A Model for Macro Economic Performance

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Economic Decision Modeling

Goal of an Economy

When analyzing various countries economies of the world, we put a lot of thought into which variables that we wanted to use to help measure an efficient and prosperous economy. We figured that we wanted to focus on both inputs and outputs of an economy. For outputs we included variables such as Gross Domestic Product and Gross Domestic Product per capita. For inputs we included variables such as interest rates, inflation, working population, unemployment (in our case we used employment for the purpose of our decision model) and life expectancy. We figured that while using these inputs and outputs, we can have a good baseline of how the economy is doing for the countries that we decided to look at. We put a large emphasis on the factors involving the financial market as well as the workforce and the outputs that all of these produce. Yes as much as there factors that we discounted such as happiness and corruption, we believe that in order to have a strong GDP, there is a negative correlation with corruption because usually the markets are very efficient in order to maintain strong GDP and GDP per capita. We narrowed down our variables into factors that best suit our model, not necessarily the only variables that we could have use. Of course all of the potential variables due play a role in the economy but they all have different importances to the overall economy so we chose the "strongest" predictors of a strong economy.

Performance Measures

The performance measures of interest in our study for quantifying the value of a country's economy are given below in Table 1. We include monetary metrics as these directly quantify an aspect of an economy. We included education metrics because a prosperous economy knows that increasing the level of education of its workforce will yield more productive and skilled workers to produce wealth. We included human development metrics because the people of a country should benefit from a good economy. We included workforce metrics as these represent the people that create the value of a country's economy. These performance measures are made available by The World Bank (https://data.worldbank.org/) for countries world-wide since 1960.

Table 1: Performance Measures

Focus	**Measure**
Education	School enrollment, primary (% net)
Education	School enrollment, secondary (% net)
Human Development	Access to electricity (% of population)
Human Development	Life expectancy at birth, total (years)
Human Development	People using basic sanitation services (% of population)

Human Development	People using basic drinking water services (% of population)
Monetary	GDP (current US$)
Monetary	GDP per capita (constant 2010 US$)
Monetary	GNI (current US$)
Monetary	GNI per capita (constant 2010 US$)
Monetary	Inflation, consumer prices (annual %)
Monetary	Real interest rate (%)
Monetary	GINI index (World Bank estimate)
Workforce	Population ages 15-64, total
Workforce	Unemployment, total (% of total labor force) (national estimate)

The first step we took in finalizing our performance metrics was to see how much of the data is incomplete for each metric because some countries don't report on metrics. The percent of incomplete data for each performance metric is given below by Figure 1. The performance metric least reported is GINI at around 90% incomplete, so this is a metric that will have to be removed to allow for more countries to be evaluated. Before removing any metrics the next characteristic of the data to check is the pairwise correlations.

