investments will prove helpful to Gulf States but it is clear that the “bread-basket” option alone will not solve the food security issue in the region. The use of export barriers to protect domestic prices in the face of food crises, have demonstrated that agro-investments alone will not guarantee food security.<sup>42</sup>

Arab states will disproportionately feel the effects of climate change.<sup>43</sup> Qatar has attempted to combat the issue of water scarcity and climate change through innovative new techniques in hydroponics, desalinization and harnessing solar energy to gather more water.<sup>44</sup> While these new investments are exciting opportunities for alternative energy sources and new agricultural methods, there is no way that the entire region could benefit from or reproduce these methods at a large enough scale to remove susceptibility to food crises.

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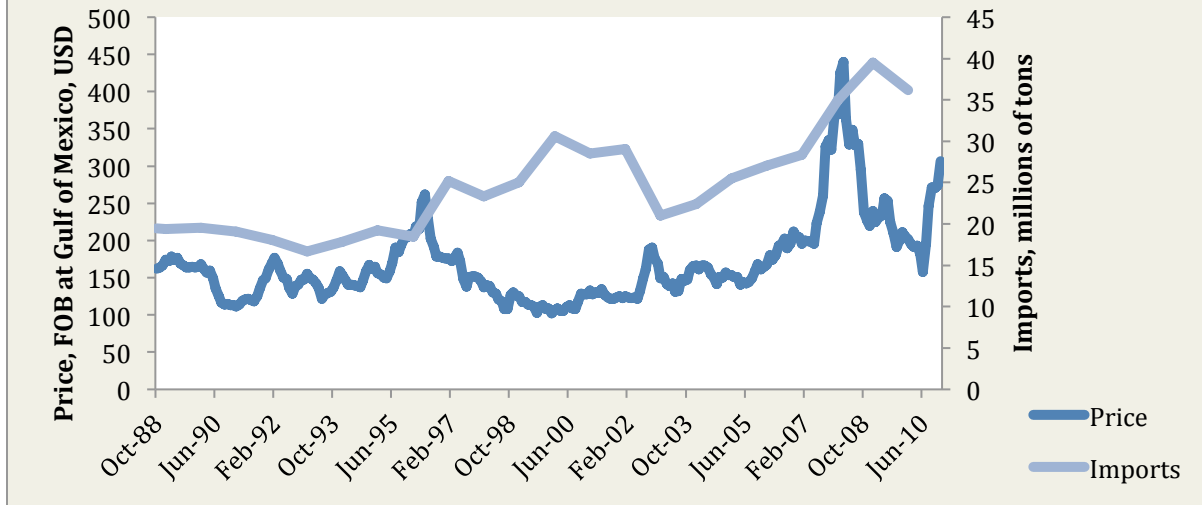
<sup>41</sup> *ibid.*

<sup>42</sup> Woertz, Eckhart. 2013. “Oil For Food: Big Business in The Middle East.” *World Financial Review*. <http://www.worldfinancialreview.com/?p=2773>.

<sup>43</sup> “Vulnerability and Adaptation of the Water Sector to Climate Change.” 2013. *UNDP: Water Governance Program for Arab States*. Accessed October 20. <http://www.wgpas-undp.org/index.php/en/vulnerability-and-adaptation-of-the-water-sector-to-climate-change>.

<sup>44</sup> TEDxSummit. 2012. “Fahad Al-Attiya: A Country with No Water.” [http://www.ted.com/talks/fahad\\_al\\_attiya\\_a\\_country\\_with\\_no\\_water.html](http://www.ted.com/talks/fahad_al_attiya_a_country_with_no_water.html).

**Table 3: Global Wheat Price and Imports to the MENA region**



Source: UN Comtrade (import quantities\*), World Bank (price).

\*Djibouti excluded from import quantities because of incomplete information.

### C. Food Security in the MENA Region: Classifying and Analyzing the Risk

This section provides an overview of food security in the MENA region, and its diverse causes and effects on the citizens of MENA countries.

The story of food insecurity in the Middle East is a story, first and foremost, of water scarcity. Since the 1970s, the region has not been able to grow sufficient food to feed its growing population because of a lack of water and arable land, and a rapidly increasing and urbanized population. Today, the Middle East is dependent on food exporters like the US, Russia or Australia.<sup>45</sup> In 2008, the region's food imports totaled USD61.4 billion (50% of its food requirement); this number is expected to grow to USD92.4 billion by 2020.<sup>46</sup>

<sup>45</sup> Woertz, Eckart. 2011. "Arab Food, Water, and the Big Landgrab That Wasn't." *Brown J. World Aff.* 1-17. [http://heinonlinebackup.com/hol-cgi-bin/get\\_pdf.cgi?handle=hein.journals/brownjwa18&section=14](http://heinonlinebackup.com/hol-cgi-bin/get_pdf.cgi?handle=hein.journals/brownjwa18&section=14).

<sup>46</sup> "MENA Food Security : Are We Doing Enough to Feed the Population?" 2011. Al Masah Capital Limited: 1-60.

The most common categorization of countries in the region is by possession of energy resources. IFPRI categorizes food security challenged countries in the MENA region by those that are resource-rich: Algeria, Iraq, Libya, Sudan, Syria and Yemen; and those that are resource-poor: Djibouti, Egypt, Jordan, Lebanon, Morocco, Tunisia, and the Palestinian territories.<sup>47</sup> Other categorizations, as shown in Table 1, also consider labor supply.

**Table 1: Classifying Food Security in the MENA Region by Labor and Resources**

| Resource-Poor<br>Labor Abundant | Resource-Rich<br>Labor Abundant | Resource-Rich<br>Labor Importing |
|---------------------------------|---------------------------------|----------------------------------|
| Comoros                         | Yemen                           | Libya                            |
| Djibouti                        | Algeria                         | Bahrain                          |
| Mauritania                      | Sudan                           | Kuwait                           |
| Somalia                         | Syria                           | Oman                             |
| West Bank and Gaza              | Iran                            | Qatar                            |
| Egypt                           | Iraq*                           | Saudi Arabia                     |
| Jordan                          |                                 | United Arab Emirates             |
| Lebanon                         |                                 |                                  |
| Morocco                         |                                 |                                  |
| Tunisia                         |                                 |                                  |
| Israel*                         |                                 |                                  |
| Acute Food Insecurity           | Moderate Food Insecurity        | Low Food Insecurity              |

Food Security is measured as total exports divided by food imports and food production per capita. Low Risk is defined as having one or both measure above global average. Moderate risk is defined as having one or both below global average. Acute risk is defined as one or both measures less than 50% the global average.  
\*Data not available

Source: CGGC based on data from world Bank Development Indicators and Breisinger et al, 2010

Some threats to food supply are purely political. Sanctions have typically resulted in a substitution effect, forcing countries to find new trading partners but not adversely affecting the food supply in a particularly grave manner. Sanctions are especially unsuccessful when placed on goods with multiple alternatives such as food. In the 1975, for example, the US food embargo on OPEC countries in retaliation to the oil boycott that same year failed because of available alternate supplies of staple food products. By contrast, in the 1990s, a UN embargo on Iraq caused approximately 500,000 deaths and

<sup>47</sup> Breisinger, Clemens, Claudia Ringler, Catherine Aragon, and Olivier Ecker. 2010. "Food Security and Economic Development in the Middle East and North Africa Current State and Future Perspectives."

instigated a policy change in neighboring Syria, promoting domestic wheat cultivation over importation.<sup>48</sup>

Price shocks in the region are of particular concern in light of the recent violence in the region over increases in prices of staple goods during the Arab Spring and before. However, some researchers find a lack of statistically significant correlations between rising food prices and risk of increased political instability or violence.<sup>49</sup> In general, the debate continues on the effect of rising food prices on the poor—in countries with significant agricultural exports, rising food prices reduce poverty. However, in countries reliant on food imports, the opposite is true. MENA region countries are typically the latter. Research shows that a global increase in food and fuel prices will have negative effects on household nutrition levels, reduce expenditures on education and health services, lower remittances coming from Europe, increase unemployment, and reduce support given to refugees in the region.<sup>50</sup>

With a problem as diverse in both its origin and its effects on the region, there is no one silver bullet that will solve all the food security concerns in the MENA region. With a diverse set of issues ranging from trade relations to climate change, from export barriers to water scarcity, and from obesity to malnutrition and hunger, there is no one solution that can assuage the concerns of all countries in the region. However, Eckart Woertz, senior

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<sup>48</sup> *ibid*, 11.

<sup>49</sup> Bazzi, Samuel, and Christopher Blattman. 2011. "Economic Shocks and Conflict : The (Absence of?) Evidence from Commodity Prices". Washington DC.

<sup>50</sup> Jones, Nicola, Caroline Harper, Sara Pantuliano, Sara Pavanello, Shreya Mitra, Katie Chalcraft, and Kim Kyunghoon. 2009. "Impact of the Economic Crisis and Food and Fuel Price Volatility on Children and Women in the MENA Region in the MENA Region." UNICEF.

researcher on food security in the MENA region at the Barcelona Centre for International Affairs, offers this analysis: *“for the Middle East at large there is no way around food imports. The challenge for resource poor countries in the Middle East is to finance them without oil; the challenge for the resource rich countries of the region will be to finance them after oil.”*<sup>51</sup>

#### **D. Current Methodology for Food Security Analysis**

This section gives an overview of food security and food security analysis, focusing on indicators that relate to international trade and a country’s ability to maintain sufficient imports.

The most widely accepted definition of food security comes from the World Food Summit in 1996. A place is food secure “when all people at all times have access to sufficient, safe, nutritious food to maintain a healthy and active life.”<sup>52</sup> There are three pillars to food security:

1. **Availability:** There must be an adequate quantity of food in proportion to the population.
2. **Access:** The population must have sufficient resources to obtain the food, and no particular vulnerable group should be denied access to the food.
3. **Utilization:** The population should have the knowledge to consume food in a safe way, being mindful of proper nutrition and sanitation.<sup>53</sup>

This project focuses on availability, or the quantity of food present in the country. Analyzing availability involves understanding ability of a country to access food, but not

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<sup>51</sup> Woertz, Eckart. 2011. “Arab Food, Water, and the Big Landgrab That Wasn’t.” *Brown J. World Aff.* 1–17. [http://heinonlinebackup.com/hol-cgi-bin/get\\_pdf.cgi?handle=hein.journals/brownjwa18&section=14](http://heinonlinebackup.com/hol-cgi-bin/get_pdf.cgi?handle=hein.journals/brownjwa18&section=14).

<sup>52</sup> “Food Security.” 2013. WHO. Accessed October 21. <http://www.who.int/trade/glossary/story028/en/>.

<sup>53</sup> *ibid*



that of an individual household. Barriers for individuals to acquire food, lack of proper sanitation or knowledge of nutrition will not be considered in this project.

Organizations such as FEWS NET (funded by USAID), the Food and Agriculture Organization (FAO), the World Food Programme (WFP), and the International Food Policy Research Institute (IFPRI) all conduct food security assessments, which range from ongoing monitoring of crop yields, local prices and buffer stocks, to one-time emergency assessments post-crisis. Perhaps one of the most comprehensive is the Economist Intelligence Unit's (EIU) ranking of a countries based on an index of 27 quantitative and qualitative food security indicators touching on food security in availability, affordability, quality and safety.<sup>54</sup>

Some food security assessments incorporate the quantity of a country's imports and exports into their calculations. For example, FAO calculates *potential purchase power* as the ability to purchase food imports with revenue from exports, or:

$$\text{potential purchase power} = \frac{\text{food imports}}{\text{total merchandise exports}}$$

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<sup>54</sup> The 27 indicators are: Consumption as a share of household expenditure, Proportion of population under global poverty line, Gross domestic product per capita, Agricultural import tariffs, Presence of food safety net programs, Access to farmer financing, Availability, Sufficiency of supply, Public expenditure on agricultural R&D, Agricultural infrastructure, Volatility of agricultural production, Political instability, Corruption, Urban absorption capacity, Quality and safety, Diet diversification, Nutritional standards, Micronutrient availability, Protein quality, Food safety.

The Economist Intelligence Unit. [Global Food Security Index](http://foodsecurityindex.eiu.com/Home/Methodology). 2013. 16 August 2013  
<<http://foodsecurityindex.eiu.com/Home/Methodology>>.

This is similar to another indicator used by IFPRI called *terms of trade*, which measures the proportional change in the price of an imported commodity  $i$   $\left(x_i \frac{\Delta p_i}{p_i}\right)$ , relative to the price of exports  $\left(x_i \frac{\Delta p_i}{p_i}\right)$  of that same commodity. The “Terms of Trade Effect” also considers GDP and total value of imports ( $x_i$ ) and exports ( $m_i$ ) of commodity  $i$ .

$$\text{terms - of - trade effect: } [\Sigma x_i \left(\frac{\Delta p_i}{p_i}\right) - \Sigma m_i \left(\frac{\Delta p_i}{p_i}\right)] / \text{GDP}^{55}$$

FAO also considers *import dependence* by calculating the following equation:

$$\text{import dependence} = \frac{\text{Imports}}{(\text{Imports} + \text{Production} - \text{Exports})}^{56}$$

Similarly, IFPRI includes the following equation in their analysis:

$$\frac{(\text{Total Exports})}{(\text{Total Food Imports})}$$

IFRI prefers this calculation over a simple measure of net food trade position, which would be calculated *total food exports – total food imports*. The previous ratio captures the relative cost of food imports, by calculating it as a ratio of total export revenue. The ratio is calculated in this way so that increases demonstrate increases in food security, or reductions in vulnerability.<sup>57</sup> Using this assessment, the average export to food import world ratio is 11.3, meaning that on average, countries spend about 8.8% of their export revenue on food imports.<sup>58</sup> However, in the MENA region an average of 11.5% of export revenue is spent on food imports, with significant variation across countries. While this indicator reveals a country’s vulnerability due to the relative cost of its imports, it does not consider the relative stability of those import sources. Trade network analysis could

<sup>55</sup> “Terms-of-Trade Effect.” *IFPRI Food Security Portal*. Web. 11 Nov. 2013.

<sup>56</sup> “Food Security Indicators.” 2013. *FAO*. <http://www.fao.org/economic/ess/ess-fs/ess-fadata/en/>.

<sup>57</sup> Breisinger, Clemens, Claudia Ringler, Catherine Aragon, and Olivier Ecker. 2010. “Food Security and Economic Development in the Middle East and North Africa Current State and Future Perspectives.”

<sup>58</sup> This is calculated as the inverse of the previous number multiplied by 100.

deepen these assessments by considering the relative strength of the networks through which countries acquire imports.<sup>59</sup>

When analyzing supply chains in the context of food security, sources such as FAO tend to focus on the supply chain analysis of domestically produced commodities.<sup>60</sup> Booz and Company has assessed the robustness of a supply chain of imported commodities using 5 parameters: (1) supply base, (2) supplier concentrations, (3) source proximity, (4) source stability, and (5) trade corridors.<sup>61</sup> This supply chain analysis considers the strength of the trade partners on several levels of its analysis, and concludes that “a country that depends on nearby supply sources with shorter lead times is more resilient to supply shocks than countries whose suppliers have long lead times due to distance.”<sup>62</sup> Using trade network analysis, this project hopes to deepen the understanding of a country’s food security risks.

## Section 2: Data and Methodology

### I. Complex Network Analysis as a Method

Complex network analysis will be used to analyze these trade networks. Complex network analysis (CNA) has been used to analyze social networks through Facebook or Twitter connections, intellectual networks through co-authorship on publications, epidemiological networks through the spread of infectious disease, or industry production

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<sup>59</sup> Definitions of network analysis methods and how strength of network is calculated are explained in the methodology section of this prospectus.

<sup>60</sup> “FAO / WFP CROP AND FOOD SECURITY ASSESSMENT MISSION To the Syrian Arab Republic.” 2013, p.22

<sup>61</sup> Maroun, Nabih, George Atalla, Saida El Harakany, and Tarek Nasser. 2009. “Food Security Key Issues for an Emerging MENA Priority.”

<sup>62</sup> *ibid*, 17.

networks through global supply chains. CNA considers the network as a set of actors, or nodes, and their relationships between each other, as connected by edges. Relationships between nodes are *continuous*, through kinship, membership in the same association, co-location in the same physical region or space or *discrete*, through an instance of communication or exchanges of information, goods or services.<sup>63</sup> Measures have been developed to determine how connected any two nodes are, or how central or important a node is to the entire network; some of these are described below. Several researchers<sup>64</sup> and organizations such as the OECD support the use of network science analysis to provide a more comprehensive understanding of trade networks, pointing to the ability of complex network analysis to assess the structure of a trade network, the magnitude of trade between countries<sup>65</sup>. Wu and Guclu used SNA (social network analysis) to consider the global maize trade with respect to food security. They selected social network analysis because of its superiority in

*“visual representation of multiple actors in food trade patterns world wide: to provide insights into the underlying structure of trade flows, to identify key actors within the network whose behaviors may have especially strong influences on the remainder of the network, and to determine other descriptive factors such as whether clustering of actors in trade occurs with implications*

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<sup>63</sup> Borgatti, Stephen P, and X U N Li. “ON SOCIAL NETWORK ANALYSIS IN A SUPPLY CHAIN CONTEXT.” *Journal of Supply Chain Management* April (2009), 7.

<sup>64</sup> Fagiolo, Giorgio, Javier Reyes, and Stefano Schiavo. “The Evolution of the World Trade Web: a Weighted-Network Analysis.” *Journal of Evolutionary Economics* April (2010): n. pag. Web. 22 Nov. 2013.

<sup>65</sup> Reyes, Javier, Martina Garcia, and Ralph Lattimore. “The BRIICS and Changes in Global Trade Architecture.” *oecd.org* 1-27. Web. 26 Nov. 2013.

