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The impact of oil price surges on economic growth

Valeria Restrepo

University of Central Florida

THE IMPACT OF OIL PRICE SURGES ON ECONOMIC GROWTH

by

VALERIA RESTREPO

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ABSTRACT

The objective of this research concerns identifying whether or not there is a relationship between oil price increases in a given quarter and the likelihood of a recession in the subsequent quarter. The data used is gathered from the St. Louis Fed's Fred II, the National Bureau of Economic Research, and the Energy Information Administration to generate modified variables. These variables are tested using a qualitative dependent variable, recession, in a binary choice model. The findings validated the assumption that oil prices do have a correlation with recessions, and that the relationship is a direct one. Based on the model, an increase in the price of oil will positively affect the likelihood of a "recession" outcome versus the alternative, "no recession". It is anticipated that the results will inspire future research into the causes and effects of oil price surges, as well as the determinants of economic contractions in the future based on policy decisions and economic decision-making practices in the present.

DEDICATIONS

For my loving family, specially my mother and grandmother who always believed in me,

guided me through my career, and helped me make the right decisions.

For all the teachers who taught me valuable lessons, without whom this would not be possible.

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INTRODUCTION

Have you ever asked yourself what impact does oil prices have in the United States economy, and whether oil price surges have had an effect on the likelihood of recessions? This research will attempt to aid in unveiling the mystery of the association between energy prices and economic contractions throughout history by identifying the presence and magnitude of correlation between oil prices and the probability of a future recession as defined by the National Bureau of Economic Research (NBER) – that is, "a significant decline in economic activity spread throughout the country, lasting for more than a few months" (US Business Cycle Expansions and Contractions [1], 2010); as well as extrapolating upon the significance of such a relationship. One major objective of this investigation is to raise awareness of the implication of the findings, should the alternative hypothesis prove to be true. According to the Natural Resources Defense Council (NRDC) (Safe, Strong and Secure: Reducing America's Oil Dependence), the US spends more than $200,000 per minute on foreign oil. The NRDC's projections of future foreign oil consumption predict a continuing rise in consumption while production trends down as shown in Figure 1 in the appendix. The United States economy is overly dependent on crude oil as society's major source of energy (Safe, Strong and Secure: Reducing America's Oil Dependence).For instance, most industries use oil in the production of materials and final goods (for example, in the operation of machines that are fueled or lubricated by oil), not to mention the transportation costs associated with shipping the final products to stores and homes. According to an article by journalist Michael Fitzimmons, US oil expenditures made up 62% of the monthly trade deficit in September 2010, and that percentage is set to

increase as oil prices fluctuate (Fitzsimmons, 2010). Any industry that utilizes motorized vehicles – from agriculture to entertainment – requires oil as an input for day-to-day operations. However, alternative energy sources would be beneficial to society *and* the economy for years to come, because it would reduce global warming around the world and the trade deficit of the United States caused mainly by foreign oil imports as stated by Fitzimmons. What's more, with respect to international competitiveness, in order to remain viable with world leaders in energy, Fitzimmons suggests the United States must reduce the dependence on oil and transition to natural gas. The campaign for alternative energy sources has been active for decades, and many authors have struggled with the determination of oil's impact on the economy for the exact purpose of enlightening the population to the potentially substantial effects of a reduction in oil dependency on the overall economic welfare of the United States. Thus, one of the main goals of this research is to test, and presumably reinforce the theory that an increase in oil prices affects the probability of significant contractions in economic growth.

Aside from providing information regarding the overall impact of oil dependency on the economy as a whole, the investigation into the correlation between oil price spikes and the macroeconomy may also provide further insight into the various underlying determinants of the likelihood of recession in the United States. As the model would lack credibility, explanatory power, and validity if there is only one solitary independent variable, it is important to justify the significance of the effect of oil prices on recessions by attempting to include the most significant influences on the likelihood of experiencing a recession.