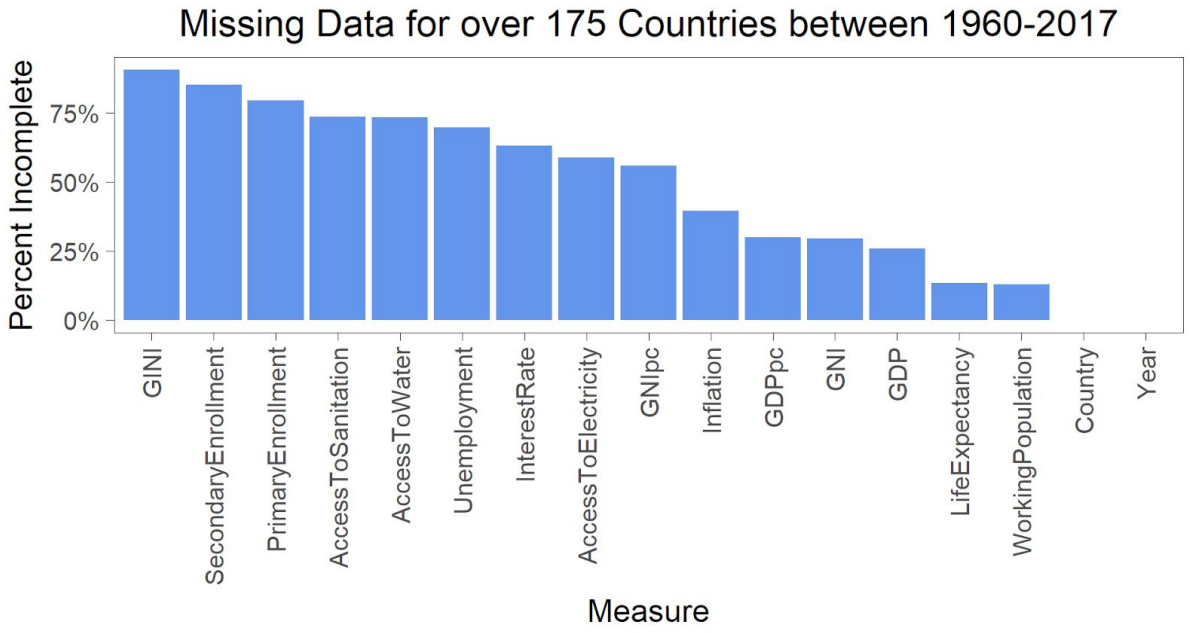

Figure 1: Missing Macro-Economic Data

The pairwise correlations of our data tells us which metrics have a strong linear relationship, and this is shown below by Figure 2. The way you read Figure 2 is by looking for a cluster of white circles and a cluster of black circles, these indicate which group of metrics are correlated. The cluster of white circles indicate positive correlation, and the black circles indicate negative correlation, whereas the gray indicate no correlation. The sizes of the circles

indicate the magnitude of correlation where a smaller circle is close to a correlation of 0. For example, GNI and GDP have a strong linear relationship with a correlation close to 1; this means that as GNI increases, so does GDP. This relationship means that if a country has a high GDP then they will have a high GNI, and vis versa, which double-counts towards or against their economic ranking relative to other countries. So, it is good to remove most if not all highly correlated variables to prevent a set of correlated metrics from biasing the rankings.

There is a cluster of white circles near the center of Figure 2 showing a lot of positive correlation. Using this cluster we decided to keep LifeExpectancy and remove AccessToWater, SecondaryEnrollment, AccessToElectricity, AccessToSanitation, and PrimaryEnrollment. The reason for keeping LifeExpectancy is two-fold, intuitively it makes sense that educated and well developed people live a longer life, and it was well-reported on by countries according to Figure 1. GDP and GNI, as well as GDPpc and GNIpc, are correlated so only one set is required. We decided to keep GDP and GDPpc as this is a more representative measure of an economy's output than GNI and GNIpc. Finally, GINI was removed due to being underreported by countries.