*for the relative independence (or dependence) of these actors on the overall flow of trade in the global system.”<sup>66</sup>*

Analysis will include both changes in network-level indicators that describe the network as a whole, and node-specific indicators, which describe individual countries within the network. A simple network-level indicator is *number of links*, which notes the number of instances of trade in a year. As number of links increases, the network becomes denser. A more in-depth consideration of this is *network density*, which describes the ratio of number of links to total possible links. Network density is on a 0-1 scale, where a higher number implies a denser network. A density score of 1 means that all nodes are connected with all other nodes. In the context of international trade, this would mean that all countries are trading with all other countries. Such a high score would be both impossible and inefficient. However, this indicator is useful for understanding the general trends of the network. Over time, a rising density score can indicate that the network on average is becoming more connected, and standardizes this increase in relation to the total number of possible connections. From density scores, we can understand if overall instances of trade are increasing or decreasing, but also the proportional size of that change.

Node-specific indicators describe changes at the level of the country, describing how an individual country is situated within the network. As there are many ways to analyze individual nodes, several indicators were selected which would be most useful for

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<sup>66</sup> Wu, Felicia, and Hasan Guclu. 2013. “Global Maize Trade and Food Security: Implications from a Social Network Model.” *Risk Analysis : an Official Publication of the Society for Risk Analysis* (May 8). doi:10.1111/risa.12064. <http://www.ncbi.nlm.nih.gov/pubmed/23656551>.

understanding a trade network. The first two, noted in Section 3A, are clustering coefficients and betweenness centrality. A country's clustering coefficient reflects the proportion of its trade that is occurring within its cluster. Again, this coefficient is on a 0-1 scale, with a score of 1 reflecting 100% trade within its cluster. Clustering coefficients could be useful in detecting a country's dependence on a certain region. For example, perhaps Country A imports wheat from many other countries, and its large number of partners implies that it has a very diversified, secure network of partners. However, a high clustering coefficient would indicate that country A's partners are all in the same cluster, and thus Country A is vulnerable to changes within that cluster. A natural disaster within that region could severely impact Country A's ability to access wheat. In contrast, Country B may have the same number of partners, but these partners are in different clusters. Country B scores the same as Country A in node degree (number of partners), but has a lower clustering coefficient. If there is a shock to the market such as a reduction in supply due to poor harvests in one cluster, Country B can increase its trade in the other cluster(s) to which it belongs. In this way it is more secure.<sup>67</sup>

Clustering coefficients and node degree consider a country's direct partnerships, but does not consider the overall network. Centrality measures take this into account. Several centrality measures appear in this analysis: betweenness, eigenvector and authority centrality. For all of these indicators, a higher score implies more a more central node.

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<sup>67</sup> It should be noted, however, that clustering coefficients rely on the assumption that the network has clearly defined clusters, presumably defined by geographical proximity or trade agreements. These clusters are determined by the analysis. In such a disconnected network, it is possible that these clusters are not clearly defined and thus clustering coefficients are not as useful as indicators. Here, average clustering coefficients are noted, but the definition of the clusters are not explored. More analysis could be done on the specific clusters detected in this wheat network.

*Betweenness centrality* of Country A indicates the proportion of countries in the network is Country A on the shortest path between. Since wheat is not traveling from one end of the network to the other, this indicator is not useful in a practical sense, however it can still be used in theory to understand how “important” a certain country is in relation to the overall network. *Eigenvector centrality* calculates a score for a country based on the centrality score of its partners. If a country is connected to another “important” player in the network, it will have a higher eigenvector centrality score. In the context of international trade, eigenvector centrality describes connections to highly connected trading partners. Being connected to major players in the wheat market would imply more security because it is presumed that the major players are the most secure partners.<sup>68</sup>

Both betweenness centrality and eigenvector centrality define both exports and imports as a connection. Therefore, major exporters and major importers may have similar betweenness or eigenvector centrality scores. Authority centrality, on the other hand, considers the direction of the connection. Authority centrality is determined by a country’s in-directed connections (imports), not out-directed connections (exports). The name of the indicator comes from social network analysis, which typically analyzes information-sharing or communication—a node is considered an “authority” if it is receiving information from nodes that are giving out a lot of information, or “hubs.” In trade analysis, a node is considered an “authority” if it is receiving imports from the major exporters, or “hubs.” This indicator is useful for understanding the centrality of net-importers in particular. If a high level of partnership with major exporters is considered an indicator of strength in the

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<sup>68</sup> However, caution should be exercised with this indicator, given the number of trade bans that have been raised by major players in the past decade.

wheat market, authority centrality is the best assessment of each MENA countries' position within the network.<sup>69</sup>

## II. Data

Data on food trade flows were gathered from UN Commodity Trade Statistics Database. Country-level data on exports and imports of wheat were gathered and analyzed. Only the summary data in Section 3C come from reported imports. All other analysis was performed using reported exports as opposed to imports, because this data was more complete and considered more reliable. Data on reported exports to MENA countries was complete, with the exception of Djibouti. However, data on reported exports was not complete for Syria, Iraq, Iran, and Libya, Sudan and Kuwait. Data on consumption, production, and ending stocks comes from FAO-Stat database.

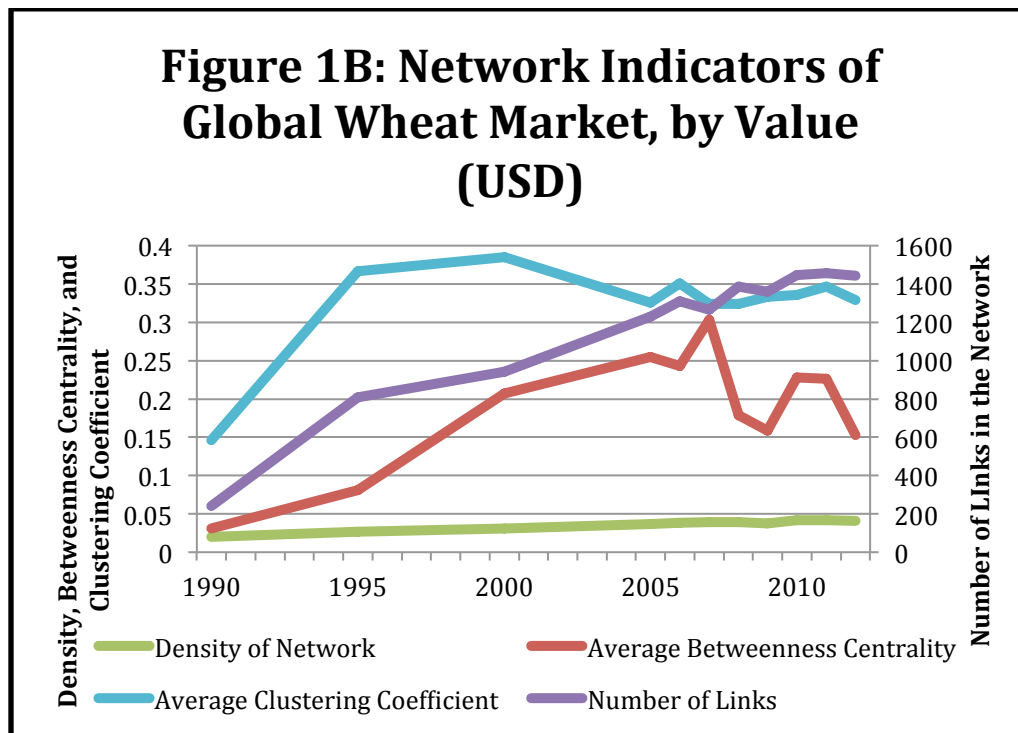
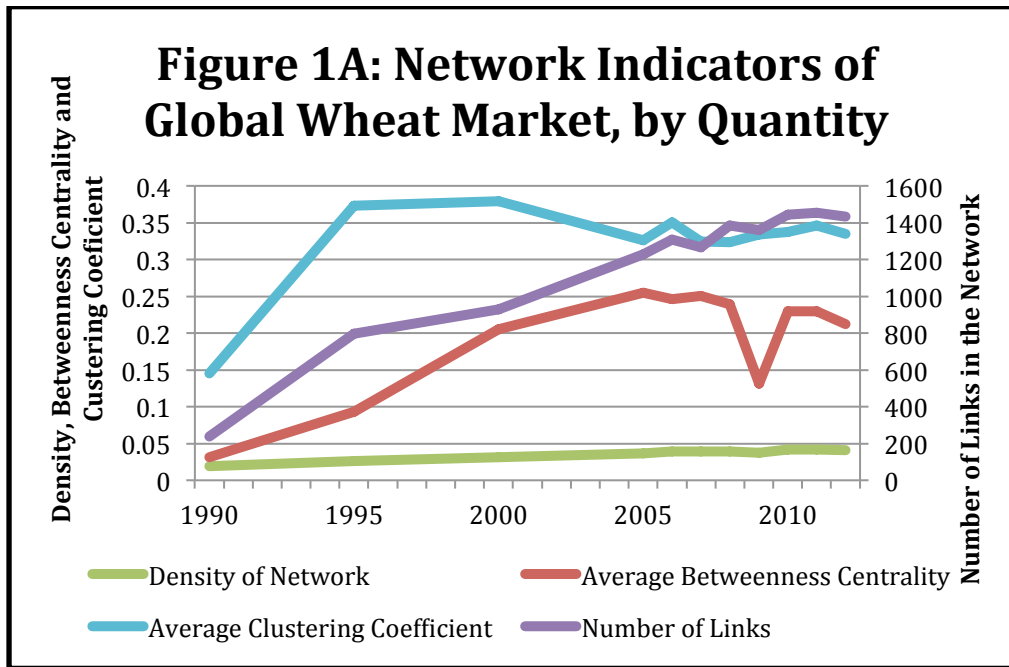
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<sup>69</sup> Again, the same caution should be exercised—if major exporters are considered unstable because of their propensity to raise trade bans, this indicator is less useful.



## Section 3: Findings

### A. Overview of the Global Wheat Network, 1990-2012



As is shown in the figures above, the global wheat trade network is following a trend of increasing links, decreasing centrality, and slightly decreasing clustering, while density has remained fairly stable. This implies that instances of trade have increased, and clusters, or groups of countries that trade primarily with each other, have decreased. Also, average decreasing betweenness centrality scores imply that relatively important countries in the network (in terms of either importers or exporters) have become less important overall. These numbers make sense in the context of an increasingly globalized network with both importers and exporters are diversifying their networks. It is also possible that importers are being forced to diversify their networks in the face of export bans from the major exporters, and this diversification reflects itself in decreased clustering and betweenness scores. Another possible explanation for these trends is the recent rise of the Black Sea countries (Kazakhstan, Ukraine and Russia) as major exporters. Increasing wheat purchases from this region could disrupt existing clusters, and dilute centrality scores of other major exporters such as Canada and Australia.

This analysis was performed with 2 sets of edge weights (or weighted connections between countries)—one by instances of trade in metric tons and one by value traded in USD. This was performed in order to see if there was a difference in the structure of the network between these two ways of analyzing the data. Its possible that a country with more or less purchasing power will appear as more or less central in the analysis by value than in that same analysis by metric ton, thus causing more fluctuation in the data. It is interesting to note that of the indicators analyzed, the betweenness centrality indicator is indeed sensitive to analysis by value instead of weight. When using value traded in USD

traded as the links between countries, betweenness centrality scores fluctuate much more than when looking at quantity traded. In particular, the score rises in 2007 when analyzing value instead of quantity. This implies that some countries are importing (or exporting) wheat at a higher value than others, and establishing themselves as important nodes in the network through either their ability to sell wheat at a higher price or willingness to pay for wheat at a higher price.

## **B. Node-Specific Indicators**

While the average change of the network overall provides useful information about the entire network as a whole, this section considers the top players on node-specific indicators. Since the network has a lot of variation in both size of trade and number of partners, average indicators do not accurately depict fluctuations on the level of the individual countries. The goal of this section is to understand how the major players in the network are changing—both in the network overall, and for MENA countries specifically. Section I describe these changes in terms of importers and exporters, through eigenvector centrality measures, while Section II uses authority centrality to focus on net-importers.

### **I. Eigenvector Centrality**

Eigenvector Centrality gives country  $x$  a score based on the centrality of the countries with which  $x$  trades. A country has a higher eigenvector centrality score if it is connected with other well-connected countries. The score is calculated without regard to whether the connection is an import or an export, so this measure allows us to see the importance of both exporters and importers together. Looking at the top ten countries in



### III. Authority Centrality

Authority Centrality is similar to eigenvector centrality, however it is calculated by considering only the out-degree (or number of exporting partners) of an importing country's partners. Over time, importing Country *A*'s authority centrality would increase as its trading partners increase export quantities or partnerships. In this measure, MENA countries, as net-importers, make more appearances in the top ten. Egypt, Algeria, and Iraq are among the highest-scoring countries in the network overall in terms of this indicator. During 2008 and 2009, Iran appears as a high-ranking country in this measure, when its production rates decreased and it increased its exports significantly. Iran accomplished these increases despite several trade bans from its partners, perhaps exhibiting its political power in the region. In 2009, during Algeria's boom in domestic production and subsequent wheat import ban, it disappears from the top ten in this measure.

### Authority centrality

A node is authority-central to the extent that its in-links are from nodes that have many out-links. Individuals or organizations that act as authorities are receiving information from a wide range of others each of whom sends information to a large number of others. Technically, an agent is authority-central if its in-links are from agents that have are sending links to many others. The scientific name of this measure is authority centrality and it is calculated on agent by agent matrices.

Input network(s): Country x Country Weight kg

| TOP TEN COUNTRIES   |                  |                  |         | 2005             |       |                  |                   | 2006             |         |                  |       | 2007             |                  |                  |         | 2008 |  |  |  |
|---------------------|------------------|------------------|---------|------------------|-------|------------------|-------------------|------------------|---------|------------------|-------|------------------|------------------|------------------|---------|------|--|--|--|
| Overall             | Country          | Value            | Ranking | Country          | Value | Ranking          | Country           | Value            | Ranking | Country          | Value | Ranking          | Country          | Value            | Ranking |      |  |  |  |
|                     | 1 Japan          | 0.549            |         | 1 Japan          | 0.527 |                  | 1 <b>Egypt</b>    | 0.555            |         | 1 Japan          | 0.579 |                  | 1 Japan          | 0.579            |         |      |  |  |  |
|                     | 2 Nigeria        | 0.531            |         | 2 <b>Egypt</b>   | 0.483 |                  | 2 Japan           | 0.555            |         | 2 <b>Iran</b>    | 0.429 |                  | 2 <b>Iran</b>    | 0.429            |         |      |  |  |  |
|                     | 3 Mexico         | 0.524            |         | 3 Mexico         | 0.454 |                  | 3 Mexico          | 0.459            |         | 3 Mexico         | 0.406 |                  | 3 Mexico         | 0.406            |         |      |  |  |  |
|                     | 4 <b>Egypt</b>   | 0.408            |         | 4 Nigeria        | 0.423 |                  | 4 Nigeria         | 0.443            |         | 4 USA            | 0.395 |                  | 4 USA            | 0.395            |         |      |  |  |  |
|                     | 5 Italy          | 0.379            |         | 5 Italy          | 0.391 |                  | 5 <b>Iraq</b>     | 0.326            |         | 5 <b>Egypt</b>   | 0.377 |                  | 5 <b>Egypt</b>   | 0.377            |         |      |  |  |  |
|                     | 6 Philippines    | 0.327            |         | 6 <b>Algeria</b> | 0.336 |                  | 6 Philippines     | 0.296            |         | 6 <b>Algeria</b> | 0.358 |                  | 6 <b>Algeria</b> | 0.358            |         |      |  |  |  |
|                     | 7 Rep. of Korea  | 0.307            |         | 7 <b>Iraq</b>    | 0.333 |                  | 7 Indonesia       | 0.284            |         | 7 Indonesia      | 0.331 |                  | 7 Indonesia      | 0.331            |         |      |  |  |  |
|                     | 8 <b>Algeria</b> | 0.291            |         | 8 Philippines    | 0.306 |                  | 8 <b>Morocco</b>  | 0.283            |         | 8 Nigeria        | 0.329 |                  | 8 Nigeria        | 0.329            |         |      |  |  |  |
|                     | 9 <b>Iraq</b>    | 0.25             |         | 9 Rep. of Korea  | 0.262 |                  | 9 Italy           | 0.271            |         | 9 <b>Iraq</b>    | 0.309 |                  | 9 <b>Iraq</b>    | 0.309            |         |      |  |  |  |
|                     | 10 Spain         | 0.246            |         | 10 Netherlands   | 0.254 |                  | 10 <b>Algeria</b> | 0.261            |         | 10 Philippines   | 0.266 |                  | 10 Philippines   | 0.266            |         |      |  |  |  |
| <b>MENA</b>         |                  |                  |         |                  |       |                  |                   |                  |         |                  |       |                  |                  |                  |         |      |  |  |  |
| Ranking             |                  |                  |         |                  |       |                  |                   |                  |         |                  |       |                  |                  |                  |         |      |  |  |  |
|                     | 4 Egypt          | 0.408            |         | 2 Egypt          | 0.483 |                  | 1 Egypt           | 0.555            |         | 2 Iran           | 0.429 |                  | 2 Iran           | 0.429            |         |      |  |  |  |
|                     | 8 Algeria        | 0.291            |         | 6 Algeria        | 0.336 |                  | 5 Iraq            | 0.326            |         | 5 Egypt          | 0.377 |                  | 5 Egypt          | 0.377            |         |      |  |  |  |
|                     | 9 Iraq           | 0.25             |         | 7 Iraq           | 0.333 |                  | 8 Morocco         | 0.283            |         | 6 Algeria        | 0.358 |                  | 6 Algeria        | 0.358            |         |      |  |  |  |
|                     | 16 Morocco       | 0.159            |         | 17 Morocco       | 0.163 |                  | 10 Algeria        | 0.261            |         | 9 Iraq           | 0.309 |                  | 9 Iraq           | 0.309            |         |      |  |  |  |
|                     | 17 Yemen         | 0.149            |         | 18 Yemen         | 0.161 |                  | 12 Yemen          | 0.226            |         | 15 Morocco       | 0.191 |                  | 15 Morocco       | 0.191            |         |      |  |  |  |
|                     | 21 Israel        | 0.1              |         | 28 Tunisia       | 0.072 |                  | 28 Tunisia        | 0.084            |         | 26 Fmr Sudan     | 0.092 |                  | 26 Fmr Sudan     | 0.092            |         |      |  |  |  |
|                     | 42 Tunisia       | 0.038            |         | 32 Iran          | 0.059 |                  | 32 Israel         | 0.067            |         | 29 Israel        | 0.076 |                  | 29 Israel        | 0.076            |         |      |  |  |  |
|                     | 47 Djibouti      | 0.035            |         | 34 Israel        | 0.059 |                  | 34 United Arab    | 0.059            |         | 30 Yemen         | 0.074 |                  | 30 Yemen         | 0.074            |         |      |  |  |  |
|                     | 62 Lebanon       | 0.018            |         | 48 Fmr Sudan     | 0.035 |                  | 37 Fmr Sudan      | 0.05             |         | 38 Tunisia       | 0.056 |                  | 38 Tunisia       | 0.056            |         |      |  |  |  |
|                     | 63 United Arab   | 0.018            |         | 50 United Arab   | 0.035 |                  | 40 Libya          | 0.044            |         | 42 United Arab   | 0.041 |                  | 42 United Arab   | 0.041            |         |      |  |  |  |
| Mean Value (st dev) |                  | 0.043<br>(0.095) |         | 0.044<br>(0.095) |       | 0.045<br>(0.095) |                   | 0.042<br>(0.094) |         | 0.042<br>(0.094) |       | 0.042<br>(0.094) |                  | 0.041<br>(0.094) |         |      |  |  |  |

