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2008

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Printed and distributed by the Czech National Bank. Available at http://www.cnb.cz.

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Project Coordinator: Kamil Galuščák

The Effect of Oil Price Shocks on the Czech Economy

Kamil Dybczak, David Voňka and Nico van der Windt *

Abstract

In the course of 2002 up to the end of 2007, very steep growth of oil prices, but no remarkable slowdown of either the world economy or the Czech economy, was observed. This phenomenon raises a question about the impact of oil prices on modern economies. Analyzing the available data we can conclude that notwithstanding the full dependence of the Czech economy on oil imports, its overall dependence on imported energy sources is relatively low. Compared to the EU15 level the energy intensity of the Czech economy is quite high. Nevertheless, further improvements in this area are expected. Furthermore, the appreciation of CZK and the set-up of the tax system significantly reduced the volatility of the consumer oil price between 2002 and 2007. Using a structural CGE model we quantify the impact of oil price changes on the Czech economy and demonstrate that it is not dramatic despite the oil price turmoil in the years 2000 to the end of 2007. We find that a 20% increase in the CZK oil price tends to decrease the GDP level by 1.5% and 0.8% in the short and long run, respectively. Short-run annual GDP growth decreases by 0.3 p.p. Concerning prices, inflation would accelerate by around 0.4 p.p. per annum in the short run.

JEL Codes: C68, Q43.
Keywords: CGE, Czech Republic, oil price.

* Kamil Dybczak, Czech National Bank (e-mail: kamil.dybczak@cnb.cz);
David Voňka, Tilburg University (e-mail: d.vonka@uvt.nl);
Nico van der Windt, Erasmus University (e-mail:n.vanderwindt@ihs.nl).

This work was supported by Czech National Bank Research Project No. E2/2007.

The authors would like to thank Jan Hošek, Michal Kejak, Marcelo Sánchez, Kamil Galuščák, Kateřina Šmídková and participants at the interim and final seminars at the Czech National Bank for helpful discussion and comments. All errors and omissions are ours. The views expressed are those of the authors and do not necessarily reflect the views of the Czech National Bank.

Nontechnical Summary

Very steep growth of oil prices was observed in the course of 2002 up to the end of 2007. As this paper was written (end 2007 – beginning 2008), the USD price of a barrel of Brent oil was threatening to reach 100 USD. By the time of submission (June 2008) it had reached 140 USD. This amounts to an increase by a factor of six since the beginning of this millennium. Simultaneously, until 2007 we observed no serious slowdown in the world economy. This paper analyzes why the impact of the oil price boom seems to have been so small. The economic problems which came thereafter were mainly triggered by other factors. On the contrary, until 2007 the world was experiencing an economic boom, mainly thanks to developments in China, India, and Russia. The Czech economy, too, was going through one of its better periods.

The Czech economy is not self-sufficient in its energy needs, but its dependence on imports of energy is relatively low, mainly because of domestic coal mining. This is reflected in the structure of energy use, where imported oil plays a smaller role than in other countries. But like many other post-communist countries, the Czech economy uses a relatively large amount of energy per unit of output. In other words, its so-called energy intensity is rather high. This intensity has been decreasing in the past decade and a further decrease can reasonably be expected.

The Czech Republic imports basically all the crude oil it needs, mainly from post-Soviet countries. Very little of it is used for electricity and heat production; the rest is transformed into various oil products that satisfy around 70% of the domestic market demand. Oil products – mainly motor gasoline and diesel – are also imported, most often from neighboring countries. The greatest part of the oil products is used in transport and in the chemical industry.