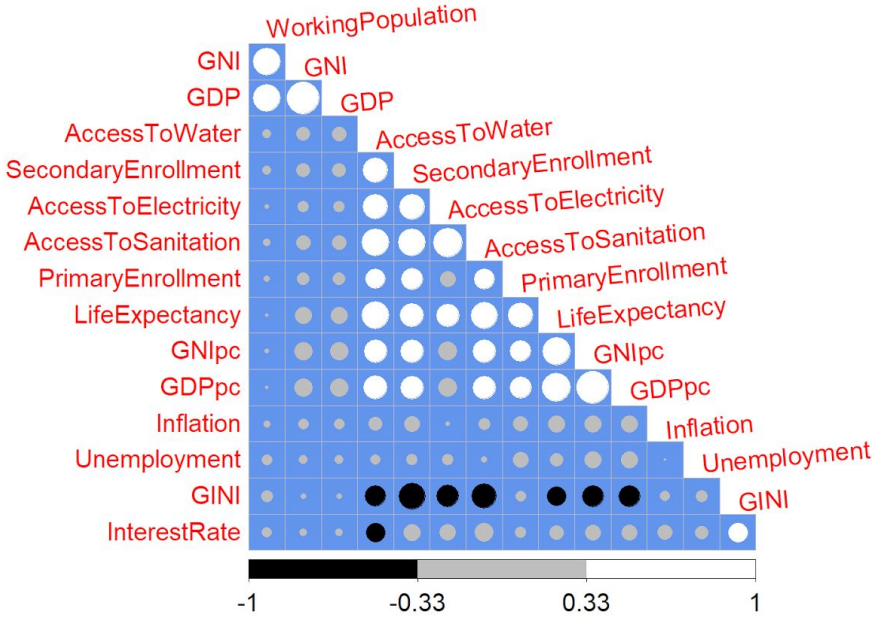

Figure 2: Correlation in Macro-Economic Data

The final set of variables that we decided to move forward with are the following:

- GDP
- GDPpc
- LifeExpectancy
- Unemployment
- WorkingPopulation
- Inflation
- InterestRate

The last aspect of our data we looked into was the time interval we want to include in our study. So, we plotted the number of countries that reported on our final set of variables

between 1960-2017 in Figure 3 below. The time interval we choose was 2000-2014 because this represents where the data is most dense with the most reports.

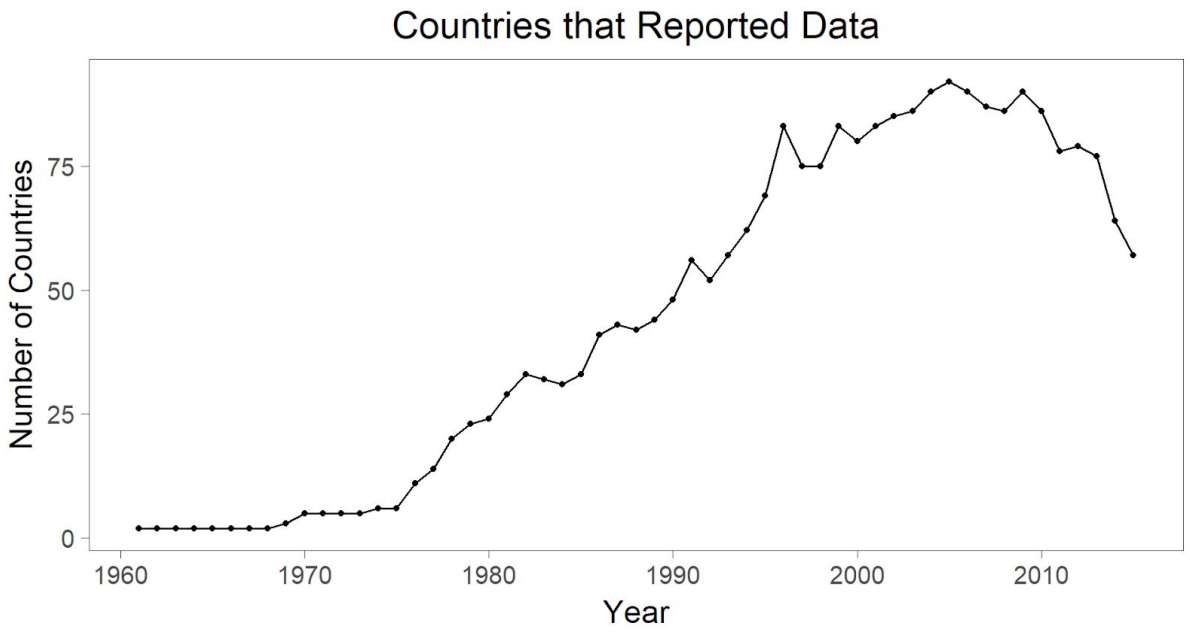

Figure 3: Countries that Report Macro-Economic Data

Benchmark Countries

The result of our data mining gave us 154 countries to rank based on how their economy performed during 2000-2014. Table 2 below gives the average GDP of the top 3, middle 3, and bottom 3 countries according to GDP. This table shows that our set of benchmark countries is large because we are considering high, middle, and low income countries when ranking countries world-wide.