| TOP TEN COUNTRIES   |                 |                  |         | 2009             |       |                  |                 | 2010             |         |                  |       | 2011             |                 |                  |         | 2012 |  |  |  |
|---------------------|-----------------|------------------|---------|------------------|-------|------------------|-----------------|------------------|---------|------------------|-------|------------------|-----------------|------------------|---------|------|--|--|--|
| Overall             | Country         | Value            | Ranking | Country          | Value | Ranking          | Country         | Value            | Ranking | Country          | Value | Ranking          | Country         | Value            | Ranking |      |  |  |  |
|                     | 1 Special Cate  | 0.476            |         | 1 <b>Egypt</b>   | 0.515 |                  | 1 Japan         | 0.569            |         | 1 Japan          | 0.55  |                  | 1 Japan         | 0.55             |         |      |  |  |  |
|                     | 2 Indonesia     | 0.447            |         | 2 Japan          | 0.489 |                  | 2 <b>Egypt</b>  | 0.502            |         | 2 Indonesia      | 0.513 |                  | 2 Indonesia     | 0.513            |         |      |  |  |  |
|                     | 3 <b>Egypt</b>  | 0.436            |         | 3 Nigeria        | 0.429 |                  | 3 Nigeria       | 0.46             |         | 3 Rep. of Korea  | 0.492 |                  | 3 Rep. of Korea | 0.492            |         |      |  |  |  |
|                     | 4 Japan         | 0.415            |         | 4 <b>Algeria</b> | 0.392 |                  | 4 Mexico        | 0.45             |         | 4 Mexico         | 0.428 |                  | 4 Mexico        | 0.428            |         |      |  |  |  |
|                     | 5 <b>Iran</b>   | 0.354            |         | 5 Italy          | 0.373 |                  | 5 Rep. of Korea | 0.382            |         | 5 Philippines    | 0.406 |                  | 5 Philippines   | 0.406            |         |      |  |  |  |
|                     | 6 Italy         | 0.314            |         | 6 Mexico         | 0.372 |                  | 6 Philippines   | 0.38             |         | 6 Nigeria        | 0.362 |                  | 6 Nigeria       | 0.362            |         |      |  |  |  |
|                     | 7 Rep. of Korea | 0.31             |         | 7 Rep. of Korea  | 0.332 |                  | 7 Indonesia     | 0.363            |         | 7 China          | 0.347 |                  | 7 China         | 0.347            |         |      |  |  |  |
|                     | 8 Nigeria       | 0.273            |         | 8 <b>Morocco</b> | 0.307 |                  | 8 <b>Iraq</b>   | 0.304            |         | 8 <b>Egypt</b>   | 0.315 |                  | 8 <b>Egypt</b>  | 0.315            |         |      |  |  |  |
|                     | 9 Bangladesh    | 0.258            |         | 9 Indonesia      | 0.291 |                  | 9 Italy         | 0.232            |         | 9 Viet Nam       | 0.245 |                  | 9 Viet Nam      | 0.245            |         |      |  |  |  |
|                     | 10 <b>Yemen</b> | 0.253            |         | 10 Philippines   | 0.275 |                  | 10 Turkey       | 0.208            |         | 10 Thailand      | 0.234 |                  | 10 Thailand     | 0.234            |         |      |  |  |  |
| <b>MENA</b>         |                 |                  |         |                  |       |                  |                 |                  |         |                  |       |                  |                 |                  |         |      |  |  |  |
| Ranking             |                 |                  |         |                  |       |                  |                 |                  |         |                  |       |                  |                 |                  |         |      |  |  |  |
|                     | 3 Egypt         | 0.436            |         | 1 Egypt          | 0.515 |                  | 2 Egypt         | 0.502            |         | 8 Egypt          | 0.315 |                  | 8 Egypt         | 0.315            |         |      |  |  |  |
|                     | 5 Iran          | 0.354            |         | 4 Algeria        | 0.392 |                  | 8 Iraq          | 0.304            |         | 11 Iran          | 0.205 |                  | 11 Iran         | 0.205            |         |      |  |  |  |
|                     | 10 Yemen        | 0.253            |         | 8 Morocco        | 0.307 |                  | 12 Yemen        | 0.18             |         | 12 Yemen         | 0.2   |                  | 12 Yemen        | 0.2              |         |      |  |  |  |
|                     | 11 Iraq         | 0.251            |         | 12 Yemen         | 0.215 |                  | 14 Algeria      | 0.172            |         | 13 Iraq          | 0.173 |                  | 13 Iraq         | 0.173            |         |      |  |  |  |
|                     | 13 Algeria      | 0.241            |         | 18 Iraq          | 0.157 |                  | 15 Morocco      | 0.143            |         | 15 Algeria       | 0.164 |                  | 15 Algeria      | 0.164            |         |      |  |  |  |
|                     | 18 Fmr Sudan    | 0.168            |         | 28 Libya         | 0.091 |                  | 21 Saudi Arabia | 0.119            |         | 19 Sudan         | 0.129 |                  | 19 Sudan        | 0.129            |         |      |  |  |  |
|                     | 21 Morocco      | 0.144            |         | 29 Fmr Sudan     | 0.089 |                  | 23 Israel       | 0.101            |         | 22 Saudi Arabia  | 0.111 |                  | 22 Saudi Arabia | 0.111            |         |      |  |  |  |
|                     | 24 Syria        | 0.143            |         | 32 Saudi Arabia  | 0.082 |                  | 25 Jordan       | 0.091            |         | 24 Morocco       | 0.095 |                  | 24 Morocco      | 0.095            |         |      |  |  |  |
|                     | 27 Saudi Arabia | 0.112            |         | 37 Israel        | 0.072 |                  | 30 Fmr Sudan    | 0.075            |         | 27 Israel        | 0.073 |                  | 27 Israel       | 0.073            |         |      |  |  |  |
|                     | 28 Israel       | 0.11             |         | 38 Tunisia       | 0.071 |                  | 38 United Arab  | 0.044            |         | 31 United Arab   | 0.064 |                  | 31 United Arab  | 0.064            |         |      |  |  |  |
| Mean Value (st dev) |                 | 0.047<br>(0.091) |         | 0.046<br>(0.093) |       | 0.042<br>(0.094) |                 | 0.042<br>(0.094) |         | 0.041<br>(0.094) |       | 0.041<br>(0.094) |                 | 0.041<br>(0.094) |         |      |  |  |  |

## B. Export bans and effects on MENA partners

After addressing the overall changes of the wheat network on a global and country-specific level, this section analyzes the impact of four trade bans on MENA partners specifically. This section describes the motivations for implementing the ban, the length of

the ban and the amount of exports reduced. It should be noted that export bans vary in both length and size of reduction—some export bans last only for one year, while some last for several. Depending on several factors including the time of the year, the structure of contracts and futures purchasing, and the amount of panic purchasing, the impact of the ban is observed in the year it is declared, or up to a year afterwards. This section also describes individual MENA countries of interest, and their reaction to the bans. Countries were able to maintain previous levels of wheat available by increasing imports from existing partners, by creating new partnerships, or by increasing domestic production.

A summary table follows each description, summarizing average effects of each ban in the MENA countries, reporting changes in import quantity, wheat availability, number of partners and betweenness centrality.<sup>70</sup> Each table includes a note of what year was considered the “pre” and what was considered “post” ban, since each ban differs in when its impact was felt.

### **2007: Ukraine**

Kazakhstan, Russia and the Ukraine, sometimes known as the Black Sea grain exporters, accounted for 15 percent of global wheat production. Their share in global wheat trade was expected to reach 26% in 2008-2009.<sup>71</sup> Because of their proximity to MENA countries, they provide a significant share of total exports to the region. In 2005, for example, exports from these three countries represented 33.6% of the total exports to the MENA region.

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<sup>70</sup> Import quantity here is calculated by summing total exports to a country as reported in the UNCOMTRADE database. Again, this is considered more reliable than reported imports. A country’s total availability is defined as: Production+Stocks+Imports-Exports. This data comes from FAO Stat Database.

<sup>71</sup> Prikhodko, Dmitry. “Grain Markets in Kazakhstan , the Russian Federation and Ukraine.” World Grain Forum (2009): n. pag.

In 2005, Ukraine served as a major exporter of wheat to the MENA region, with significant instances of exports (over 100,000 MTs) to Tunisia, Algeria, Morocco, Libya, Egypt and Jordan. Ukraine produces several types of wheat, with differing planting and harvesting seasons. Thus, both summer and winter weather patterns affect Ukraine's production of wheat. From August to November 2005, Ukraine experienced a drought that the USDA estimated would reduce total production in 2006 by 8 million tons. The drought caused 26% of the country's wheat to be in poor condition (as opposed to 9% in the prior year).<sup>72</sup>

Responding to the reduced output, in October 2006 Ukraine instituted a quota system for grain exporters, with the justification that the system would protect domestic prices and availability. However, the quota system was poorly targeted because it didn't benefit consumers and instead hurt both grain producers and traders.<sup>73</sup> In the MENA region, Ukraine reduced trade with most of its previous MENA partners, but increased trade with both Egypt and Yemen.

Continued drought and high spring temperatures further reduced wheat harvests by roughly 1 million MT's 2007.<sup>74</sup> In this year, Ukraine instituted resolutions 794 and 844, which reduced quotas to 3,000 MT from March 1, 2007 until State Reserves were returned

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<sup>72</sup> Lindeman, Mark. "Ukraine: Wheat Yield Forecast to Drop Due to Severe Fall Drought." *USDA Foreign Agricultural Service: Commodity Intelligence Report* (2006): n. pag.

<sup>73</sup> Cramon, Stephan v., and Martin Raiser. "The Quotas on Grain Exports in Ukraine : Ineffective , Inefficient and Non-Transparent." *Institute for Economic Research and Policy Consulting in Ukraine* (2006): 1-12.

<sup>74</sup> "Ukraine Drought Threatens Grain Crop, Quotas Loom." *bdnews24.com* 2007.



to adequate levels.<sup>75</sup> A quota this low is essentially a grain export ban. Again this ban adversely affected wheat traders and does not improve prices for consumers. The ban was regarded as illogical because it reduced trade further than necessary to maintain domestic stocks.<sup>76</sup>

During 2007, Ukraine reduced overall exports by 77.4 percent, eliminating exports entirely with twenty of its previous partners. Exports were reduced to all MENA partners; however, Egypt and Tunisia still received over 100,000 MT of Ukrainian wheat. Several of Ukraine's largest trading partners in the region (Egypt, Tunisia, Israel and Yemen) reacted by increasing imports from their existing partners, Russia and Kazakhstan. This is evident in the visualizations in Appendix 1. When viewing the network sized by out-degree (or number of partners for exporting countries), Ukraine becomes much smaller between 2006 and 2007. But Russia and Kazakhstan grow in size during this time. Other MENA partners such as Algeria and Saudi Arabia established new trading relationships with Russia and Kazakhstan. Overall, grain exports from Russia and Kazakhstan increased by 46.9 and 53.4 percent, respectively.<sup>77</sup>

In late 2007, the government instituted a licensing system, allowed a quota of 200,000 MT of wheat exports. In April 2008, Ukraine expanded the export quotas to 1.2 million MT. During this year, Ukrainian wheat exports increased to all MENA partners.

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<sup>75</sup> Weather and Policy Risks - Are the Grain Export Restrictions Unavoidable to Achieve Food Security in Ukraine ?" *INSTITUTE FOR ECONOMIC RESEARCH AND POLICY CONSULTING : German-Ukrainian Agricultural Policy Dialogue* Policy Pap (2007): n. pag.

<sup>76</sup> *ibid.*

<sup>77</sup> Dollive, Kendall. "The Impact of Export Restraints on Rising Grain Prices The Impact of Export Restraints on Rising Grain Prices." US International Trade Commission Office of Economics Working Paper 2008-09-A (2008): 25.

This is visible in Appendix 1, Out Degree visualizations, where Ukraine re-emerges as a major player in 2008. However, reductions in trade from other important partners in 2008 inhibited the rise of overall wheat supply for most of Ukraine’s trading partners in the region.

| Average Impact of Ukraine's Trade Ban in MENA Region* |                                     |          |        |                         |                           |
|---|-------------------------------------|----------|--------|-------------------------|---------------------------|
| Outcome Variable                                      | Average Change (Standard Deviation) | Min      | Max    | % of countries reducing | % of countries increasing |
| Change in Import Quantity (MT)                        | -109453<br>(115542)                 | -304164  | -11    | 100.00%                 | 0.00%                     |
| Change in Wheat Availability (MT)                     | -402034<br>(1309042)                | -4451488 | 787407 | 61.54%                  | 38.46%                    |
| Number of Partners                                    | -3<br>(3.85)                        | -9       | 4      | 84.62%                  | 0.00%                     |
| Betweenness Centrality                                | 134<br>(288)                        | -195     | 691    | 30.77%                  | 53.85%                    |

\*Average change for all MENA trading partners with Ukraine between 2007 and 2006

### 2008: Kazakhstan

In 2007, Kazakhstan’s major trading partners in the MENA region included four countries: Tunisia, Egypt, Yemen and Iran. As noted above, both Egypt and Tunisia had increased imports from Kazakhstan as a reaction to the Ukrainian trade ban.

In 2008, the Kazakhstani government first levied export taxes on wheat in March, then banned wheat exports entirely from April 15 to September 1, or the beginning of the

new harvesting season. This short-term ban was aimed at protecting domestic supply as the country was nearing capacity for exports.<sup>78</sup> However, it allowed the exportation of milled flour, in order to raise the domestic mill production.<sup>79</sup> This short-term trade ban did not affect global wheat prices, but it did harm neighboring countries that did not have the capital to purchase wheat at higher prices and with a larger transportation cost. During this time, Kazakhstan reduced trade with 75% of its MENA trading partners; however it increased trade with Iran and nearly doubled its exports to Egypt, which gained 10 other new trading partners. A majority of Kazakhstan's trading partners were able to withstand the ban by adding new partners. Again this is visible in Appendix 1. When nodes are sized by out-degree, Kazakhstan can be seen to shrink in influence in 2008 and 2009, with Russia and Ukraine growing to compensate for this reduced trade. In 2008, many more MENA countries are visible in the visualizations by centrality as compared to this same visualization in 2007. One potential reason for this change is that many MENA countries formed new partnerships in response to Kazakhstan's ban.

In 2009, while the ban was lifted, Kazakhstan did not resume trade with any MENA countries. In fact, it reported exports only to Iran, with which it nearly tripled its trade. In 2010 the country resumed exports to several of its prior partners in the region.

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<sup>78</sup> Lillis, Joanna. "Kazakhstan: Grain Export Ban Stokes Inflation Fears Elsewhere in Central Asia." Eurasianet.org 2008.

<sup>79</sup> "Kazakhstan's Government Decides to Ban Wheat Exports." *Reliefweb.int* (2008): n. pag.

Impact of Kazakhstan's Trade Ban in the MENA Region\*

| Outcome Variable             | Average Change (Standard Deviation) | Min      | Max     | % of countries reducing | % of countries increasing |
|------------------------------|-------------------------------------|----------|---------|-------------------------|---------------------------|
| Change in Import Quantity    | -6985<br>(147638)                   | -196943  | 391765  | 75.00%                  | 25.00%                    |
| Change in Wheat Availability | -293934<br>(1833997)                | -5169292 | 2508935 | 41.67%                  | 58.33%                    |
| Number of Partners           | 3<br>(3)                            | -1       | 10      | 8.33%                   | 83.33%                    |
| Betweenness Centrality       | -24<br>(409.39)                     | -532     | 1090    | 58.33%                  | 33.33%                    |

\*Average change for all MENA trading partners with Kazakhstan between 2008 and 2007

### 2009: Argentina

In Argentina wheat is planted from April to September and harvested October to January. In 2005, Argentina represented 7% of the total exports to the MENA region. Argentina raised recurring export restrictions between 2007 and 2009. Argentina banned wheat exports effectively by closing its export registry from March to November 2007. After re-opening the registry briefly in November, it was again closed in December 2007, re-opened in January, but then closed again from February to May 2008. In between these changes, Argentina raised export taxes on several grain products and shortened the period in which the registration must be used, from 365 to 45 days. All of these restrictive actions prompted farmer strikes, which further reduced local wheat supply.<sup>80</sup> In 2007, Argentina had major exports (over 100,000 MT of wheat) to Algeria, Yemen, UAE, and Egypt. In 2008

<sup>80</sup> Dollive, Kendall. "The Impact of Export Restraints on Rising Grain Prices The Impact of Export Restraints on Rising Grain Prices." US International Trade Commission Office of Economics Working Paper 2008-09-A (2008): 25.

it maintained a large trade relationship with Algeria, UAE, and increased trade five times with Morocco. However, trade with Egypt decreased significantly.