The price of oil products that a Czech firm or consumer faces is dependent not only on the USD price of oil on the world market. An important determinant is the USD exchange rate. The appreciation of CZK has moderated the impact of the past oil price changes greatly. Another cushioning factor is the system of consumption taxes on gasoline and diesel, since this tax is levied per quantity (liter) and not per monetary value. Therefore, the tax does not change as the oil price changes. During the period January 2000 – June 2008, the world oil price in USD has risen by around 600%. Thanks to the compound effect of strong CZK appreciation and the stabilizing impact of consumption taxes, Czech consumers have faced only a 50% increase in the price of gasoline and diesel in the same period. The dampening role of taxes exceeded that of the exchange rate.

Regression outcomes of several domestic price indices on the oil price suggest that the effect of the oil price on aggregated price indices is very low. A 10% increase in the world oil price cannot be expected to increase the domestic PPI or CPI by more than 0.1%.

A CGE model is used for the oil price simulations. The model incorporates (inter alia) a very detailed industrial production structure based on input-output tables for the Czech economy.

We simulate the effect of a gradual increase of the oil price Czech consumers face (i.e., the final consumption price in CZK) by 5% p.a. over 4 years. The three simulations differ in their assumptions about the potential future improvement in oil use intensity and in their assumptions about the effects of oil prices on Czech trade partners.

In the model, the oil price shock hits the economy as a cost shock leading to higher prices and a corresponding decrease in competitiveness and in both domestic and foreign demand. The resulting unemployment leads to a lower bargaining power of employees and a gradual decrease of real wages (or at least slower wage growth). In the long run, the lower real wages allow businesses to cut prices and restore competitiveness, production, and employment. The long-run simulation outcomes suggest a rather low effect on GDP, but much a larger effect on household consumption, due to permanently worse terms of trade.

Within each simulation a rich set of robustness checks were performed. The robustness checks include alternative specifications concerning the functioning of the labor market, foreign trade developments and characteristics, and the government reaction to the oil price shock. The effects of the oil price change are comparable in all the simulations, in the sense that nothing too dramatic happens. The results are therefore rather robust. In the first years after the shock, prices increase slightly and so do nominal wages, since they are assumed to be CPI indexed. The resulting price increase of Czech products has a negative impact on demand and especially on competitiveness. The lower demand leads to less employment and a minor slowdown compared to the baseline scenario. The slowdown in economic activity leads to real wage cuts, price cuts, and a partial restoration of demand. In the long run, GDP decreases a little. There is a slightly higher impact on the purchasing power of households, since they bear the brunt of the price shock.

In the simulations, the initial increase of the CPI caused by oil prices amounts to around 2% after 5 years and becomes around -0.5% in the long run. The effect on the GDP level is around -1 to -2% after 5 years and stabilizes at -0.8%.

The negative effect on GDP depends on the assumption about the global impact of the oil price. As expected, the larger the depression caused in the world economy, the bigger the impact on the Czech Republic. However, if in reaction to the oil price increase the global GDP decreases, by more than 2 %, the long-run GDP decline in the Czech Republic is estimated to be about -1.5%. Also, the short-run inflationary effect gets somewhat more pronounced if the price level abroad is assumed to be affected more seriously. We estimate that an increase in inflation of our trade partners, due to an oil price increase, would have to augment by 1.1 percentage points in order to produce a short-run inflation increase of more than 0.8 percentage points in the Czech Republic.

The overall effects get somewhat smaller if we assume that the energy intensity in the Czech Republic will converge to the average energy intensity in the EU15. In a nutshell, our model simulations indicate that the impact of oil prices on both nominal and real variables is not too high, although the effects are higher than those reported for the EU and the USA in the literature.

1. Introduction

Very steep growth of oil prices was observed in the course of 2002 up to the end of 2007. At the time of writing this paper (end of 2007 – beginning 2008), the USD price of a barrel of Brent oil was threatening to reach 100 USD. At the time of submission of the final version (May 2008) we were at 140 USD. This amounts to an increase by a factor of 6 since the beginning of this millennium. Simultaneously, until recently we observed no serious slowdown in the world economy, and the recent slowdown is arguably due to other causes. On the contrary, the world experienced an economic boom, mainly thanks to developments in China, India, and Russia. The Czech economy, too, is going through one of its better periods.