Table 2: Average GDP (2010 USD$) between 2000 - 2014

Country	GDP	GDP Rank
United States	$13,797,093,333,333	1
Japan	$4,980,170,000,000	2
China	$4,550,581,333,333	3
Uruguay	$31,859,481,434	74
Tanzania	$31,080,665,432	75
Ethiopia	$30,967,587,984	76
Djibouti	$591,122,040	152
Tonga	$248,340,470	153
Kiribati	$132,704,929	154

Decision Model

This section will present two models for ranking countries. The first model answers the question: How efficiently does a country use its workforce to yield its GDP? This question is answered by a linear programming model known as Data Envelopment Analysis (DEA) [Callen]. This model requires a set of inputs, outputs, and decision-making units (DMUs) to determine how efficiently each DMU uses its inputs to achieve its outputs. The formulation of our DEA model is decomposed and explained below.

The first step is to define the sets in this model. Sets are the categories containing all the information there is to know in the system you are modeling. The sets for our model include the following:

$Inputs - a\ set\ of\ inputs\ that\ a\ DMU\ can\ use$

$Outputs - a\ set\ of\ outputs\ that\ a\ DMU\ produces$

$DMUs - a\ set\ of\ decision\ making\ units\ that\ will\ be\ ranked\ against\ each\ other$

Then we define the parameters. Parameters are what define the relationships between the sets and contain numeric values that represent the problem in the system. The parameters for our model include the following:

$dmu - represents\ a\ single\ DMU\ that\ is\ to\ be\ ranked$

$input\_value\{i\ in\ Inputs,\ u\ in\ DMUs\} - the\ value\ of\ Input\ i\ that\ DMU\ u\ used$

$output\_value\{o\ in\ Outputs,\ dmu\ in\ DMUs\} - the\ value\ of\ Output\ o\ that\ DMU\ u\ achieved$

Next, we define the variables. Variables are what define the solution to the problem in the system that we want to solve. Variables contain the values we don't know and define the complexity of the optimization problem in terms of it being a linear, integer, or nonlinear program or any mixture of the three. The variables for my model include the following:

$input\_weight\{i\ in\ Inputs\} - puts\ Input\ i\ on\ the\ same\ unit\ of\ measure\ as\ all\ Inputs$

$output\_weight\{o\ in\ Outputs\} - puts\ Output\ o\ on\ the\ same\ unit\ of\ measure\ as\ all\ Outputs$

Now we will define the objective function to be a maximization of the efficiency of a DMU. DEA defines efficiency as the weighted sum of outputs divided by the weighted sum of inputs. Given that efficiency is meant to take on a value between 0 and 1, we can rewrite the objective function to just be the weighted sum of outputs if we ensure the sum of weighted inputs is always equal to 1.

$$maximize\ EFFICIENCY: \sum_{o\ in\ Outputs} (output\_value_{[o,dmu]} * output\_weight_{[o]})$$

The first constraint regards the relationship between outputs and inputs. This constraint says that the weight sum of outputs can never exceed the weight sum of inputs. This constraint represents the idea that you can't get more than you put in.

$$s.t.\ OUTPUT\{u\ in\ DMUs\}: \sum_{i\ in\ Inputs}(input\_value_{[i,u]} * input\_weight_{[i]})$$

$$- \sum_{o\ in\ Outputs}(output\_value_{[o,u]} * output\_weight_{[o]}) \geq 0$$

The next constraint ensures that the weight sum of inputs equals to 1. This constraint represents that your total input is 100% of your investment towards achieving your outputs.