Because exporters were previously allowed to use their export license within 1 year of receiving it, effects of the ban in late 2007 were not evident in the market until late 2008. It is for this reason the effect of the ban in the MENA region was not observed until 2009. In this year, Argentina reduced trade with the majority of its MENA partners, but more than tripled its exports to Iran, which had faced a severe drought<sup>81</sup> as well as an invasive fungus<sup>82</sup> both of which severely reduced Iran's domestic harvests. However, Algeria and Egypt experienced a boom in domestic production, and thus reduced imports overall. Algeria went so far as to halt imports altogether starting in April 2009.<sup>83</sup>

Argentina's ban was observed for most of 2009 as well, and wasn't lifted until October 1, 2009, at which time the export agency Oncca allowed registration for exporters who committed to simultaneously supply the domestic market to meet government targets.<sup>84</sup>

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<sup>81</sup> Shean, Michael. "Iran: Another Disappointing Wheat Harvest Ahead in 2009/10." *USDA Commodity Intelligence Report* (2009): n. pag.

<sup>82</sup> "GLOBAL: Killer Wheat Fungus a Threat to Global Food Security?" *IRIN News* 2008.

<sup>83</sup> Seifarth, Kurt, and Nabila Hales. "Algeria Grain and Feed Annual." *USDA Global Agricultural Information Network* AG1105 (2011): n. pag.

<sup>84</sup> Orihuela, Rodrigo, and Ruitenber, Rudy. "Argentina Ends Corn, Wheat Export Ban as Crops Shrink." *Bloomberg* (2009): n. pag.

Impact of Argentina's Trade Ban in the MENA Region\*

| Outcome Variable                 | Average Change (Standard Deviation) | Min     | Max     | % of countries reducing | % of countries increasing |
|----------------------------------|-------------------------------------|---------|---------|-------------------------|---------------------------|
| Change in Imports from Argentina | -52467<br>(152753)                  | -346363 | 218560  | 60.00%                  | 20.00%                    |
| Change in Wheat Availability     | 1473645<br>(2524827)                | -61860  | 8341250 | 20.00%                  | 80.00%                    |
| Number of Partners               | -2<br>(1.52)                        | -4      | 1       | 80.00%                  | 10.00%                    |
| Betweenness Centrality           | -83<br>(254)                        | -679    | 198     | 40.00%                  | 50.00%                    |

\*Average change for all MENA trading partners with Argentina between 2009 and 2008

#### 2010: Russia

After an extreme heat wave in 2010, with the highest recorded temperatures seen in 130 years, Russia's grain crop suffered significantly. In response, Russian government instituted Resolution 599, a grain export ban from August 15 2010 to December 31, 2010. The ban was later extended to July 2011.<sup>85</sup> Resolution 599 was declared on August 5, and began to be enforced on August 6<sup>th</sup>, with local authorities forbidding the loading of already purchased grain onto railcars. The ban allowed existing grain contracts to be canceled without payment of penalties. It was suspected that traders requested this ban, as the gap between current purchase price and contract price increased, along with local prices.<sup>86</sup> Since Russia is an important exporter, global prices rose as a result of this ban.

<sup>85</sup> Welton, George. "The Impact of Russia's 2010 Grain Export Ban." *Oxfam Policy and Practice*. (2011): n. pag. Web. 2 Mar. 2014.

<sup>86</sup> Vassilieva, Yelena, and Mary Ellen Smith. "Ban on Grain Exports from Russia Comes to Force on August." *USDA Global Agricultural Information Network RS1039* (2010): n. pag. Print.

The impact was largest for Egypt, which previously relied on Russia for 50% of its wheat imports. Estimates of the incurred costs for Egypt, which had to rely on existing stocks and make short-term purchases at higher prices, range from USD36 million (a 31% increase) to USD68 million (a 68% increase). Including the costs of subsidies on both grain and bread, total costs to the government were predicted to reach USD400-700 million.<sup>87</sup>

### **C. Summary of MENA Countries' Key Indicators**

The table below depicts summary information for all countries in the MENA region that consistently reported total imports and value of imports. Countries are ordered from approximately most vulnerable to least, as determined by the number of losses they incurred on all of these indicators. An increase in average price paid or import dependency ratio is considered a loss, since increases in these categories imply a negative outcome for that country. Djibouti, Kuwait, Syria, Iraq and Iran did not have complete data in this category and thus were not included in this analysis.

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<sup>87</sup> *ibid.*

Table 1: Overview of Indicators for MENA Countries

|                                 | 2005       | 2006              |       | 2007       |       | 2008                 |       | 2009       |      | 2010             |      |
|---------------------------------|------------|-------------------|-------|------------|-------|----------------------|-------|------------|------|------------------|------|
|                                 |            | Ukraine trade ban |       |            |       | India trade ban      |       |            |      | Russia trade ban |      |
|                                 |            |                   |       |            |       | Kazakhstan trade ban |       |            |      |                  |      |
|                                 |            |                   |       |            |       | Argentina trade ban  |       |            |      |                  |      |
|                                 | 2005       | 2006              |       | 2007       |       | 2008                 |       | 2009       |      | 2010             |      |
| Syria                           |            |                   |       |            |       |                      |       |            |      |                  |      |
| Total Wheat Imports (kg)        | 191721000  | 154728055         | -19%  | 44568910   | -71%  | 310699884            | 597%  | 1661235437 | 435% | 1101030603       | -34% |
| Value of Wheat Imports (USD)    | 30610719   | 25215762          | -18%  | 7952845    | -68%  | 96269180             | 1110% | 334379349  | 247% | 242961290        | -27% |
| Average Wheat Import Price**    | 0.16       | 0.16              | 2%    | 0.18       | 9%    | 0.31                 | 74%   | 0.20       | -35% | 0.22             | 10%  |
| IDR (Import Dependency Ratio)** | 0.02       | 0.02              | 0%    | 0.01       | -50%  | 0.05                 | 400%  | 0.19       | 280% | 0.15             | -21% |
| Number of Partners              | 7          | 6                 | -14%  | 5          | -17%  | 8                    | 60%   | 14         | 75%  | 11               | -21% |
| Betweenness Centrality          | 463.55     | 310.114           | -33%  | 390.026    | 26%   | 241.192              | -38%  | 376.32     | 56%  | 214.703          | -43% |
| Malta                           |            |                   |       |            |       |                      |       |            |      |                  |      |
| Total Wheat Imports (kg)        | 29861387   | 20368506          | -32%  | 65852493   | 223%  | 63542851             | -4%   | 45283479   | -29% | 32960822         | -27% |
| Value of Wheat Imports (USD)    | 5695475    | 4226782           | -26%  | 19946509   | 372%  | 25460383             | 28%   | 11019128   | -57% | 7830050          | -29% |
| Average Wheat Import Price**    | 0.19       | 0.21              | 9%    | 0.30       | 46%   | 0.40                 | 32%   | 0.24       | -39% | 0.24             | -2%  |
| IDR (Import Dependency Ratio)** | 0.67       | 0.53              | -21%  | 0.77       | 45%   | 0.99                 | 29%   | 0.64       | -35% | 0.37             | -42% |
| Number of Partners              | 7          | 7                 | 0%    | 9          | 29%   | 7                    | -22%  | 4          | -43% | 8                | 100% |
| Betweenness Centrality          | 8.122      | 0                 | -100% | 621.667    | 0%    | 10.986               | -98%  | 53.333     | 385% | 49.064           | -8%  |
| Algeria                         |            |                   |       |            |       |                      |       |            |      |                  |      |
| Total Wheat Imports (kg)        | 5685248260 | 7804165197        | 37%   | 4855880916 | -38%  | 6486531056           | 34%   | 5719727585 | -12% | 5232372429       | -9%  |
| Value of Wheat Imports (USD)    | 1024483543 | 997023966         | -3%   | 1394314539 | 40%   | 3174186861           | 128%  | 1830345530 | -42% | 1251588298       | -32% |
| Average Wheat Import Price**    | 0.18       | 0.13              | -29%  | 0.29       | 125%  | 0.49                 | 70%   | 0.32       | -35% | 0.24             | -25% |
| IDR (Import Dependency Ratio)** | 0.54       | 0.51              | -6%   | 0.5        | -2%   | 0.66                 | 32%   | 0.52       | -21% | 0.45             | -13% |
| Number of Partners              | 22         | 22                | 0%    | 21         | -5%   | 21                   | 0%    | 18         | -14% | 16               | -11% |
| Betweenness Centrality          | 409.717    | 152.002           | -63%  | 50         | -67%  | 87.028               | 74%   | 284.658    | 227% | 10.417           | -96% |
| Morocco                         |            |                   |       |            |       |                      |       |            |      |                  |      |
| Total Wheat Imports (kg)        | 2636872376 | 1825800255        | -31%  | 3683481822 | 102%  | 4083575296           | 11%   | 2390344284 | -41% | 3236619650       | 35%  |
| Value of Wheat Imports (USD)    | 468797713  | 351567375         | -25%  | 1129025053 | 221%  | 1613508056           | 43%   | 683063196  | -58% | 878460906        | 29%  |
| Average Wheat Import Price**    | 0.18       | 0.19              | 8%    | 0.31       | 59%   | 0.40                 | 29%   | 0.29       | -28% | 0.27             | -5%  |
| IDR (Import Dependency Ratio)** | 0.35       | 0.17              | -51%  | 0.58       | 241%  | 0.46                 | -21%  | 0.23       | -50% | 0.3              | 30%  |
| Number of Partners              | 14         | 16                | 14%   | 20         | 25%   | 22                   | 10%   | 19         | -14% | 18               | -5%  |
| Betweenness Centrality          | 114.665    | 47                | -59%  | 605.958    | 1189% | 277.781              | -54%  | 115.608    | -58% | 68.978           | -40% |
| Yemen                           |            |                   |       |            |       |                      |       |            |      |                  |      |
| Total Wheat Imports (kg)        | 2883670000 | 2429423788        | -16%  | 2362601742 | -3%   | 2126632142           | -10%  | 2798891482 | 32%  | 2654890637       | -5%  |
| Value of Wheat Imports (USD)    | 357270726  | 390964896         | 9%    | 671948675  | 72%   | 955743282            | 42%   | 735580299  | -23% | 708593820        | -4%  |
| Average Wheat Import Price**    | 0.12       | 0.16              | 30%   | 0.28       | 77%   | 0.45                 | 58%   | 0.26       | -42% | 0.27             | 2%   |
| IDR (Import Dependency Ratio)** | 0.97       | 0.9               | -7%   | 0.9        | 0%    | 0.78                 | -13%  | 0.81       | 4%   | 0.77             | -5%  |
| Number of Partners              | 10         | 15                | 50%   | 11         | -27%  | 14                   | 27%   | 12         | -14% | 12               | 0%   |
| Betweenness Centrality          | 96.26      | 120.205           | 25%   | 227.526    | 89%   | 41.677               | -82%  | 128.156    | 207% | 62.681           | -51% |
| United Arab Emirates            |            |                   |       |            |       |                      |       |            |      |                  |      |
| Total Wheat Imports (kg)        | 1678384159 | 0                 |       | 631346123  |       | 775472716            | 23%   | 0          |      | 0                |      |
| Value of Wheat Imports (USD)    | 217865390  | 150498853         | -31%  | 169066528  | 12%   | 297617419            | 76%   | 232158626  | -22% | 214456239        | -8%  |
| Average Wheat Import Price**    | 0.13       | 0.18              | 36%   | 0.27       | 51%   | 0.38                 | 43%   | 0.27       | -29% | 0.25             | -7%  |
| IDR (Import Dependency Ratio)** | 1          | 1.02              | 2%    | 1          | -2%   | 1.03                 | 3%    | 1.23       | 19%  | 2.32             | 89%  |
| Number of Partners              | 21         | 22                | 5%    | 20         | -9%   | 19                   | -5%   | 16         | -16% | 22               | 38%  |
| Betweenness Centrality          | 916.734    | 732.75            | -20%  | 1342.427   | 83%   | 810.768              | -40%  | 838.57     | 3%   | 1241.673         | 48%  |
| Egypt                           |            |                   |       |            |       |                      |       |            |      |                  |      |
| Total Wheat Imports (kg)        | 5687760187 | 5816910057        | 2%    | 5911035945 | 2%    | 4077543052           | -31%  | 4059927117 | 0%   | 9926578119       | 145% |
| Value of Wheat Imports (USD)    | 924572493  | 964539092         | 4%    | 1563939816 | 62%   | 2110912135           | 35%   | 1576054905 | -25% | 2181907400       | 38%  |
| Average Wheat Import Price**    | 0.16       | 0.17              | 2%    | 0.26       | 60%   | 0.52                 | 96%   | 0.39       | -25% | 0.22             | -43% |
| IDR (Import Dependency Ratio)** | 0.32       | 0.39              | 22%   | 0.41       | 5%    | 0.39                 | -5%   | 0.39       | 0%   | 0.46             | 18%  |
| Number of Partners              | 13         | 20                | 54%   | 11         | -45%  | 21                   | 91%   | 19         | -10% | 19               | 0%   |
| Betweenness Centrality          | 928.506    | 379.967           | -59%  | 391.576    | 3%    | 1481.56              | 278%  | 802.968    | -46% | 116.133          | -86% |
| Tunisia                         |            |                   |       |            |       |                      |       |            |      |                  |      |
| Total Wheat Imports (kg)        | 1132924204 | 1338643043        | 18%   | 1696282951 | 27%   | 1762439922           | 4%    | 1232426102 | -30% | 1914864072       | 55%  |
| Value of Wheat Imports (USD)    | 176990595  | 233770037         | 32%   | 575666388  | 146%  | 810606886            | 41%   | 322174639  | -60% | 476161558        | 48%  |
| Average Wheat Import Price**    | 0.16       | 0.17              | 12%   | 0.34       | 94%   | 0.46                 | 36%   | 0.26       | -43% | 0.25             | -5%  |
| IDR (Import Dependency Ratio)** | 0.31       | 0.39              | 26%   | 0.42       | 8%    | 0.52                 | 24%   | 0.32       | -38% | 0.55             | 72%  |
| Number of Partners              | 12         | 18                | 50%   | 17         | -6%   | 20                   | 18%   | 11         | -45% | 17               | 55%  |
| Betweenness Centrality          | 0          | 32.714            |       | 0          | -100% | 271.387              |       | 93.912     | -65% | 266.225          | 183% |