How is this possible? During the oil crises in 1973 the oil price quadrupled, which led to a period of stagflation. The effects of the 1979 crisis were also pronounced. Has the impact of oil prices on the economy really become so small during the past 30 years?

This paper studies the impact of oil prices on the Czech economy from several perspectives. First, we analyze the available data on the sources and use of energy in the Czech Republic and the determinants of energy prices for the domestic consumer. Second, our main tool is a computable general equilibrium (CGE) model of the Czech economy, which models the production structure in great detail. From both perspectives we find a rather moderate effect of oil prices on the economy. We demonstrate that this result is rather robust with respect to reasonable changes in the assumptions. It is worth emphasizing that we do not analyze the factors behind world oil price developments. The Czech Republic is a small open economy with no real impact on the world oil price. Although there has been much public debate on oil price issues, to our knowledge there has been no detailed analysis of the reaction of the Czech economy to the oil price. Furthermore, even outside the Czech Republic, there are very few models analyzing the price shock in such industrial detail.

Based on the results of our investigations we believe that the structure of the Czech economy is indeed different from the structure of the economies hit by the oil price shocks in the 1970s. The weight of less oil intensive industries has increased and the overall oil intensity of the technology used has decreased. There are more substitution possibilities in production. These conclusions may also apply to many other countries around the world.

The paper is organized as follows. Section 2 gives an overview of the relevant literature about CGE models and about the impact of oil prices. Section 3 describes the sources and use of oil in the Czech economy. It focuses on a description of energy dependence and intensity (section 3.1), the sources and consumption of oil (section 3.2), and pricing of oil products (section 3.3).

The CGE-model-related results are concentrated in section 4 of this paper. Section 4.1 focuses on the dissemination of the oil price shock in the model. Section 4.2 introduces the model simulations of the impact of oil price increases and describes their construction. Sections 4.3 to 4.5 describe the results of the simulations under alternative assumptions about the potential development of the oil intensity of the Czech economy and about the reaction of the rest of the world to the shocks. As already mentioned, the simulations demonstrate that the impact of oil prices on the Czech economy is not really dramatic, regardless of reasonable changes in the assumptions. Section 6 concludes the paper. Appendix A presents and discusses robustness checks. Appendix B gives a detailed description of the model used.

2. Literature Overview

It is generally accepted that the oil shocks (i.e., huge rises in the price of crude oil) in 1973–1974 and in 1979 caused a world-wide decline in output. In a more general view, Hamilton (1983) shows that almost all post-war US recessions appear to have been associated with increasing prices of oil. Moreover, his reduced-form regressions for the unemployment rate suggest the presence of strong oil-price effects. The unemployment effects of rising oil prices were further studied by Carruth et al. (1993). They deal with an efficiency wage model where higher energy costs indirectly force up unemployment.

A more recent study by Jimenez-Rodriguez and Sanchez (2004) applying multivariate VAR analysis to OECD countries demonstrates the non-linearities of the oil price effect on the price level and output. The authors show that oil price increases have a greater impact than oil price decreases and that the influence of a price hike is conditional on the oil price volatility in previous periods (i.e., in a situation of stable oil prices, the impact of an unexpected hike is greater than when prices were very volatile before). They also note that the impact of oil prices is much higher in the USA than in other countries. Many similar studies are available, usually concentrating on the United States.

As for sectoral approaches, to our knowledge the literature does not offer that many relevant papers. An interesting one is Keane and Prasad (1991), which shows by means of panel data analysis that oil shocks have an impact on relative wages and employment shares across industries. On the other hand, there is little evidence on evoked labor flows between industries.

Recently European Central Bank released a Monthly Bulletin article (ECB (2004)) on oil prices and the euro area economy. The study declares that the European economy is now more resilient to oil price shocks compared to the situation thirty or more years ago. Analyzing both the first and second-round effects of oil price shocks the study concludes that the current rise in world oil prices should have a more limited impact on economic activity and inflation than is usually expected.