$$s.t.\ INPUT: \sum_{i\ in\ Inputs}(input\_value_{[i,dmu]} * input\_weight_{[i]}) = 1$$

The final constraints state that the weights must be positive and must take on some value even if it's really small.

$$s.t.\ POSITIVITY1\{i\ in\ Inputs\}: input\_weight_{[i]} \geq 1e-16$$

$$s.t.\ POSITIVITY2\{o\ in\ Outputs\}: output\_weight_{[o]} \geq 1e-16$$

The performance metrics that we decided to use as inputs for our DEA model are: WorkingPopulation, LifeExpectancy, and Employment. These inputs represent the workforce of a country and therefore are considered economic resources in this model. The performance metrics that we decided to use as outputs was just GDP. GDP is what defines economic output so this naturally fits the description of outputs in a DEA model. The metrics we didn't include was GDPpc because we have GDP and WorkingPopulation already in the model, and then we didn't include Inflation and InterestRate because those are already captured by the constant 2010 USD value of GDP for all countries we are evaluating. So, if a country can show larger values of GDP with a smaller workforce then the DEA model considers that country to be more efficient relative to the other countries.

Figure 4 below shows how efficient countries are with respect to GDP and Working Population. If you look at the top left corner of the chart, where GDP is higher and Working Population is lower, then you can see an efficiency frontier where the green defines the frontier of 100% efficiency. This efficiency frontier is what DEA is meant to find when analyzing the inputs and outputs of DMUs.

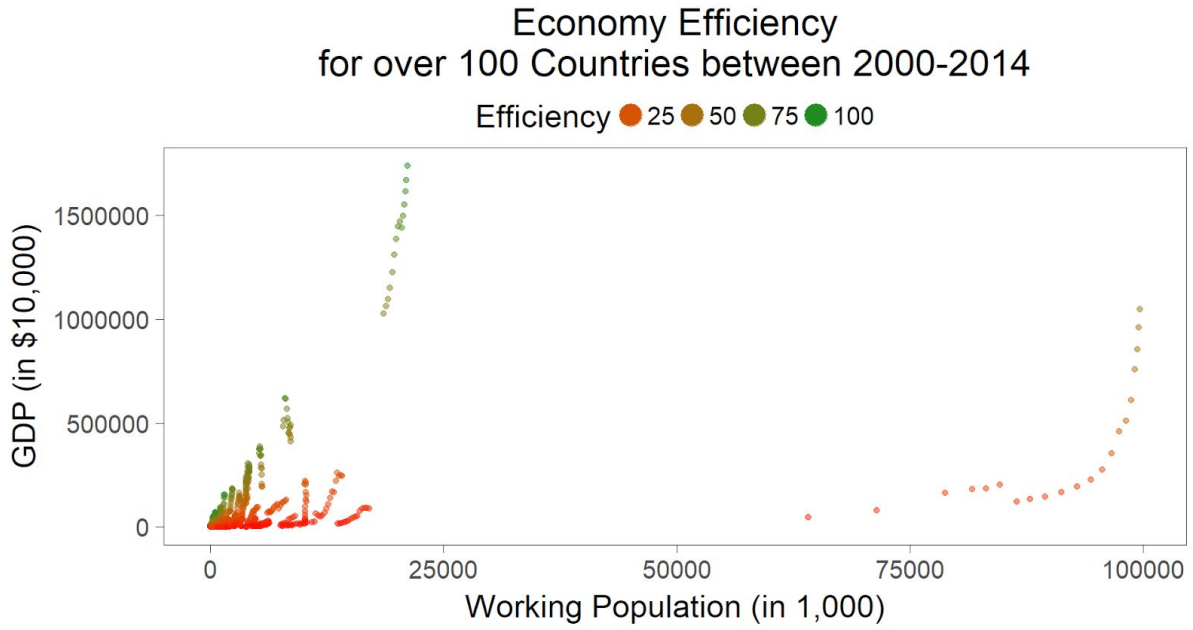

Figure 4: GDP v. Working Population and Economic Efficiency

Figure 5 below shows the relationship between GDP and Life Expectancy for all countries. The cluster of efficient countries is towards the right where a country with longer living people are the ones able to achieve higher values of GDP. This shows that the countries with a life expectancy under 70 cannot produce enough GDP to be considered efficient.