Table 1 cont. Overview of Indicators for MENA Countries

|              | 2005                            | 2006     | 2007      | 2008                 | 2009      | 2010   |           |       |            |       |            |       |
|--------------|---------------------------------|----------|-----------|----------------------|-----------|--------|-----------|-------|------------|-------|------------|-------|
|              | Ukraine trade ban               |          |           | India trade ban      |           |        |           |       |            |       |            |       |
|              |                                 |          |           | Kazakhstan trade ban |           |        |           |       |            |       |            |       |
|              |                                 |          |           | Argentina trade ban  |           |        |           |       |            |       |            |       |
|              |                                 |          |           | Russia trade ban     |           |        |           |       |            |       |            |       |
| Bahrain      | Total Wheat Imports (kg)        | 83333149 | 14443358  | -83%                 | 3060309   | -79%   | 126414102 | 4031% | 63497159   | -50%  | 88053001   | 39%   |
|              | Value of Wheat Imports (USD)    | 15956755 | 3305026   | -79%                 | 1495593   | -55%   | 52379907  | 3402% | 17364311   | -67%  | 35934407   | 107%  |
|              | Average Wheat Import Price**    | 0.19     | 0.23      | 20%                  | 0.49      | 114%   | 0.41      | -15%  | 0.27       | -34%  | 0.41       | 49%   |
|              | IDR (Import Dependency Ratio)** | 1        | 1         | 0%                   | 1         | 0%     | 1         | 0%    | 1          | 0%    | 1          | 0%    |
|              | Number of Partners              | 9        | 8         | -11%                 | 3         | -63%   | 7         | 133%  | 4          | -43%  | 4          | 0%    |
|              | Betweenness Centrality          | 5.667    |           |                      |           |        |           |       |            |       |            |       |
| Jordan       | Total Wheat Imports (kg)        | #N/A     | 402516584 | #N/A                 | 793390670 | 97%    | 975748578 | 23%   | 229175229  | -77%  | 489645249  | 114%  |
|              | Value of Wheat Imports (USD)    | #N/A     | 62729964  | #N/A                 | 223491825 | 256%   | 381828730 | 71%   | 109316578  | -71%  | 110610223  | 1%    |
|              | Average Wheat Import Price**    | #N/A     | 0.16      | #N/A                 | 0.28      | 81%    | 0.39      | 39%   | 0.48       | 22%   | 0.23       | -53%  |
|              | IDR (Import Dependency Ratio)** | 0.6      | 0.54      | -10%                 | 0.71      | 31%    | 0.67      | -6%   | 0.49       | -27%  | 0.43       | -12%  |
|              | Number of Partners              | 13       | 10        | -23%                 | 6         | -40%   | 10        | 67%   | 6          | -40%  | 9          | 50%   |
|              | Betweenness Centrality          | 212.749  | 269.374   | 27%                  | 74.042    | -73%   | 153.779   | 108%  | 153.211    | 0%    | 232.07     | 51%   |
| Oman         | Total Wheat Imports (kg)        | 1.21E+08 | 204702711 | 69%                  | 242308627 | 18%    | 248267752 | 2%    | 174739304  | -30%  | 246330779  | 41%   |
|              | Value of Wheat Imports (USD)    | 25708671 | 41853861  | 63%                  | 103859353 | 148%   | 155737298 | 50%   | 41458593   | -73%  | 65851920   | 59%   |
|              | Average Wheat Import Price**    | 0.21     | 0.20      | -3%                  | 0.43      | 110%   | 0.63      | 46%   | 0.24       | -62%  | 0.27       | 13%   |
|              | IDR (Import Dependency Ratio)** | 1.08     | 1.04      | -4%                  | 1.02      | -2%    | 1.06      | 4%    | 1.01       | -5%   | 1          | -1%   |
|              | Number of Partners              | 7        | 11        | 57%                  | 8         | -27%   | 12        | 50%   | 8          | -33%  | 11         | 38%   |
|              | Betweenness Centrality          | 27.726   | 304.531   | 998%                 | 44.068    | -86%   | 36.88     | -16%  | 156.119    | 323%  | 17.829     | -89%  |
| Qatar        | Total Wheat Imports (kg)        | 59119232 | 21506829  | -64%                 | 100505875 | 367%   | 114201672 | 14%   | #N/A       | #N/A  | 138914155  | #N/A  |
|              | Value of Wheat Imports (USD)    | 11940792 | 5243476   | -56%                 | 32755441  | 525%   | 61372704  | 87%   | #N/A       | #N/A  | 39591628   | #N/A  |
|              | Average Wheat Import Price**    | 0.20     | 0.24      | 21%                  | 0.33      | 34%    | 0.54      | 65%   | #N/A       | #N/A  | 0.29       | #N/A  |
|              | IDR (Import Dependency Ratio)** | 1        | 1         | 0%                   | 1         | 0%     | 1         | 0%    | 1          | 0%    | 1          | 0%    |
|              | Number of Partners              | 11       | 6         | -45%                 | 7         | 17%    | 7         | 0%    | 3          | -57%  | 4          | 33%   |
|              | Betweenness Centrality          | 144.095  | 38.562    | -73%                 | 2.9       | -92%   | 73.5      | 2434% | 2.25       | -97%  | 0.857      | -62%  |
| Lebanon      | Total Wheat Imports (kg)        | 4.03E+08 | 321452338 | -20%                 | 410442109 | 28%    | 418863285 | 2%    | 537691541  | 28%   | 506182766  | -6%   |
|              | Value of Wheat Imports (USD)    | 63042000 | 59322923  | -6%                  | 114721413 | 93%    | 160784733 | 40%   | 108886493  | -32%  | 129266439  | 19%   |
|              | Average Wheat Import Price**    | 0.16     | 0.18      | 18%                  | 0.28      | 51%    | 0.38      | 37%   | 0.20       | -47%  | 0.26       | 26%   |
|              | IDR (Import Dependency Ratio)** | 0.74     | 0.68      | -8%                  | 0.80      | -1087% | 0.79      | -107% | 0.85       | -179% | 0.91       | -151% |
|              | Number of Partners              | 5        | 12        | 140%                 | 6         | -50%   | 7         | 17%   | 11         | 57%   | 14         | 27%   |
|              | Betweenness Centrality          | 683.19   | 688.443   | 1%                   | 1379.933  | 100%   | 1102.537  | -20%  | 811.551    | -26%  | 874.095    | 8%    |
| Saudi Arabia | Total Wheat Imports (kg)        | 2277299  | 2286211   | 0%                   | 1985895   | -13%   | 151006000 | 7504% | 1300922000 | 762%  | 1619540000 | 24%   |
|              | Value of Wheat Imports (USD)    | 760197   | 1013182   | 33%                  | 657793    | -35%   | 50225396  | 7535% | 373168063  | 643%  | 400014367  | 7%    |
|              | Average Wheat Import Price**    | 0.33     | 0.44      | 33%                  | 0.33      | -25%   | 0.33      | 0%    | 0.29       | -14%  | 0.25       | -14%  |
|              | IDR (Import Dependency Ratio)** | 0        | 0         | 0%                   | 0         | 0%     | 0.05      | 0%    | 0.26       | 420%  | 0.29       | 12%   |
|              | Number of Partners              | 14       | 17        | 21%                  | 12        | -29%   | 14        | 17%   | 15         | 7%    | 17         | 13%   |
|              | Betweenness Centrality          | 223.025  |           |                      |           |        |           |       |            |       |            |       |

Source: UN Comtrade, Reported Imports from World, and FAO Stat: Production

\*\* in these categories, a reduction is an improvement

**Definitions:**Import Dependency Ratio: Import dependency ratio (IDR) is defined as:  $IDR = \text{imports} * 100 / (\text{production} + \text{imports} - \text{exports})$ . FAO 2011

Betweenness Centrality of node v in a network is defined as: across all node pairs that have a shortest path containing v, the percentage that pass through v.

Individuals or organizations that are potentially influential are positioned to broker connections between groups and to bring to bear the influence of one group on another or serve as a gatekeeper between groups. This agent occurs on many of the shortest paths between other agents. The scientific name of this measure is betweenness centrality and it is calculated on agent by agent matrices. ORA 2014

## Section 4: Conclusions and Discussion

This project attempted to understand the global wheat network, with a focus on developments in the MENA region, to add to the body of knowledge that can be used for predicting food security risks for net-importers. New indicators from Social Network Analysis were used.

First, the global wheat network was analyzed from 1990-2012, using both network level indicators such as number of links and density, and averages of node-specific indicators such as centrality and clustering coefficients. Overall trade instances and density are increasing, while clustering and betweenness centrality are decreasing. This implies that the network is overall becoming more diversified and less centralized or clustered. Further research is recommended in regards to the clusters that are detected using Social Network Analysis calculations—do these clusters correspond to regions or trade agreements? Are they tight clusters or fairly fluid? Do they change over time?

Next, the wheat network was analyzed using several node-specific centrality measures, with a focus on MENA countries. For eigenvector centrality, which scores both net-importers and net-exporters highly, the major exporters consistently receive the highest scores. However, impacts of trade bans can be seen in the case of Egypt, which disappears from the top ten rankings during the year that it faced multiple export bans from its partners. Analyzing the network by Authority Centrality demonstrates net-importing countries' strength of partners. Iran's ability to maintain partners despite trade bans is observed through its continued high ranking in this category. Authority centrality seems to be the best indicator of a strong network for net-importers.

Finally, the analysis took a more in-depth look at MENA countries' reactions to export bans. Some countries were able to maintain wheat availability despite partners' trade bans through building new partnerships, increased imports from existing partners, or a boom in production simultaneous with the ban. Major players such as Egypt and Iran were able to increase trade with the country implementing the ban. Iran in particular greatly increased its trade with both Kazakhstan and Argentina when these countries implemented trade bans. Further research should explore how these countries were able to accomplish this—some hypotheses include trade agreements, futures or contract purchasing, exertion of political influence, or willingness to pay a higher price.

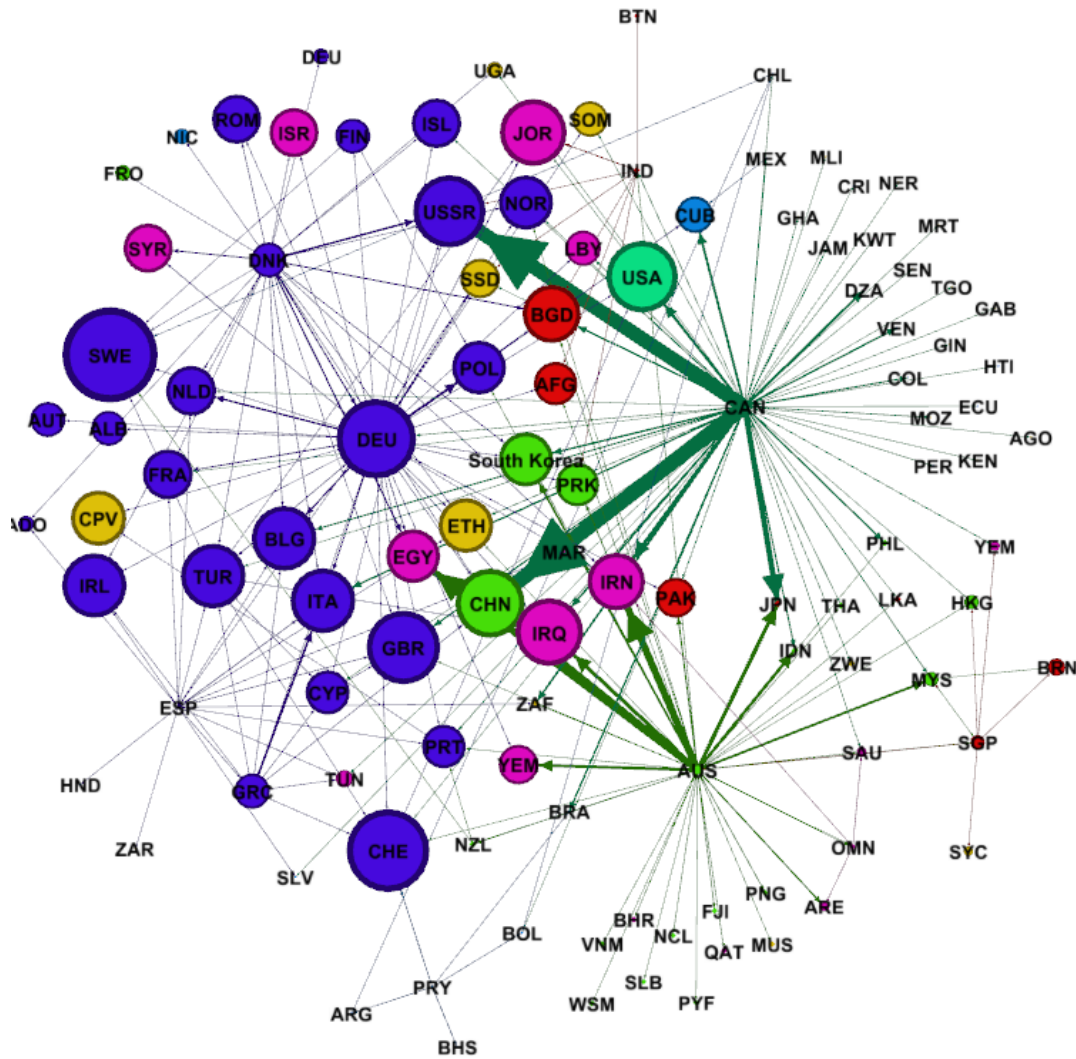
Centrality measures such as eigenvector centrality and authority centrality are reflective of reactions to bans but perhaps not predictive. Impacts of trade bans are seen in the eigenvector centrality measures but this is ex-post analysis. For example, Egypt consistently had a high eigenvector centrality, until the year that it faced several bans and was not able to increase its imports. In 2008 and 2009, when Iran increased its imports from the very countries that were implementing trade bans, it rises from a ranking of over 50<sup>th</sup> in authority centrality in 2007 to 2<sup>nd</sup> in 2008 and 5<sup>th</sup> in 2009. Again, this demonstrates a sensitivity of the indicator to changes in power structures within the network, but only after the country has reacted to a shock.

The first step in predicting a country's ability to withstand a shock in a certain market is to understand the trade network itself. This network analysis methods was

highly useful in describing the wheat trade network. However, further research is needed to be able to understand if these network science indicators provide any predictive power in regards to either crisis or resilience. One hypothesis is that if a country has a high clustering coefficient (meaning it trades mainly within its own cluster), and low centrality indicators, it is more at risk for a crisis in food trade. If there is a decline in availability within that country's region or cluster, there will not be an alternative for that country, since it does not have the external or more powerful connections necessary. However, several countries, such as Egypt and Iran, were able to maintain wheat supplies in the face of trade bans, despite scoring low on centrality indicators prior to the ban. It is possible that, given the fluidity of the network, and the presence of many partners (since many countries can produce wheat), network analysis is not a useful tool in predicting a country's ability to withstand a shock to the wheat market. In a more structured network where there are a defined number of producers, such as oil, perhaps network analysis would be more predictive. However, it is also possible that there is an indicator that could provide the necessary prediction, and that it was not analyzed in this study. For this reason, further research would improve understanding of the ability of social network analysis methods to predict both vulnerability to a crisis and ability to withstand this crisis.

## Appendix 1: Evolution of the Global Network

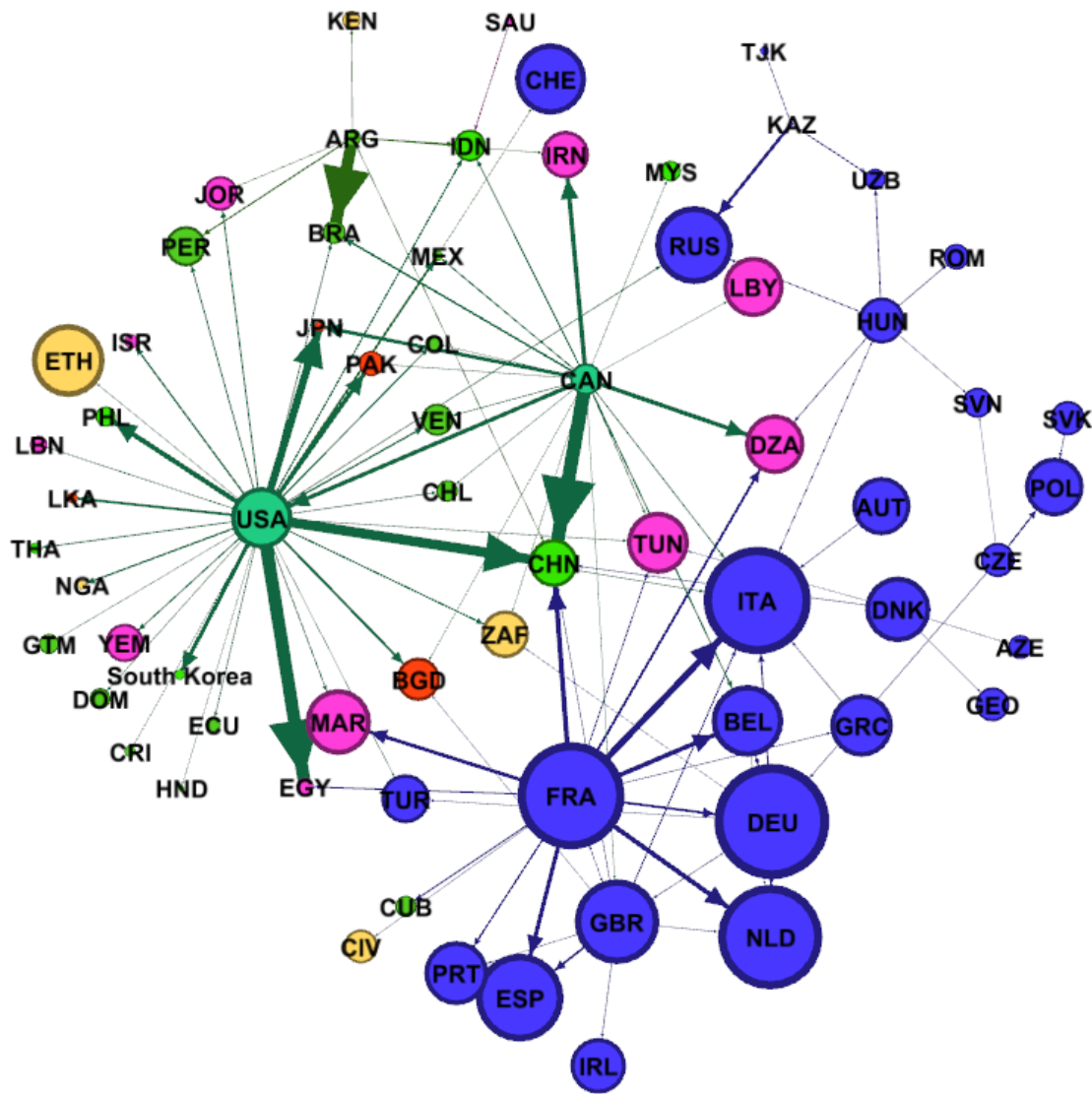
### Global Wheat Trade Network, 1990



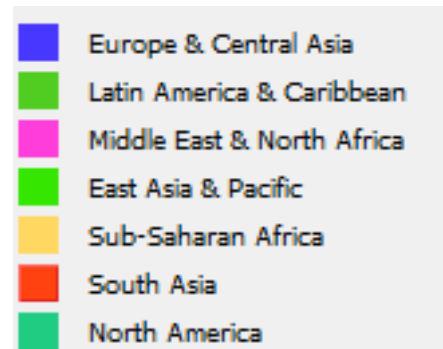
Source: UNCOMTRADE database, reported exports. Nodes are sized by eigenvector centrality. Visualization was created in Gephi.