In order to attain the most accurate and pertinent information, a highly structured plan of research execution, beginning with the collection of data is being followed. Quarterly data has been compiled, analyzed and organized for real GDP, historical oil prices, aggregate unemployment, and interest rates represented via the federal funds rate from the first quarter of 1970 to the most recent available data, designated to be the first quarter of 2010. Various sources are compared in order to determine with accuracy the quarters, which were affected by a recession, which was designated as the binary dependent variable. Other relevant independent variables which may affect the likelihood of a recession are determined, including the occurrence of an energy crisis and changes in consumption, investment, net exports and government spending as opposed to the net effect of these factors, represented by changes in real GDP. The next step is to run the regression. Since the dependent variable "recession", is a binary variable, the qualitative dependent variable model is used and a logistic regression is run comparing the event of a recession to the independent variables of lagged oil prices, lagged change in the federal funds rate, lagged change in unemployment, growth in real GDP, and oil crisis (Note: each lagged variable is lagged by one quarter behind the event of a recession in the current quarter). A one-quarter lag was chosen because when lagging these variables by more than one quarter they either proved to be insignificant or decreased the pseudo-R^2. I analyzed the logistic regression results and determined the presence and magnitude of correlation between the dependent variable and each independent variable, identifying any potential errors, multicollinearity issues (using STATA's <vif,uncentered> command), or influences in the process (tested by comparing pseudo-R^2 values between model specifications). Based on the regression outcome, it was possible to determine whether or not oil price increases are correlated

with periods of recession in the United States by analyzing the coefficient of the lagged oil prices.

Overall, this topic is one that requires a very high level of specificity with regard to specifying the model as well as rigorous testing in order to properly assess the correlations implied by historical trends. If it is found to be true that oil price spikes have a seminal effect on periods of economic recession in the United States, the research will have provided one of many necessary conditions to a more widespread investigation into the determinants of recessions throughout history, as well as providing insights that could aid in policymaking strategies aimed at preventing or reducing the drastic effects of business cycle contractions in years to come.

LITERATURE REVIEW

The research question focuses on the correlation of oil price surges in relation to significant contractions in aggregate economic output, specifically recessions as identified by the National Bureau of Economic Research in the United States, since the 1970s. The majority of prior research on this subject, such as that undertaken by (Bernanke, Gertller, & Watson, 1997), (Barsky & Kilian, 2004), (Bohi, 1991), (Brown & Yucel, 1999), (Guo & Kliesen, 2005), (Hamilton, Oil and the Macroeconomy, 2005), (Hamilton, What is an oil shock?, 2003) and (Kilian, 2007) focuses on the relationship between gross domestic product and oil price, accounting for oil supply shocks, often with binary variables used to indicate periods of political turbulence in oil-exporting countries which elicit these shocks. Though the quantity and interpretation of independent variables in the model vary among authors on the subject, it is found that the proposed model specification, which includes the growth rate of real GDP as well as the lagged change in the federal funds rate and the lagged change in aggregate unemployment rate as independent variables, is a well-developed model incorporating highly relevant data. A strong level of correlation between the dependent and independent variables is expected.

The topic of the effect of energy prices on the macroeconomy has been extensively researched in the past, yet the true nature of the relationship between oil price and recessions has yet to be exactly identified. This is due to a combination of difficulties that tend to arise in the process of researching consumption indicators with respect to the macroeconomy and the level of analytical proficiency required in order to identify and avoid the numerous pitfalls associated with such research. According to (Barsky & Kilian, 2004) one such fallacy is the threat of