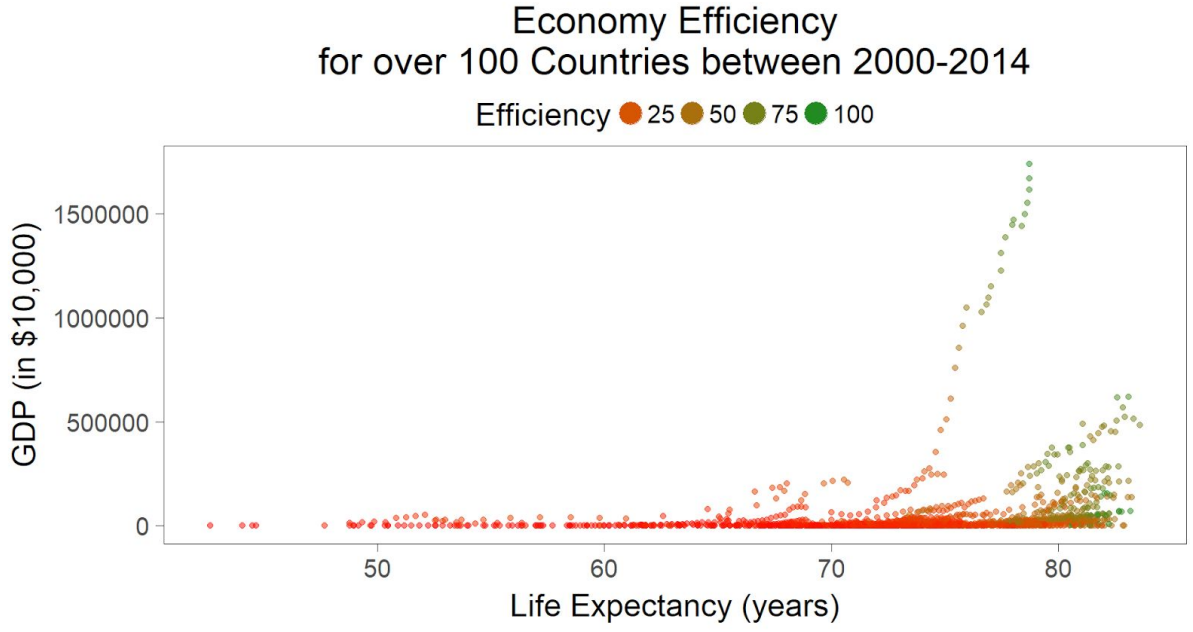

Figure 5: GDP v. Life Expectancy and Economic Efficiency

Figure 6 below shows where efficient countries are with respect to GDP and Employment. This shows that the countries with 90-99% employment are the countries that can achieve higher levels of GDP but doesn't ensure higher levels of GDP because there exists countries

with this level of employment but still cannot produce enough GDP to be considered efficient.