In the case of the Czech Republic Hlédik (2003) uses a small-scale open-economy dynamic rational expectations model to quantify the second-round effects of selected supply-side shocks and of shocks to the nominal exchange rate on wages and subsequently on inflation. The study mainly demonstrates the model's dynamics under various policy rules corresponding to different loss functions of the central bank. The conclusions presented by Hlédik (2003) suggest that the second-round effects of shocks to import prices and the nominal exchange rate on inflation should not be ignored in practical policy-making. In contrast to this study, we concentrate mainly on the impact of changes in the prices of oil and oil-related goods. Next, our approach is more detailed, as it distinguishes between 16 industries and commodities, at the expense of rather simplified dynamic behavior.

A complete description of the various methodological approaches to studying the economic effects of oil price fluctuations is beyond the scope of this paper (see, for example, IMF (2005) or Williams (2006), for an overview). In the following text, we therefore limit ourselves to the method chosen in this paper and intend to explain its main properties, as developed by economic research.

The determinants and predictors of the world oil price are not in the centre of our interest; we treat its development as strictly exogenous. We focus on the Czech economy, which plays no real role in world oil price determination. For a recent treatment of this topic, see, for example, DG-ECFIN (2005a), DG-ECFIN (2005b), DG-ECFIN (2005c), and DG-ECFIN (2005d) by European Commission DG ECFIN.

An interesting set of answers to frequently asked questions about oil is Kingma and Suyker (2004). It discusses the role of oil in a modern economy, the power of OPEC, the role of taxes, the oil price impacts from different studies, and many other issues related to oil.

In our research, we decide to explore computable general equilibrium (CGE) models to examine the economic consequences of fluctuations in oil prices. The essence of the model is to estimate how an economy might react to changes in policy, technology or other external factors. The intellectual origin of (neoclassical) CGE models can be traced back to the general equilibrium theory of Walras (1926) and the input-output models pioneered by Leontief (1986). The neoclassical general equilibrium approach was rigorously elaborated by Debreu (1959). Though mathematically rigorous, this work did not pretend to describe really existing economic systems, but rather attempted to prove the existence of a Pareto optimal equilibrium of a competitive economy under highly restricted assumptions.

Johansen (1960) was the first to try and bridge the gap between theory and reality by developing the first empirical or computable general equilibrium model, applied to the Norwegian economy. The Cambridge Growth Project in the UK is another example of early efforts aimed at an analogous goal. It was two decades later before CGE models became used more frequently, primarily in the field of (optimal) taxation and trade policies in developed countries. The Australian MONASH model is a representative of this class.

Work on a CGE model for less developed countries started in the 1970s, culminating in the pioneering work of Adelman and Robinson (1977) on Korea. This work triggered a huge stream of CGE models. These models were an improvement on the rather rigid input-output models based on fixed relative prices and limited scope for substitution. The CGE models, largely based on neoclassical optimizing behavior, were able to generate endogenously determined prices and allowed for all kinds of substitution processes – between primary inputs, between intermediate primary inputs, and between tradable and non-tradable commodities. Furthermore, the labor market was endogenised and even different technological strata within sectors were sometimes distinguished.

The recessions in the developed world in the 1970s and the debt crises in the less developed world shifted the earlier focus on development strategies, poverty, and income distribution away towards structural adjustment and stabilization. Trade problems were increasingly considered important, and it was no surprise that CGE models became an important instrument for the analysis of trade policies.

Recently, there has been renewed interest in the type of problems which used to be studied in the 1960s and 1970s. Poverty and income distribution, though never absent in applied work, have regained a central position, alongside environmental problems. CGE models may also become an important instrument in the latter field, as witnessed by applications to energy problems and environmental questions in a wider framework. Our direct source of inspiration is the Athene model produced by the Dutch CPB – see Smid (2006) for details.