multicollinearity among independent variables due to the broad scope of influences on the macroeconomy, which have the potential to increase or decrease the likelihood of recession. Other errors that have the potential to undermine the relevancy of estimated correlation coefficients include timing inaccuracies with respect to lagging or leading variables, and the exclusion or inaccuracy of significant endogenous effects correlated with oil price surges. This factor influences the automobile industry, most notably its effect on demand and employment within the industry. This and the implication that oil price shocks can lead to inflation, have both been investigated by James D. Hamilton (2003). (Bernanke, Gertller, & Watson, 1997), among others, gave insight to the fact that reactionary monetary policy (that is, changes in the federal funds rate) can compound the economic consequences of oil price volatility. Yet another endogenous effect of oil price shocks that should not be overlooked is the shift in focus of investment from predominantly oil-based inputs toward energy-saving inputs caused by a surge in energy prices, a topic scrutinized by (Bohi, 1991), and (Hamilton, Oil and the Macroeconomy, 2005). This reallocation of investment resources has a significant effect on the overall impact of oil price fluctuations on the macroeconomy. Despite the thoroughness of research to which the determination of the correlation between oil prices and macroeconomic aggregates has been subjected, a definitive measure of the true nature of this relationship has yet to be attained.

METHODS AND DATA

This research topic is particularly prone to misinterpretations, due to the assumption that there was no change in the underline structure of the macro-economy during the forty and a quarter years studied. In contrast, changes have been apparent in several areas affecting economic development, for instance, technological innovations like the personal computer or the internet. Due to the amount of data used in this research it is necessary to be meticulous in the efforts to compile, organize, and analyze effectively only the most relevant information. One potential setback is the fact that the dependent variable, which is the qualitative variable "recession", is strongly affected by a vast array of independent variables. Thus, weeding out irrelevant data is of utmost importance, and identifying the exact scale of the correlation between the independent and dependent variables requires a great measure of diligence. According to (Hamilton, What is an oil shock?, 2003), one of many pitfalls in determining the relevance of particular variables lies in specifying the functional form relating the independent variables to the dependent variable. For instance, most models dealing with the relationship between oil prices and the macro-economy view recessions as supply driven rather than demand driven, as suggested by Hamilton. This is, however, only one of many potentially dangerous assumptions that could determine the validity of the research findings. In the process of interpreting the results, reverse causality must also be a concern, since most microeconomic decisions (such as OPEC's oil pricing strategies) are in fact founded upon observations of international macroeconomic trends. (Guo & Kliesen, 2005) pointed out the potential impact of uncertainty about future energy prices on investment and consumption, two major influences on the independent variable "gdpgrowth". This unquantifiable variable could definitely impact the

overall predictive power of the model, as measured by the pseudo-R^2 value. Other secondary effects of oil spikes can also be attributed to fluctuations in aggregate output and economic welfare, as exposed by (Barsky & Kilian, 2004). They found that when isolated from any secondary effects, the direct effect of oil prices on the macroeconomy is far too small to justify its alleged role in contributing to periods of general economic decline over consecutive quarters, i.e. recessions.

Previous research has shown that there are several common trends in the research process of this topic. One such trend is the tendency of researchers to modify the independent variables with respect to timing. This trend directly relates to this study in that there is a desire to specify the effect of the independent variables notably that of oil prices, on the likelihood of a recession. In order to achieve this distinction, the variable "oil price" is lagged by one quarter prior to the event of a recession. Another common method in the body of prior research is the tendency to include one or several binary variables in the specification of the model. The most common qualitative variable, which was determined to impact, oil price surges and consequently the likelihood of a recession is the incidence of political turmoil in oil-exporting countries which leads to a spike in oil prices. However, it is difficult to extract only the relevant incidences (those which have a direct impact on oil prices in the United States) from the extensive base of data on periods of "political turmoil" – wars and embargoes – in these countries. Therefore, it is important to identify only the crises that have impacted OPEC countries, which are the mayor exporters of oil in the world and thus have the greater impact on oil prices.