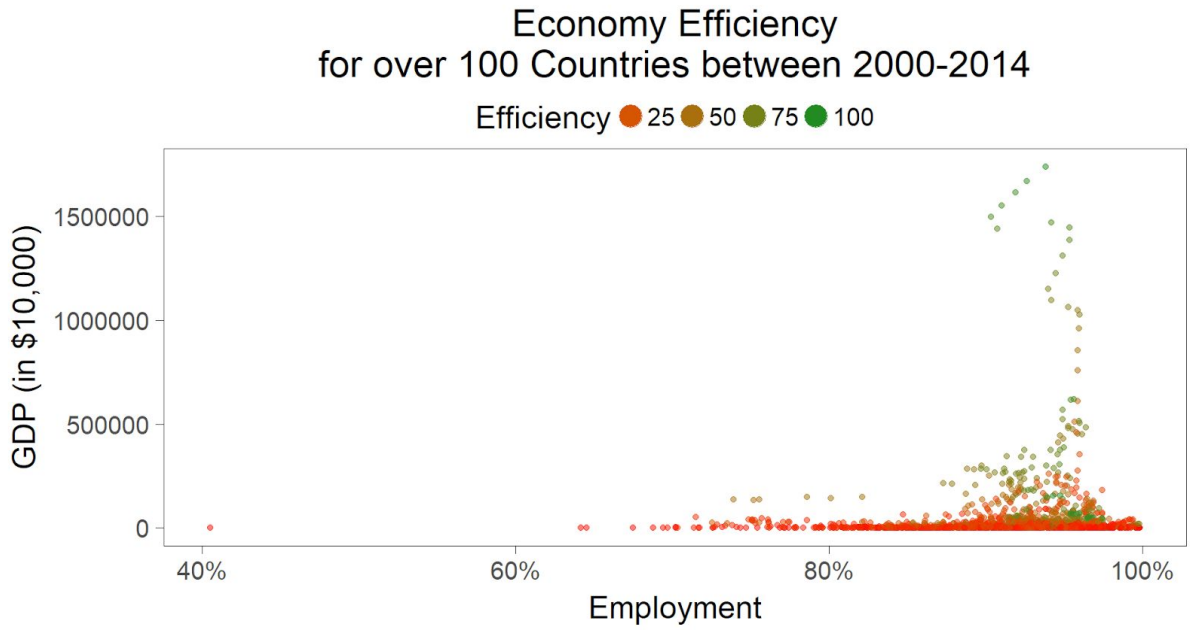

Figure 6: GDP v. Employment and Economic Efficiency

The most efficient economies between 2000-2014 are given below. These are the countries that consistently fall into the efficiency clusters shown in Figures 4-6.

Table 3: Top 5 Efficient Economies between 2000-2014

Country	Efficiency	Rank
United States	0.835364	1
Luxembourg	0.768259	2
Norway	0.727244	3
Switzerland	0.715785	4
Japan	0.707101	5

Reasons for Success

Based on our ranking on the countries, we found the top five countries that are the best among the 154 countries we got in the model. In this section we will explain the economic advantages in each of the top five countries to support why they performed so well in our model.

United States

For the purposes of seeing the benchmarks that all economies should be compared to, we wanted to look at the United States Economy. That being said, this is a shear comparison

because constraints have put into place that the United States cannot be chosen as the strongest economy. As you may have already know, the United States has the highest GDP in the world at $19.417 trillion, while only ranked 20th in the world in GDP per capita of $57,400 per person. The United States inflation rate was about a 2%, which ironically was our benchmark for a good inflation rate as well. The United States interest rates have been slowly creeping up, averaging about a 1-1.25% federal funds rate. These are just a few to point out that the United States economy is fairly stable.

Now to the working aspects of the economy which were important to us. The unemployment rate is relatively high compared to the rest of the world. It was ranked 66th at a rate of 4.9%. Although it has slowly decreased going into 2017, it is still concerning how high it is compared to other strong economies. The working population is very high at over 200 million who are able to work. When you take into account the high unemployment rate, this is concerning because there are many who are able to work who are not employed. That could be reasons such as not enough jobs in the labor force, or just people who do not want to work, either or it is still concerning and does not prove to be as efficient economy as some think.