Nowadays, CGE models are a standard tool of economic policy analysis. The models are extremely flexible and can therefore be applied to a wide range of economic problem areas, such as foreign trade, income distribution, public finance, and the environment. They are constructed not only for individual countries, but also for interregional analysis within countries and across countries or groups of countries. Note, among others, GTAP (2006) or Coady and Harris (2001) for examples of their application. In central bank research, the CGE approach is still discussed, too, despite the ongoing expansion of monetary macro models involving inter-temporal dynamics (such as DSGE) – see, for example, Chumacero and Schmidt-Hebbel (2004).

3. Sources of Energy in the Czech Republic

This section briefly reviews the importance of the energy sector in general and oil in particular in the Czech economy. The description focuses on the dependence of the Czech economy on energy imports, the efficiency of its energy use, the structure of that use, and on price setting mechanisms. The main sources of information are the energy statistics provided by the Czech Statistical Office, Eurostat and the BP Statistical Review Of World Energy and the input-output tables of the Czech Republic. These data indicate the relative importance of oil in the structure of the Czech economy in terms of the use of oil as an input by the various sectors as well as the final use of oil and refined products.

3.1 Energy Dependence and Intensity

The Czech economy is not self-sufficient in its energy needs. Although it has important deposits of hard coal and lignite, it has to import, mainly oil and natural gas, to meet its demand for energy. The situation is described in Table 3.1, where energy dependence is defined as the ratio of net imports to gross inland consumption of a given energy resource. The Czech Republic is a net exporter of hard coal (3,489,000 tons in 2005), while it is a net importer of natural gas (7,535 TOE[1] in 2005) and oil (9,499 TOE in 2006). Overall, the Czech economy imports more energy than it exports. The structure of Czech energy use reflects this (see Table 3.2). The Czech economy uses a lot of coal and it also exports electricity, which is produced mainly from coal. All in all, on the basis of the international comparison given in Figure 3.1, we can see that the position of the Czech Republic is relatively good in terms of energy dependence.

The situation is different regarding the energy intensity of the Czech economy, defined as the ratio of gross inland consumption to gross domestic product. The indicator reflects the amount of a resource used to produce one unit of GDP. Countries with higher energy intensity are more sensitive to energy price shocks than countries with a relatively low intensity. The absolute value is a combination of energy inefficiency on the one hand and the structure of the economy on the other. In order to compare countries, GDP can be expressed either in constant prices of

[1] TOE=tons of oil equivalents

Table 3.1: Energy Dependence of the Czech Republic by Resource

	Oil	Coal	Gas	TOTAL
1995	98.3%	-25.6%	98.0%	20.6%
1996	97.1%	-22.8%	100.1%	24.3%
1997	100.1%	-21.4%	99.2%	24.3%
1998	99.7%	-24.3%	99.1%	25.5%
1999	94.9%	-29.8%	96.3%	25.1%
2000	95.4%	-21.9%	99.8%	23.1%
2001	97.5%	-21.0%	96.3%	25.7%
2002	93.4%	-18.6%	102.0%	26.3%
2003	95.8%	-17.4%	98.2%	24.9%
2004	93.6%	-16.4%	91.1%	24.6%
2005	97.4%	-17.4%	97.8%	27.4%