Quarterly data is used for real GDP and its components (consumption, private domestic investment, government spending, and net exports), the federal funds rate, the unemployment rate from the first quarter of 1970 to the first quarter of 2010 from The St. Louis Federal Reserve's "Fred II" website. Information is also obtained on historical nominal oil prices as monthly averages from the Energy Information Association (EIA), which is converted to quarterly averages using Excel and then to real prices using CPI values gathered from Fred II. CPI is the standard index used in this literature. Each aggregate measure of the above variables is subsequently transformed into quarterly percent change using Excel, thus generating an entirely new set of modified variables. Next, the exact dates of every NBER acknowledged recession in the United States according to National Bureau of Economic Research (NBER) are identified as well as the date ranges of energy crises triggered by exogenous political events in oil-exporting countries. This data was the hardest to interpret accurately, since the exact dates of these so-called "energy crises" which were spurred by wars and embargoes varied from source to source. However, the data used is from James D. Hamilton's 2003 research paper, "Oil and the Macro-economy" (specifically Table 1: Exogenous disruptions in world petroleum supply) combined with information from (Barsky & Kilian, 2004) research paper, "Oil and the Macro-economy Since the 1970's" (their Table 1: The Coincidence of Oil Dates and Recessions after 1972) and other relevant OPEC crisis obtained from "http://www.emnrd.state.nm.us/ocd/timeline.htm" in order to create the variable "oilcrisis"; where a qualitative dummy variable has been implemented. Such variable takes a value of one if a recession is observed and a value of zero otherwise. This qualitative variable indicates whether or not each particular quarter is affected by periods during which there was an unexpected and uncharacteristic fluctuation in oil prices due

to political turmoil, such as wars and embargoes, in oil-exporting countries. The energy and oil shocks relevant for this research are illustrated in Table 1 in the next page.

Table 1: Relevant Energy and Oil Shocks

Dates	Quarters	Events
January 1970 - August 1971	7	Energy Crisis of 1970
October 1973 - March 1974	2	Arabic Oil Embargo
August 1978 - March 1979	3	Iranian Revolution/Oil Crisis
September 1980 - March 1981	3	Iran-Iraq War
August 1985 - December 1986	6	OPEC Price War/Collapse
August 1990 - February 1991	3	Persian Gulf War/Kuwait Invasion
March 1999 - December 1999	4	OPEC Cuts in Production Quotas
October 2001 - December 2001	1	Afghanistan War
March 2003 - December 2003	4	Iraq War
January 2008 - December 2008	4	Middle East Revolution

Following (Hamilton, What is an oil shock?, 2003) footsteps, there is an attempt to further ameliorate the specification of the model by running test regressions which incorporated each modified variable in turn while holding all others constant, all the while being careful to note the individual effect of each modification on the model by analyzing and comparing each unique model's chi^2-test, z-test p-values, and pseudo-R^2 value. These regressions are performed using STATA, each time modifying only a single independent variable in order to determine the most appropriate form of each. Using a backward elimination procedure, like the one used in a stepwise regression; those variables with less than a ninety five percent confidence probability were extracted from the regression. In addition to the specificity with which it was required to select the variables, it is also necessary to maintain awareness of the rival risks of multicollinearity and omitted variable bias. In order to detect the former, variance inflation factor (VIF) tests are performed in STATA for each potential model to measure the collinearity

between independent variables. As for the latter, it is recognized that there are some omitted variables in this model as proven by a pseudo-R^2 of 67.80%. In order to check for serial correlation I also regressed the model's residuals against their lags, and found no evidence of correlation with a t-stat p-value of 0.759.

Using this method of trial and error in order to determine the most relevant variables and subsequently the appropriate modification of each, several variables are modified and others are excluded. Instead of using simple coincident aggregates for the final variables – oil prices, the federal funds rate, unemployment, and real GDP – these are modified to maximize the accuracy and relevance of its effect on the likelihood of a recession. As for the federal funds rate and the unemployment rate, a transformation into percent changes and also a lag of one quarter behind the event of a recession seemed appropriate due to the theory and deductive logic that these factors would influence recessions in the near future. The hypothesis with respect to this relationship was validated by the test regressions, which showed an overwhelming dichotomy of relevance between this modification and these variables in their coincident or aggregate forms. The real GDP variable proved relevant and logically fitting as a coincident rate of change, since GDP's relationship to the event of a recession would require no alteration of timing.