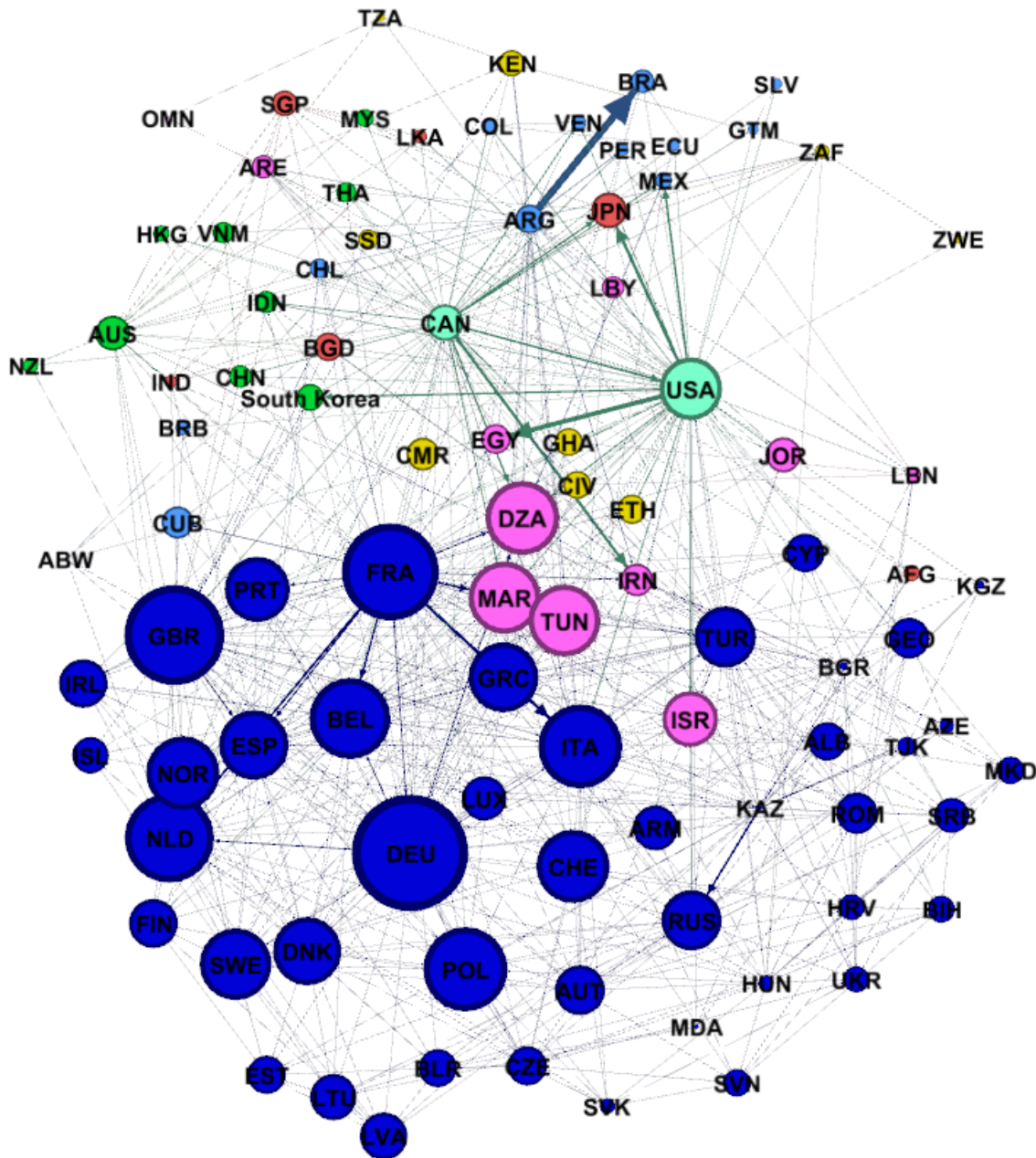
## Global Wheat Trade Network, 1995



Source: UNCOMTRADE database, reported exports. Nodes are sized by eigenvector centrality. Visualization was created in Gephi.



## Global Wheat Trade Network, 2000

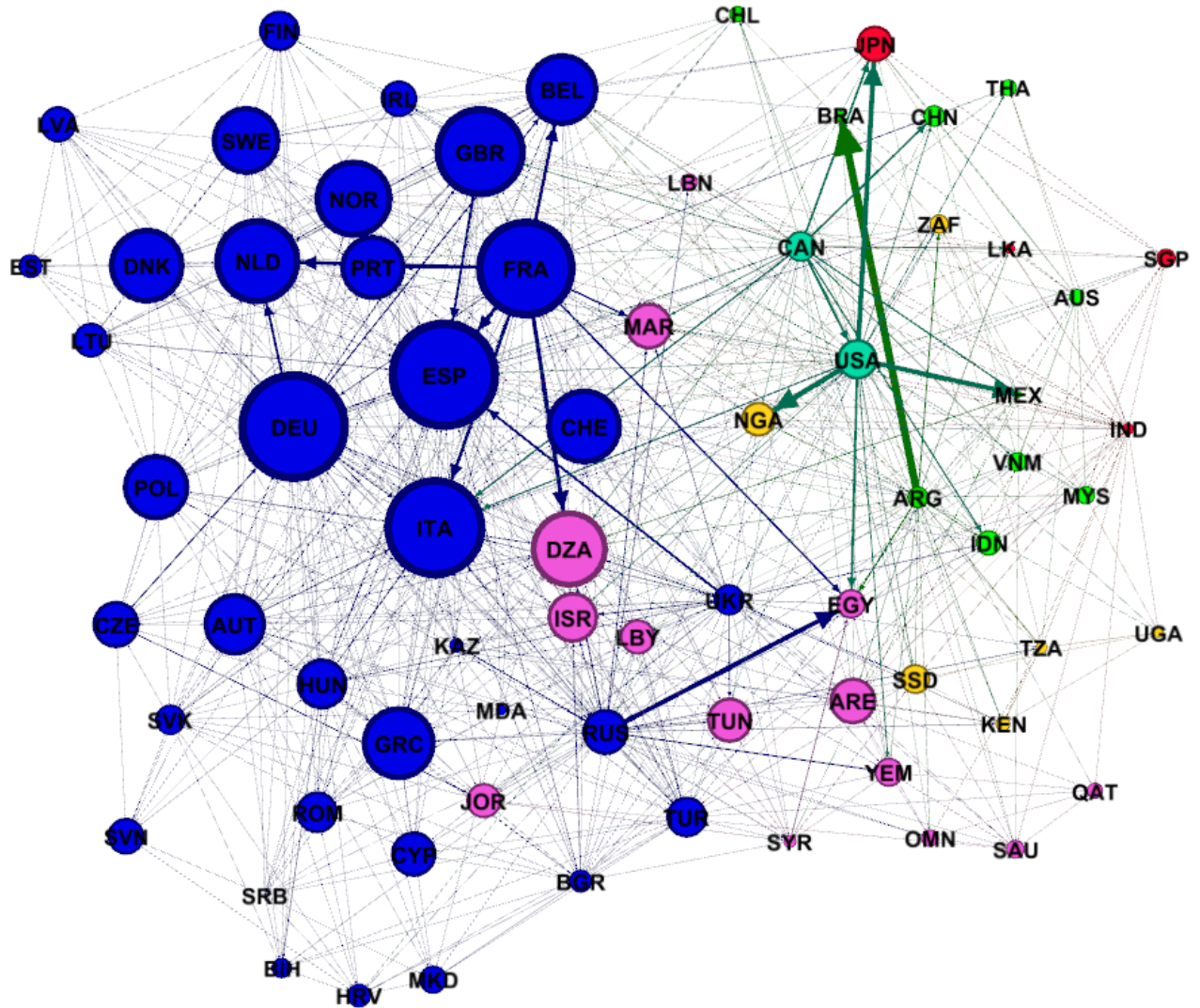


Source: UNCOMTRADE database, reported exports. Nodes are sized by eigenvector centrality, and filtered by node degree higher than 5. Visualization was created in Gephi.





## Global Wheat Trade Network, 2005

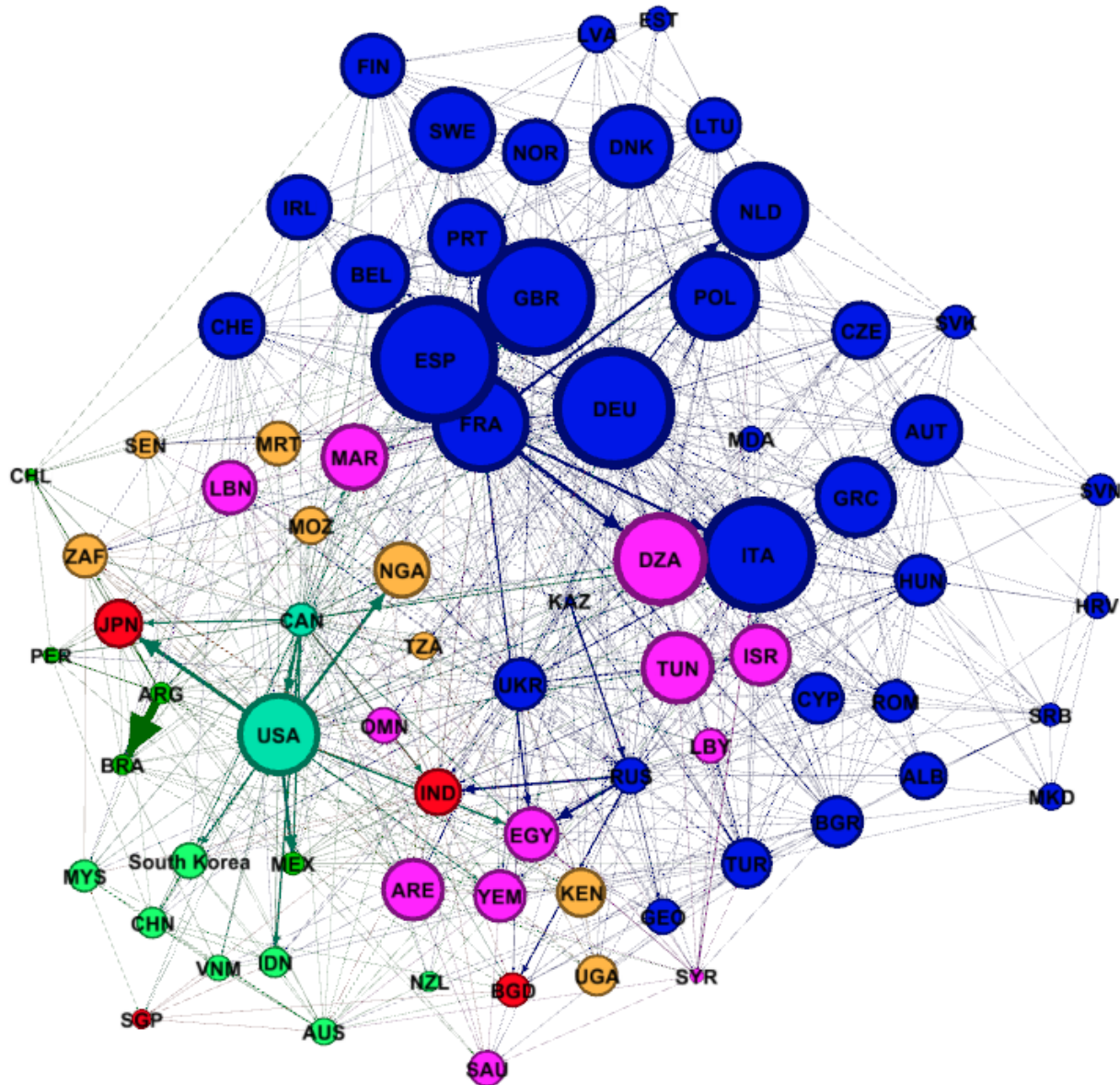


Source: UNCOMTRADE database, reported exports. Nodes are sized by eigenvector centrality, and filtered by node degree higher than 10. Visualization was created in Gephi.





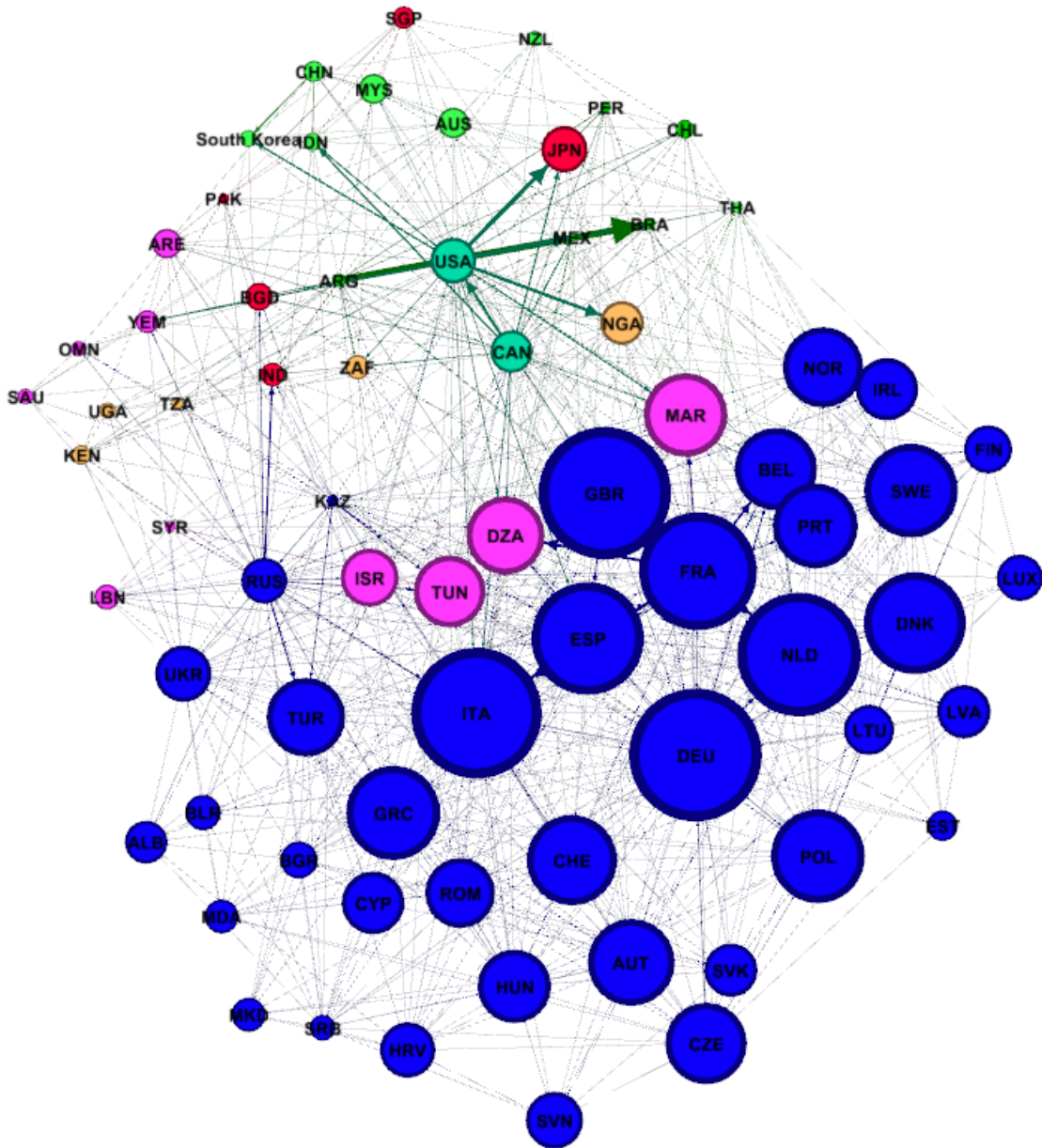
## Global Wheat Trade Network, 2006



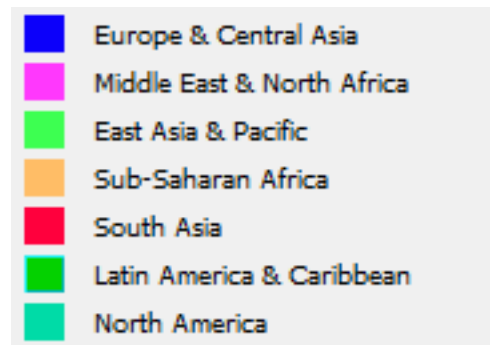
Source: UNCOMTRADE database, reported exports. Nodes are sized by eigenvector centrality, and filtered by node degree higher than 10. Visualization was created in Gephi.



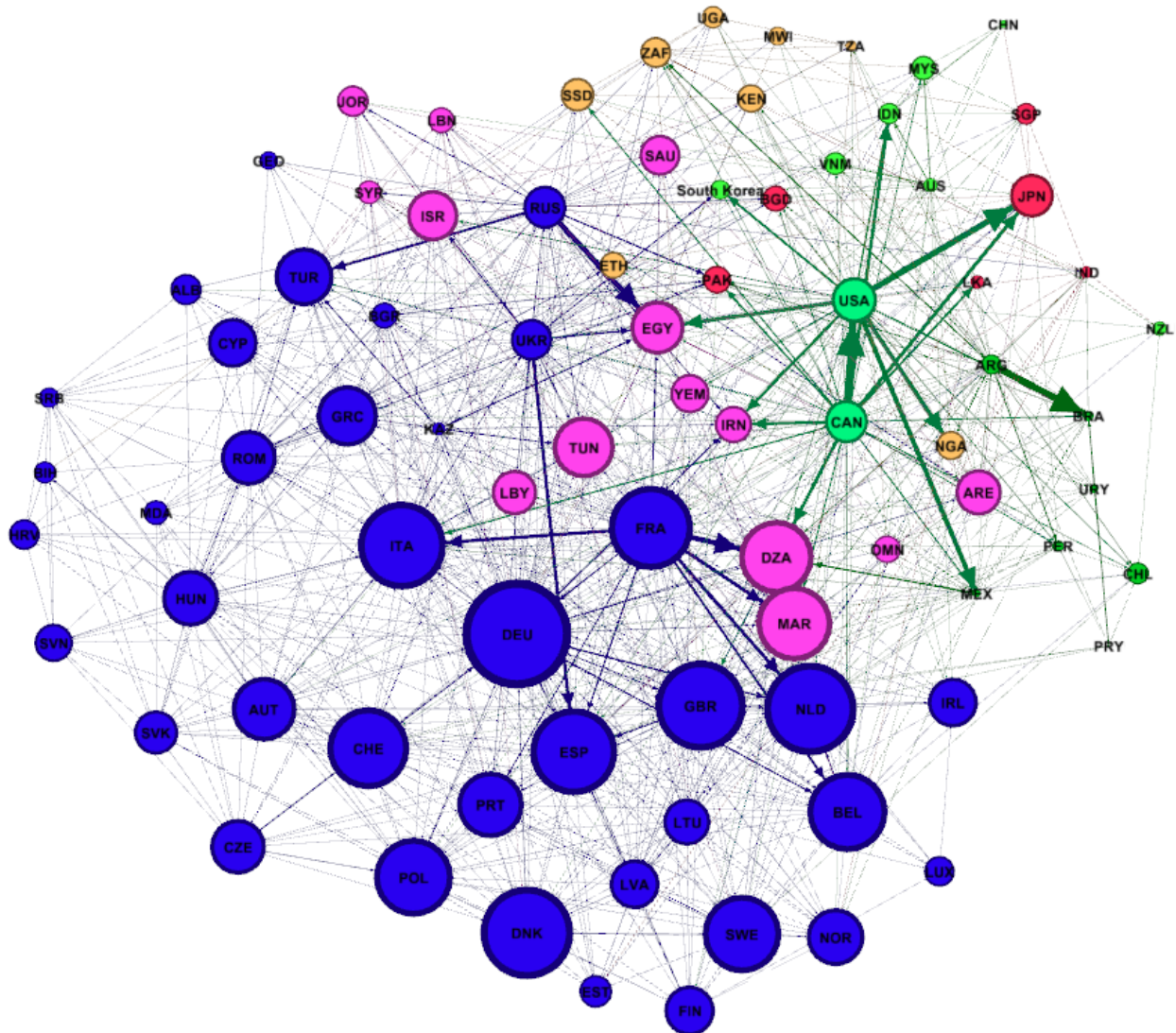
## Global Wheat Trade Network, 2007



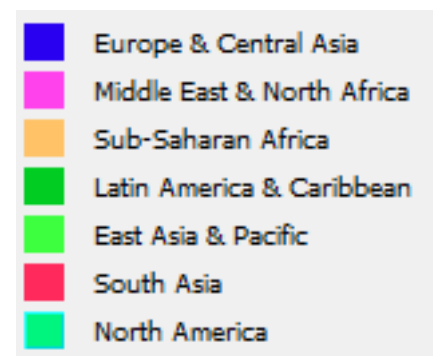
Source: UNCOMTRADE database, reported exports. Nodes are sized by eigenvector centrality, and filtered by node degree higher than 10. Visualization was created in Gephi.