Luxembourg

One of the countries in which we were fairly surprised about in terms of making it into our top 5 was Luxembourg. It is a very small country with a total population of about 580,000 people. It has a total GDP of around $60 billion, which is ranked very low, however due to its very small population its GDP comes in at around $102,000 which is ranked first in the world according to statisticaltimes.com. Luxembourg's inflation rate is very low at 0.47% which is positive because the value of their currency is not being depreciated relative to their goods and services. The working population has a very high life expectancy of 82 years which is 13th highest in the world which shows that they are able to work longer because they need to survive financially longer, which helps boost the economy,

The one puzzling factor about Luxembourg's statistic is its very high unemployment rate. It's rate of unemployment is 6.4% which is ranked 84th in the country according to cia.gov. The amount of GDP per capita and high unemployment rate tells us either that there are potentially a lack of jobs, which could be attributed to the high life expectancy which has more people working longer.

Japan

Japan has the third highest GDP in the world with a medium GDP per capita. In 2014, Japan has the most long life expectancy in world. As we know, Japan's olders weight in the society is increasing every year. They have entered a population structure called aged society in 1994, which means more than 14% of population are older than 65 years old. Which for US, it's 2014 to enter that structure[1]. This may illustrate the long life expectancy for Japan society. Also, long life expectancy means a better welfare and health system to support a longer life.

Japan has a unemployment rate of around 8% during 2000-2014. Another key factor for Japan economy works well is the control over their monetary system. They has managed to make their inflation rate and interest rate to meet their ideal goals every year. They

[1] Zhang Wenbin, *The countermeasures of population aging of Japan and the Enlightenment to China,* 2008. 7, <Around southeast Asia>.

successfully maintained a steady monetary policy over the past decade. Japanese Yen has been defined as a "risk averse" currency for investors. It has several positive performances correlated to gold when important events like "Britain quit Euro" happened in the world.

Norway

Although Norway's GDP can't compare to those big economies in the world, it has the 13th best GDP per capita in world. Especially in 2007, Norway's GDP per capita reached 48900 Euros in 2014, which is 177% of the average of Euro Union. Oslo, the capital of Norway has 194% over the average GDP per capita of EU[2]. The reason for a high GDP per capita for Norway is its oil export industry, which is same as Qatar and other OPEC countries. This is a non-sustainable development, Norway may need to reconstruct their industry for future development. They already created an oil-fund for their country to make further investment to avoid this situation.

Norway has a good welfare system for people. Northern Europe countries like Norway all created a high-welfare society. This provided a high life expectancy and a stable economy for Norway. A peace time since WW Ⅱ give them a period to develop the welfare system. Also low population and rich natural resources is the base for the system.

Switzerland

Switzerland has been admitted to be the best economy in EU. Its GDP per capita is higher than most Euro countries.It's one of the most important economies in the world[3]. It has world-famous manufacturing industry and banking system. Low unemployment and stable currency all contributed to a good economy for Switzerland. Switzerland has a low tax-rate and the "safest" bank UBS. These conditions attract not only investors, but also immigrants coming to Switzerland. 21.8% of Switzerland's population are immigrants in 2004[4], which is the same as Australia.

Conclusion

We chose Luxembourg to be our best and most efficient economy. It came in 2nd to just the United States in our model. Using our model, it had an efficiency rating of 76.8259 out of 100. The factors that we looked into had the best score using our models which were GDP, GDP per capita, interest rates, inflation, working population as well as unemployment rate. We viewed these as great predictors of an economy and this is a reason that Luxembourg came in so efficient when measuring the entirety of an economy. Given its small size, in terms of both population and land, it uses its resources the most efficient to allow the economy to be stable as well as producing the highest GDP per capita which was pretty surprising because not many people think of Luxembourg as an efficient economy. We believe that both of our models that we used were unique in their own way and they yielded very similar results. Luxembourg will be a surprise to many but it makes sense after digging into economic factors.

[2] Gross domestic product (GDP) at current market prices by NUTS 2 regions, Eurostat
[3] Western Europe. Routledge. 2002: 645–646. ISBN 1-85743-152-9
[4] Swiss Statistical Yearbook 2008 by Swiss Federal Statistical Office

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