After much deliberation and after running many regressions on different quantities and modifications of independent variables, the best-fitted model is determined by exemplifying the correlation between the dependent variable- recessions in the United States, which contribute to its likelihood. The model was determined as best fitted by its higher pseudo-R2 value when compared to the other regressions. This logit model is shown in Table 4 in the Appendix. This

definitive model consists of the binary dependent variable "recession" which is equal to 1 if recession occurred and 0 otherwise, logistically regressed against the independent variables oilprice_lag (the percentage change in oil prices), ffr_lag (the percentage change in federal funds rate), unemp_lag (quarterly unemployment rate), gdpgrowth (quarterly percentage change in real gross domestic product), and oilcrisis (binary variable which is equal to 1 if crisis occurred and 0 otherwise) Each variable is calculated per quarter, and oilprice_lag, ffr_lag, and unemp_lag have been lagged by one quarter.

Summary Statistics for the dependent and independent variables are displayed in Table 2.

Table 2: Summary Statistics

Variables	Observations	Mean	Standard Deviation	Minimum	Maximum
recession	161	0.2049689	0.4049385	0	1
oilprice_lag	161	27.15242	20.91742	-0.51	1.35
ffr_lag	161	6.254099	3.541691	-0.74	0.61
unemp_lag	161	1.165839	5.629588	-8.7	25.7
gdpgrowth	161	0.7086957	0.8682159	-2	3.9
oilcrisis	161	0.242236	0.4297732	0	1

On a side note, it is important to clarify the distinction between real GDP growth as an independent variable and the dependent variable, recession. Real GDP growth is included in the model due to its famously postulated interdependent relationship with recessions. However, the actual event of a recession and changes in real GDP are still independent events with many mutually exclusive contributing factors. This is shown in concrete form by the logistic regression of recession against "gdpgrowth", which produces a pseudo-R^2 value of 43%, compared to the 63% measure of the goodness of fit (pseudo-R^2) of the complete model.

The task that required the most meticulous research was the determination of the modification of the key independent variable: that representing the effect of oil price spikes on the likelihood of a recession. After eliminating alternative timing modifications due to the main research objectives – to determine whether oil price surges influence the likelihood of future recessions – it was necessary to incorporate oil prices as a lagged variable, lagged one quarter behind the quarter in which the recession outcome would be determined. It was also determined that percent change in oil prices is more appropriate for the objective, since the objective is to conclude whether an increase in oil prices affected the dependent variable.

All of the work described above led to this final form of the model to be estimated:

$$Recession = \hat{\beta}_0 + \hat{\beta}_1(oilprice\_lag) + \hat{\beta}_2(ffr\_lag) + \hat{\beta}_3(unemp\_lag) - \hat{\beta}_4(gdpgrowth) + \hat{\beta}_5(oilcrisis)$$

RESULTS

This definitive qualitative dependent variable (QDV) model passed the chi^2-test with a chi^2 statistic p-value of 0.0000. This statistical measurement, which in the binary choice model is the equivalent to the F-test p-value of an OLS regression, shows that the model is valid – that is, that one or more of the coefficients is nonzero, signaling that at least one independent variable affects the dependent variable. The measure of the fit of the model gives evidence of the model's validity – the pseudo-R^2 statistic of 0.6780 shows that the model has a moderate goodness of fit. The model can be considered well-specified in that every independent variable is significant at the 95% confidence level – that is, each z-test (the QDV equivalent of the t-test) p-value measured less than the level of significance of 0.05. As for the coefficients of the variables, due to the fact that the model contains a qualitative dependent variable, only the sign, and not the magnitude, of the numerical coefficient is relevant. The coefficient of oilprice_lag is positive, signifying that an increase in the one-quarter lagged change in real oil prices will *increase* the chance of a recession in the subsequent quarter. That is, oil price spikes do in fact play a part in the chance of a recession. Based on this result, the null hypothesis is rejected, which states that fluctuations in the price of crude oil will have no effect on the likelihood of a recession in the United States in the subsequent quarter.