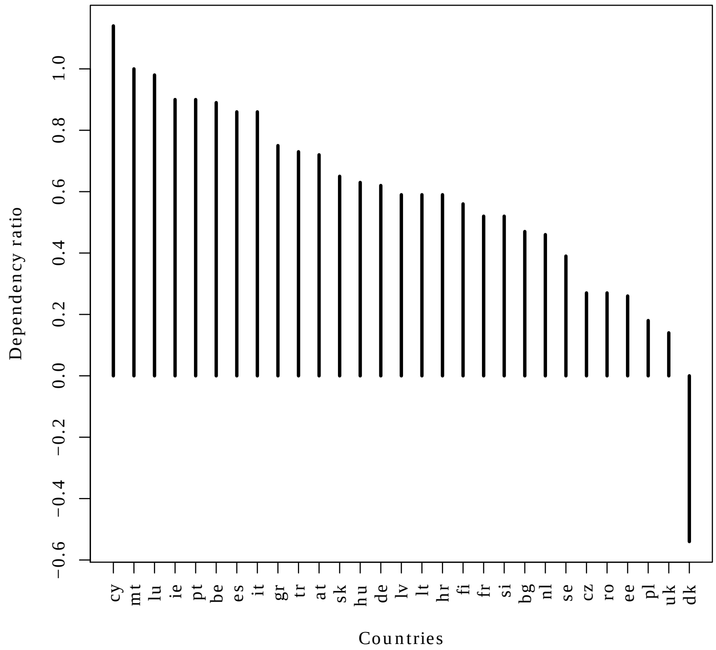
Note: Energy dependence is defined as $\frac{\text{net imports}}{\text{gross inland consumption}}$. Negative numbers imply that the Czech Republic is a net exporter of the resource.
Source: Czech Statistical Office.

Table 3.2: Structure of Energy Consumption in the Czech Republic

	Coal	Oil	Gas	Nuclear	Renew	Electricity*	Heat*
1995	55.3%	19.3%	16.1%	7.7%	1.5%	0.1%	0.0%
1996	53.6%	19.2%	17.9%	7.8%	1.4%	0.0%	0.0%
1997	54.6%	18.3%	18.0%	7.6%	1.6%	-0.2%	0.0%
1998	51.7%	20.0%	18.8%	8.3%	1.6%	-0.5%	0.0%
1999	47.5%	21.5%	20.4%	9.1%	1.9%	-0.7%	0.0%
2000	53.7%	19.3%	18.6%	8.7%	1.5%	-2.1%	0.0%
2001	51.1%	20.1%	19.5%	9.2%	1.7%	-2.0%	0.0%
2002	49.5%	20.1%	18.8%	11.7%	2.1%	-2.4%	0.0%
2003	47.0%	19.5%	17.9%	15.2%	3.5%	-3.2%	0.0%
2004	45.4%	20.9%	17.4%	15.1%	4.0%	-3.0%	0.0%
2005	44.9%	21.8%	17.2%	14.2%	4.1%	-2.4%	0.0%

*These are not primary energy sources. These columns are included to account for the net imports of these produced energies. The point is that the Czech economy's need for primary resources used for electricity production (mainly coal) is in fact lower than its share suggests, as some part of the electricity is exported.
Source: Czech Statistical Office.

Figure 3.1: International Comparison of Energy Dependence



Note: Energy dependence is defined as $\frac{\text{net imports}}{\text{gross inland consump.}}$. Negative numbers denote a net energy exporter. Numbers greater than 1 can occur due to reserve building.
Source: Eurostat.

a single currency (using market exchange rates to convert currencies) or in purchasing power parities. Due to the different price levels in the countries compared, we prefer to use purchasing power parities in order to compare countries in a given year. For conclusions about intensity changes over time, we prefer to use constant price intensities, otherwise the intensity decrease is overestimated. Table 3.3 gives us the intensity development in the Czech Republic.

The Czech Republic ranks relatively high regarding energy intensity, with its 6^{th} highest intensity within the EU25 group of countries. However, there has been an improvement compared to the situation 10 years ago, see Figure 3.2. Table 3.3 shows that the energy intensity of the Czech economy has been declining almost continuously (though not much) over the past 10 years. Similar (or bigger) improvements in energy use can be observed for the other post-communist countries (see Figure 3.3).