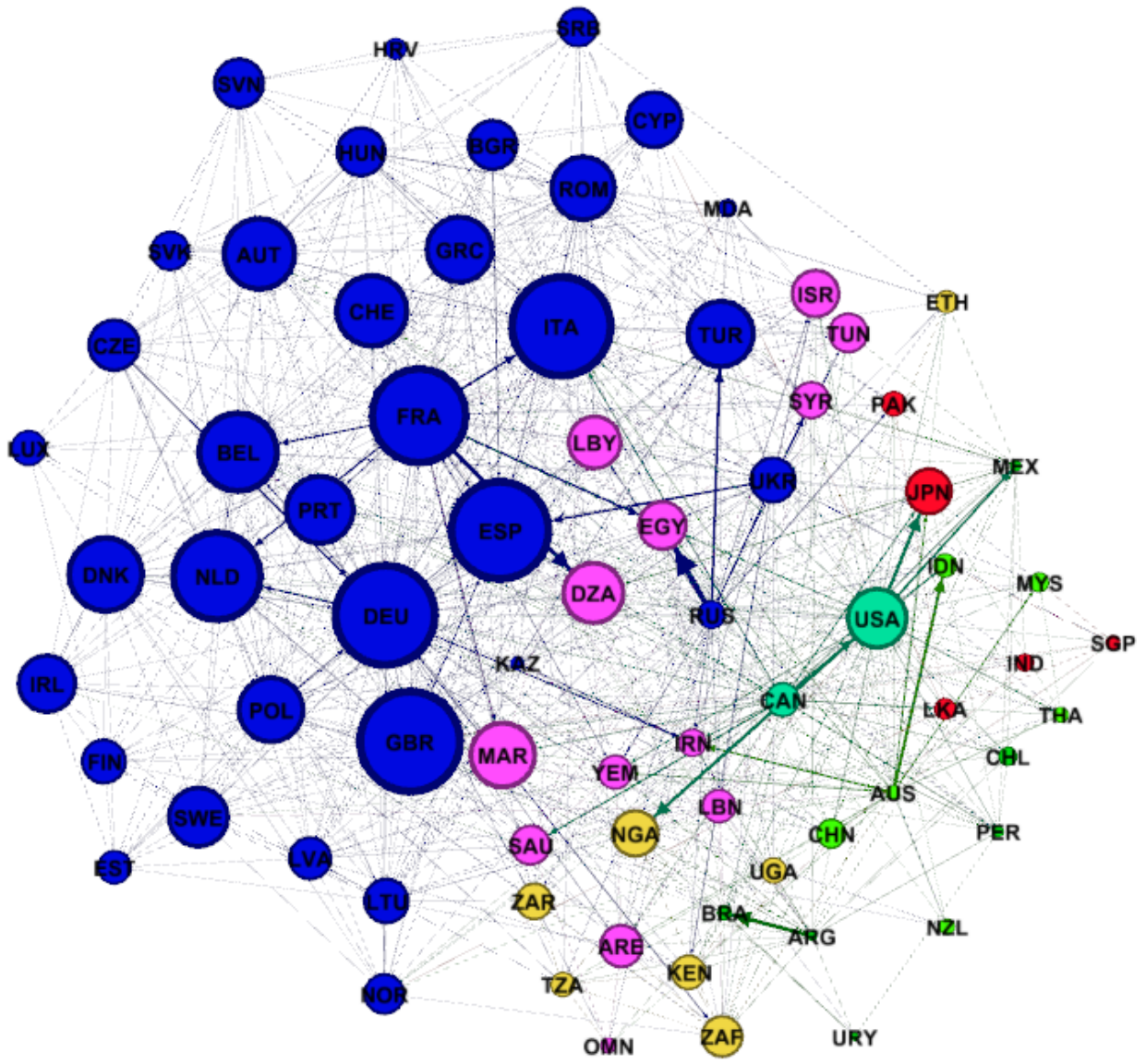
## Global Wheat Trade Network, 2008



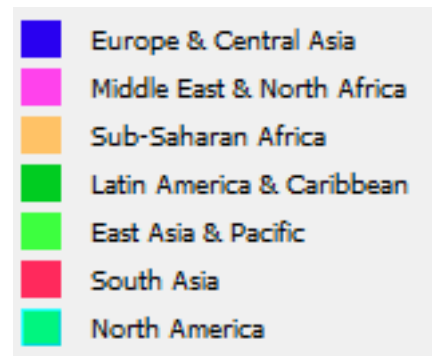
Source: UNCOMTRADE database, reported exports. Nodes are sized by eigenvector centrality, and filtered by node degree higher than 10. Visualization was created in Gephi.



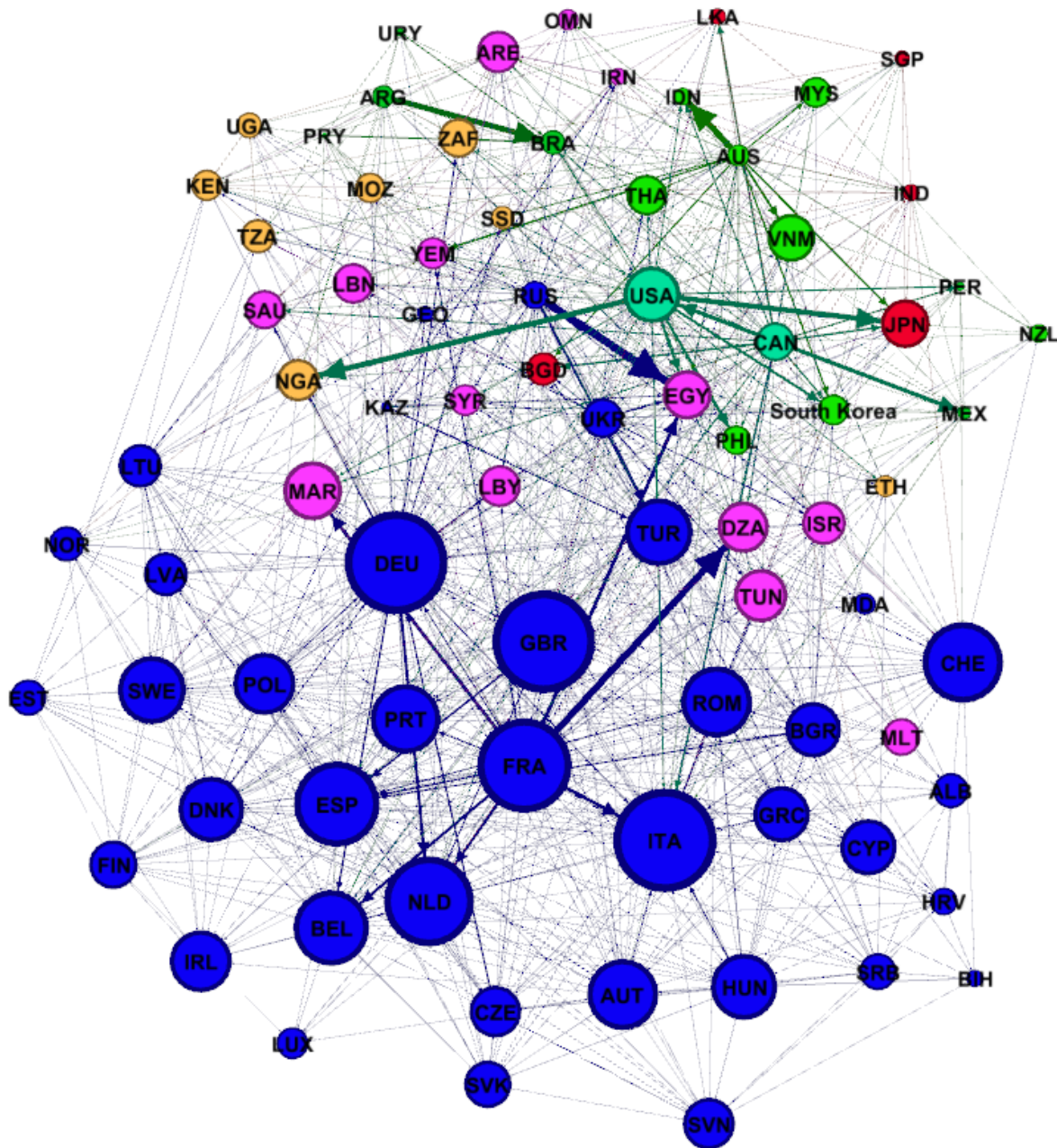




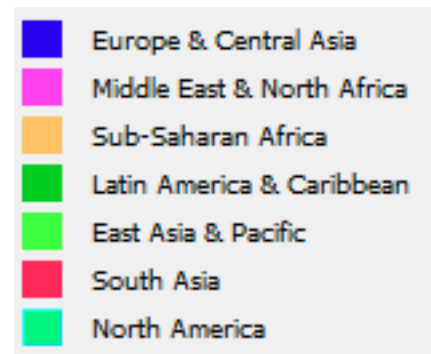
Source: UNCOMTRADE database, reported exports. Nodes are sized by eigenvector centrality, and filtered by node degree higher than 10. Visualization was created in Gephi.



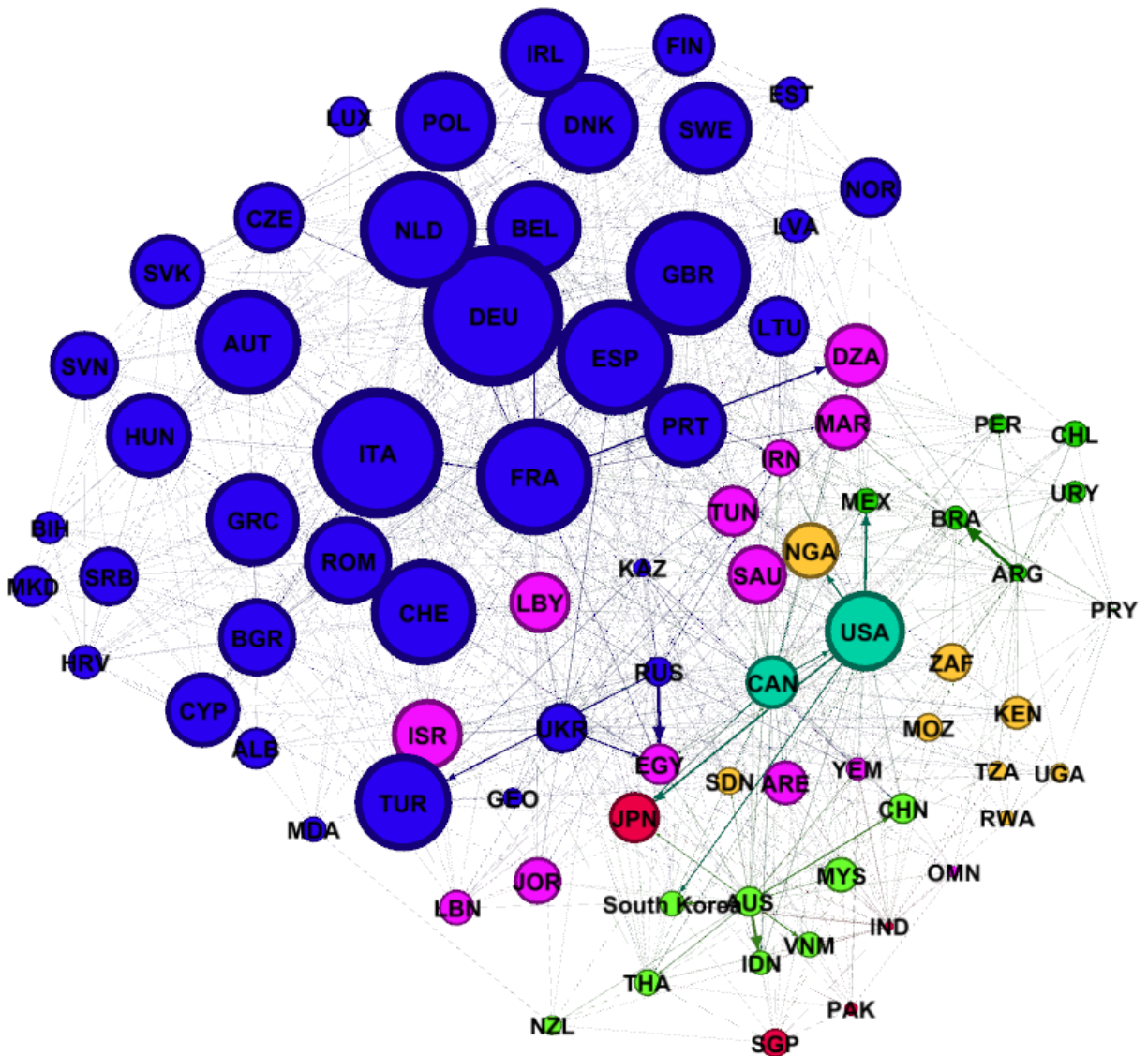
## Global Wheat Trade Network, 2010



Source: UNCOMTRADE database, reported exports. Nodes are sized by eigenvector centrality, and filtered by node degree higher than 10. Visualization was created in Gephi.



## Global Wheat Trade Network, 2012

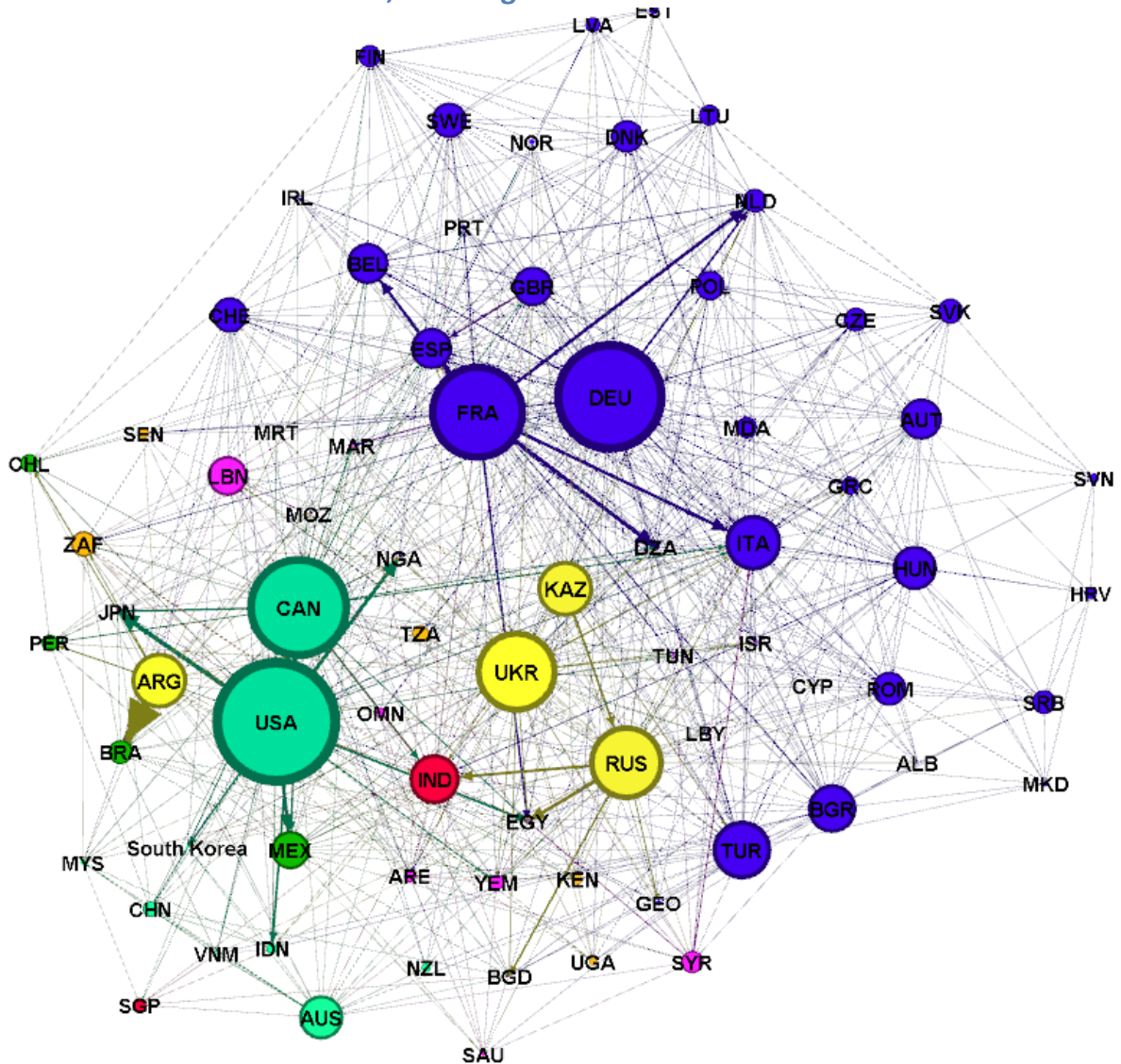


Source: UNCOMTRADE database, reported exports. Nodes are sized by eigenvector centrality, and filtered by node degree higher than 10. Visualization was created in Gephi.