The findings regarding the supplementary independent variables could be put to use in future research pertaining to the contributing factors to periods of recession in the United States. These variables are therefore useful and should be analyzed; the sign of the coefficient of ffr_lag is positive, signaling a positive relationship between an increase in the federal funds rate and the

likelihood of recession. The coefficient sign of unemp_lag is also positive, indicating yet another

direct relationship. When unemployment rises during the following quarter, the likelihood of

recession increases as well. The variable gdpgrowth, defined as the coincident percent change in

real GDP, is the only independent variable found to have a negative sign on its coefficient. This

indicates an inverse relationship between it and the dependent variable, recession – in effect, an

increase in real GDP growth will *decrease* the likelihood of the event of a recession. This can be

deduced intuitively if one considers the innate identity of a recession, however it is highly

important to account for this influence. Finally, the coefficient on the variable oilcrisis is

positive, indicating that the event of an oil crisis increases the probability of a recession. The

partial effect of each continuous variable on the probability of a recession was also calculated

using the following method. For the model, $z = \hat{\beta}_0 + \hat{\beta}_1 x_1 + \cdots + \hat{\beta}_n x_n + e$ the partial effect of

each continuous variable x_j is the change in the probability (P) of a recession occurring when an

x changes and is given by $\dfrac{\partial P(y=1 \mid x)}{\partial x_j} = \dfrac{\partial G(z)}{\partial z} * \dfrac{\partial z}{\partial x_j} = \dfrac{e^z}{(1+e^z)^2} * \hat{\beta}_j$ where e^z is an exponential

function and *e* is the Euler's number. These results as well as the regression results are displayed

in Table 3 below.

Table 3: Partial effects of continuous variables

Variables	Coefficient	Partial Effect
oilprice_lag	0.0451654*	0.00345745
ffr_lag	0.3519158**	0.02693949
unemp_lag	0.2455736**	0.01879889
Gdpgrowth	-2.649482**	-0.20282036
Oilcrisis	2.309576**	0.17680028

Note: *, ** indicate significance at the 5%, and 1% levels respectively.

The overall finding of the definitive model is that it is quite well-specified and accurately represents the influence of the independent variables on the dependent variable. The pseudo-R^2 statistic, though not identical to the goodness-of-fit measurement of the OLS model (adjusted R^2), is high enough at 67.80% to indicate that the model is statistically relevant in predicting the likelihood of a recession.

CONCLUSION

Due to these conditions and the diligence and in-depth analysis of the material and the results generated, the main research objective has been satisfied, namely to determine the presence of a correlation between oil price surges and recession occurrences as well as the nature of the relationship, which is a direct one. The investigation into the optimal model of the likelihood of a recession is based on previous literature on the effects of oil prices on real GDP. After a number of less-than-satisfactory regressions, the results of the final model are very similar to that of James D. Hamilton in his 2003 report, "Oil and the Macroeconomy", the only difference being that Hamilton's model compares oil shocks to real GDP and the one in this research compares oil shocks to the likelihood of recession. This model, however, distinguished itself from prior research models in that it is a binary choice model, which measured not quantitative changes in aggregate economic activity, but instead the likelihood that the economy would contract into an actual recession. One potential defect that may have distorted the results is the interdependence of real GDP growth, an independent variable, and the dependent variable, recession. The real GDP growth variable is, however indispensable to the model, as it plays a large part in the likelihood of a recession and the model would suffer from omitted variable bias if it is excluded on these grounds. Another limitation of this model is the ambiguity with which recessions (and oil price surges, for that matter) are determined, not to mention that the potential causes and contributions to a recession are practically infinite and difficult to extract from macroeconomic aggregates. In the future, it would be wise for researchers to avoid overlooking not only the broad scope of influences on the dependent variable, but also the minute

modifications to time lag and units of measurement that can vastly affect the results of this investigation.

Overall, the results of this research could inspire future investigation into the correlation between macroeconomic performance indicators such as recessions and real GDP growth and energy consumption, as well as the relationship between exogenous political events and oil prices. Further research into these topics will raise awareness of the potential gains to aggregate welfare of a reduction in oil dependence. There is hope for business and government policy changes in order to minimize the fluctuations in economic performance currently associated with oil price surges.

APPENDIX

APPENDIX

Table 4: Logit model - impact of oil price surges on economic growth

. logit recession oilprice_lag ffr_lag unemp_lag gdpgrowth oilcrisis

Iteration 0:   log likelihood = -80.064388
Iteration 1:   log likelihood = -35.109461
Iteration 2:   log likelihood = -26.572527
Iteration 3:   log likelihood = -25.784503
Iteration 4:   log likelihood = -25.781876
Iteration 5:   log likelihood = -25.781876

Logistic regression

Log likelihood = -25.781876

	Number of obs	=	160
	LR chi2(5)	=	108.57
	Prob > chi2	=	0.0000
	Pseudo R2	=	0.6780

recession	Coef.	Std. Err.	z	P>|z|	[95% Conf. Interval]	
oilprice_lag	.0451654	.0216611	2.09	0.037	.0027105	.0876203
ffr_lag	.3519158	.1115185	3.16	0.002	.1333436	.570488
unemp_lag	.2455736	.0653389	3.76	0.000	.1175117	.3736355
gdpgrowth	-2.649482	.7164187	-3.70	0.000	-4.053637	-1.245327
oilcrisis	2.309576	.8769754	2.63	0.008	.5907361	4.028417
_cons	-5.450412	1.431177	-3.81	0.000	-8.255467	-2.645357

Figure 1: Consumption of foreign oil vs. production of local oil

U.S. Dependence on Imported Oil, 1970 to 2025

Consumption
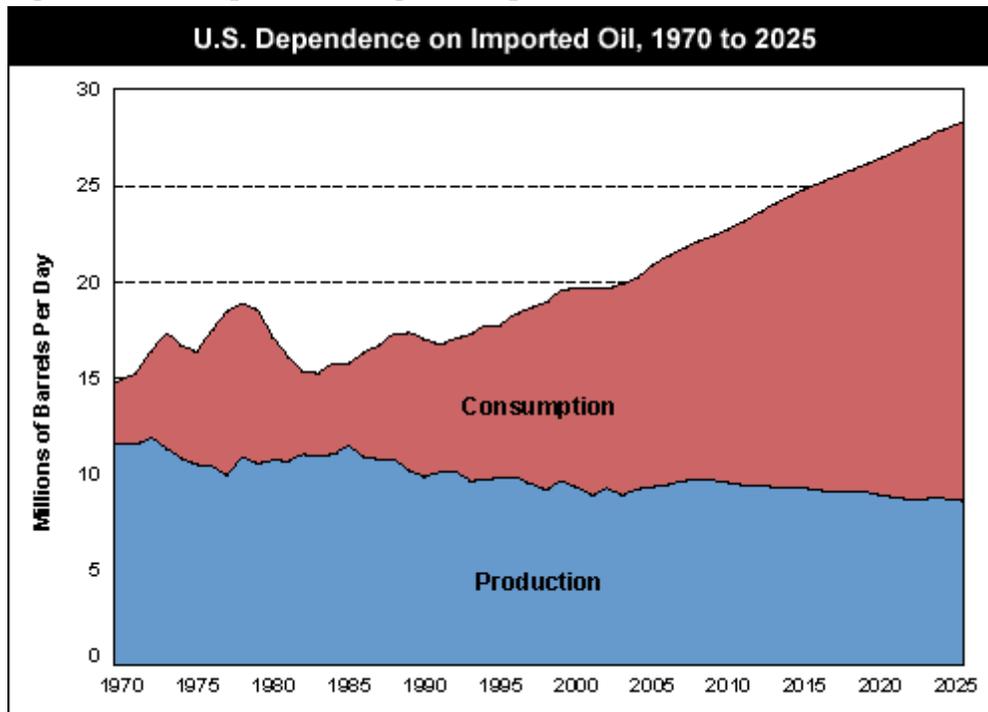
Production

Source: Energy Information Administration, *Annual Energy Outlook 2004*

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