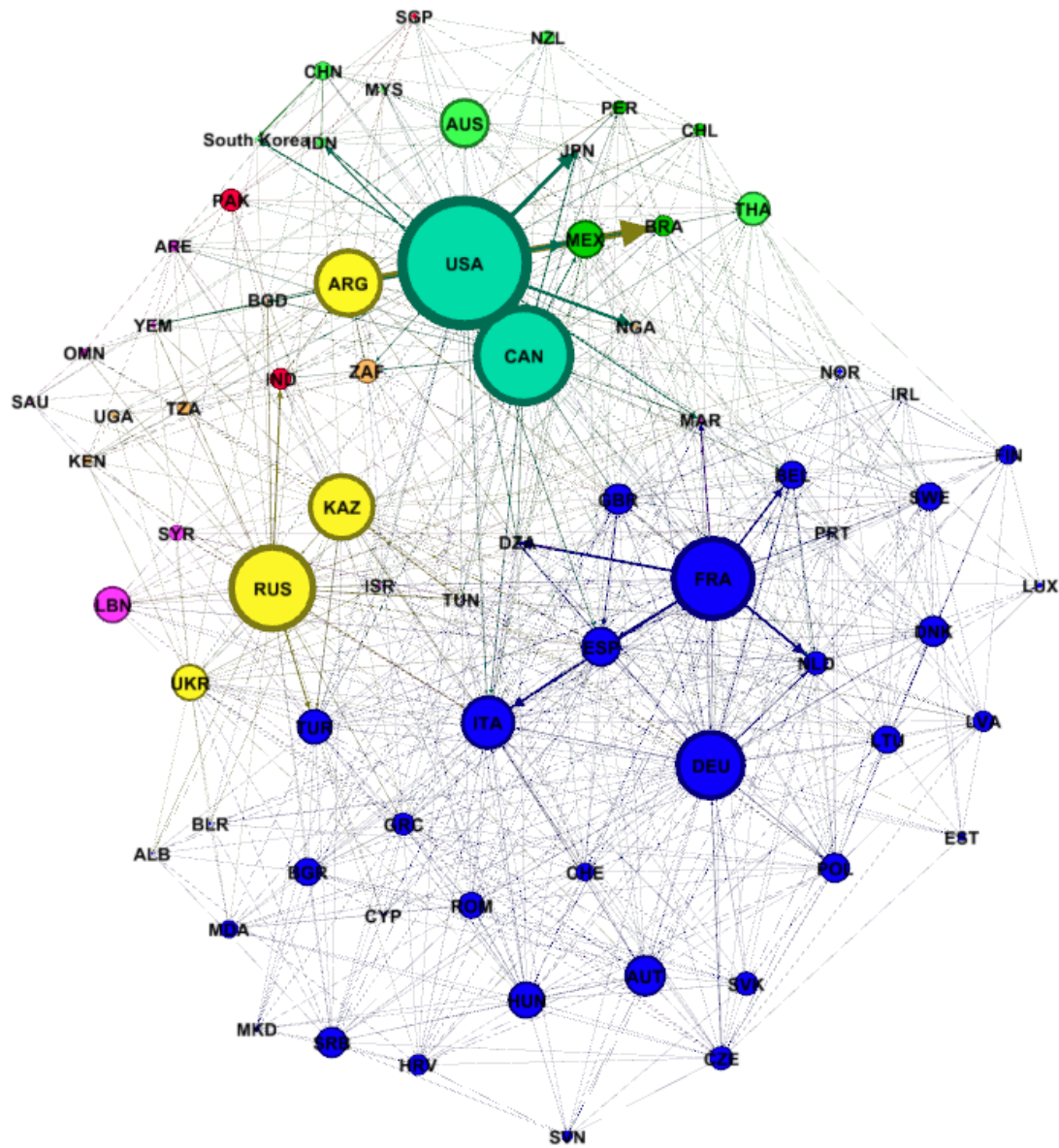
## Global Wheat Trade Network, Out-Degree 2006



Source: UNCOMTRADE database, reported exports. Nodes are sized by out degree, and filtered by node degree higher than 10. Visualization was created in Gephi. Yellow nodes indicate countries that implement export bans.



## Global Wheat Trade Network, Out-Degree 2007

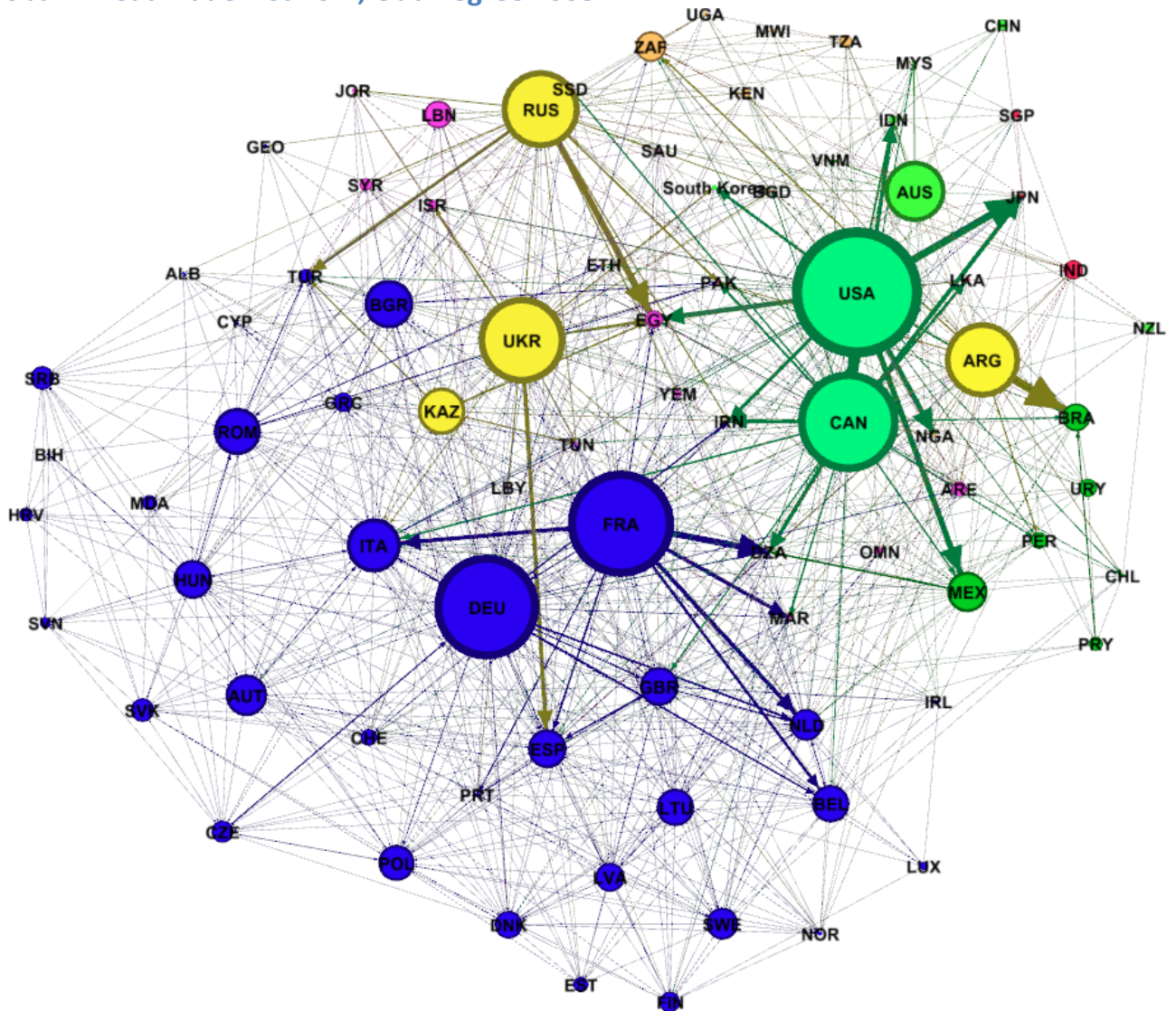


Source: UNCOMTRADE database, reported exports. Nodes are sized by out degree, and filtered by node degree higher than 10. Visualization was created in Gephi. Yellow nodes indicate countries that implement export bans.





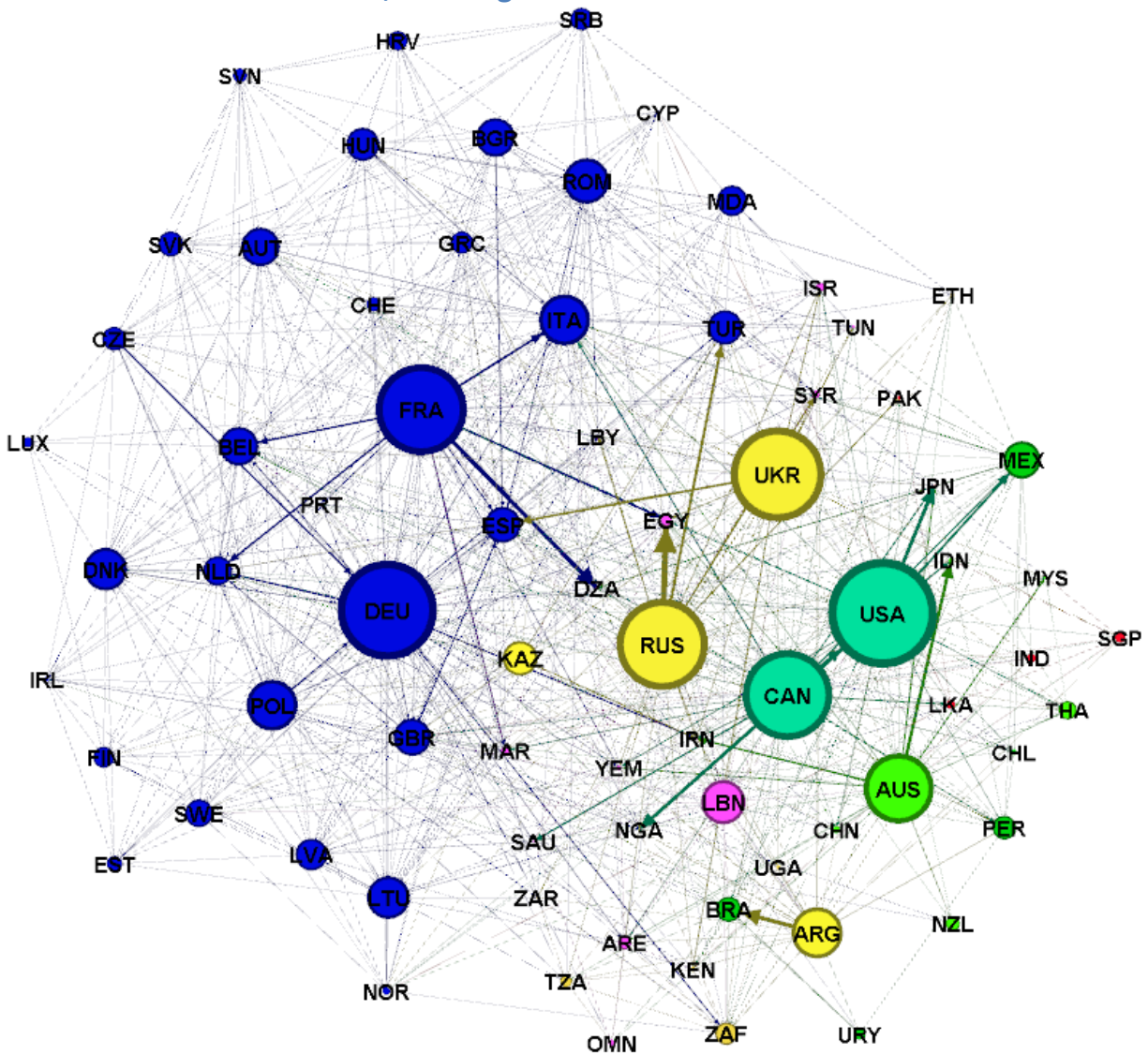
## Global Wheat Trade Network, Out-Degree 2008



Source: UNCOMTRADE database, reported exports. Nodes are sized by out degree, and filtered by node degree higher than 10. Visualization was created in Gephi. Yellow nodes indicate countries that implement export bans.



## Global Wheat Trade Network, Out-Degree 2009

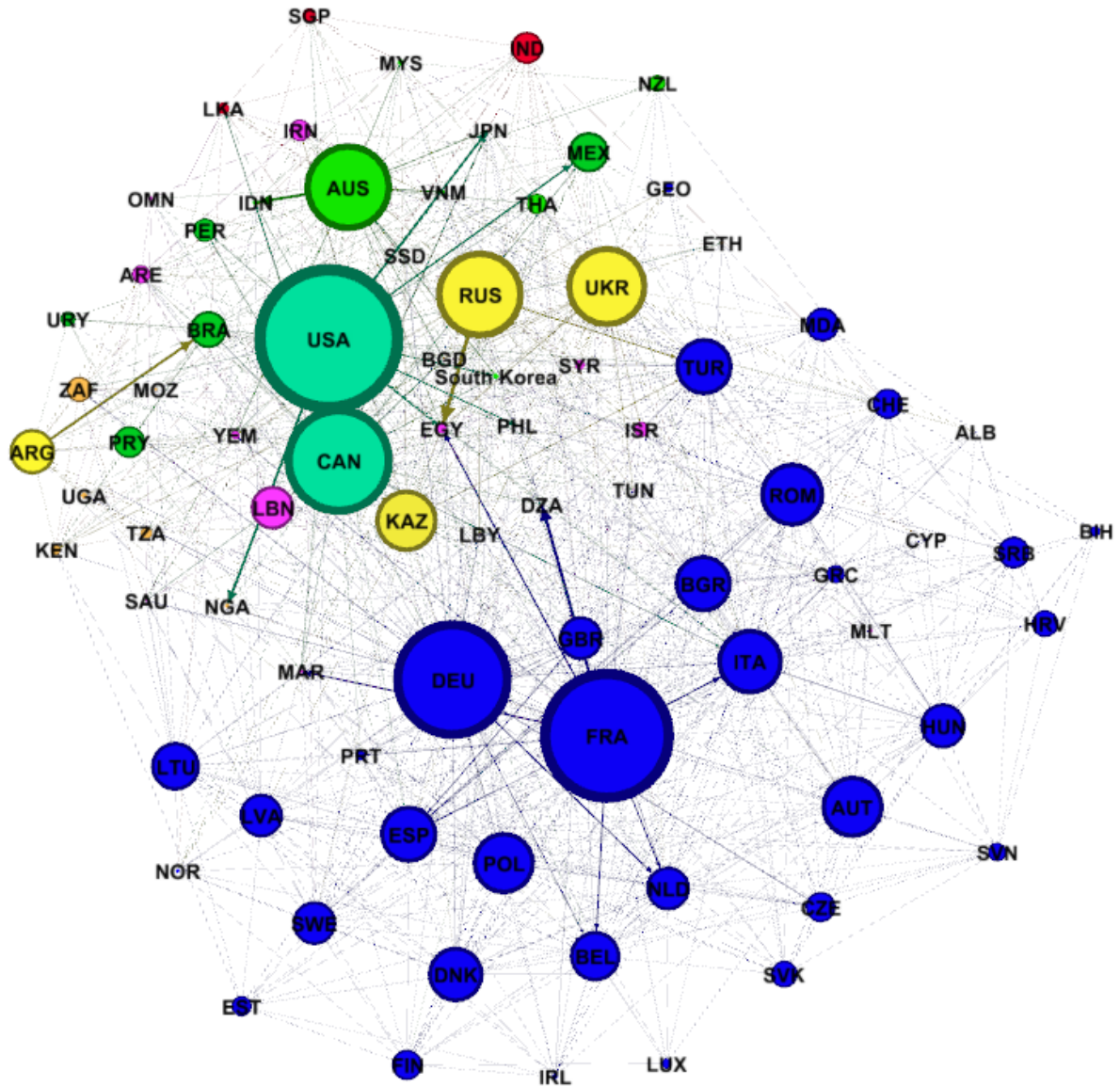


Source: UNCOMTRADE database, reported exports. Nodes are sized by out degree, and filtered by node degree higher than 10. Visualization was created in Gephi. Yellow nodes indicate countries that implement export bans.

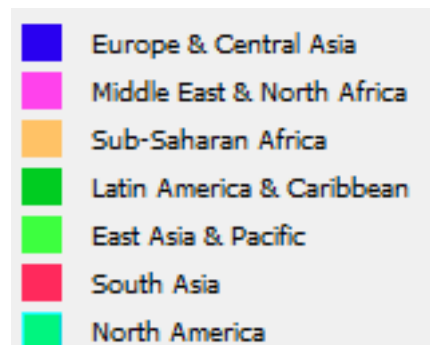




## Global Wheat Trade Network, Out-Degree 2010



Source: UNCOMTRADE database, reported exports. Nodes are sized by out degree, and filtered by node degree higher than 10. Visualization was created in Gephi. Yellow nodes indicate countries that implement export bans.



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