It is unclear whether the intensity improvements are mainly due to change in industrial structure or due to more efficient use within a given industry. Full decomposition is hard to achieve, since the energy use data is not available in the same industrial classification as the production data. Figure 3.4 shows the energy intensity changes in those industries where the energy and production classifications are compatible. These industries cover 70% of GDP. From the figure we can conclude that within-industry energy intensity has been decreasing, so the aggregate intensity decrease is at least partly influenced by the within-industry intensity decrease. The

Table 3.3: Total Use of Energy and Energy Intensity of the Czech Economy

	Total use in TJ	Intensity*
1995	40800	965
1996	42236	961
1997	42503	974
1998	40897	944
1999	37944	864
2000	40304	886
2001	41158	883
2002	41391	871
2003	43884	892
2004	44846	871
2005	44795	817

*Energy intensity of the economy in kg of oil equivalent per 1000 EUR GDP (exch. rate).
Source: Czech Statistical Office.

share of the greatest energy user – the chemical industry[2] – in GDP decreased by 0.3 p.p. during the period 1995–2006. The share of services (very low intensity) increased by 2%. This indicates that change in the structure of the economy also plays a role.

From the figures and tables discussed we can conclude that energy intensity has decreased in the Czech Republic, but some comparable countries (such as Poland) have experienced a much more pronounced improvement. Also, the Czech intensity decline seems to have been slowing down in recent years. Therefore, it is difficult to make a good guess about the future development of energy intensity. Consequently, we consider two scenarios of energy intensity development in our model simulations.

The price development of the main primary energy sources is depicted in Figure 3.5. It is evident that the prices are heavily interlinked. Thus, we can expect observed oil price shocks to be accompanied by shocks in prices of other energy sources. The total effect of this on the Czech economy is ambiguous, since the Czech Republic exports coal and imports gas and nuclear fuel.

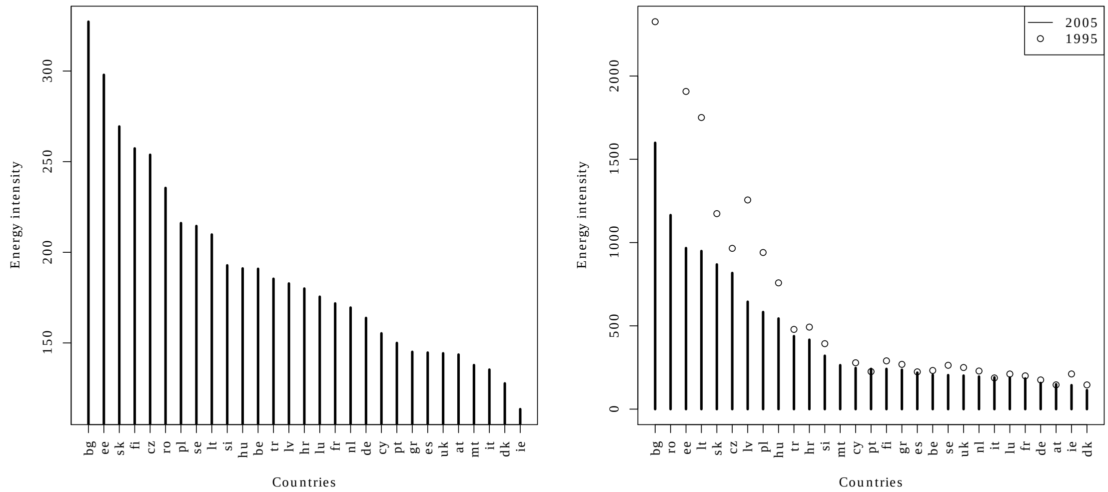
However, the importance of the prices of different types of energy sources varies. For example, the price of nuclear fuel has about a 10% share in the price of the resulting electricity (the main part is the building of the power plant). In coal power plants, the importance of the coal price is much higher.

3.2 Sources of Oil and the Structure of its Use

According to information from the Czech Statistical Office (CZSO), the Czech Republic imported 7,767,000 tons of crude oil[3] in 2006. As we can see in Table 3.4, the greatest part of the

[2] Thanks to the non-energy use of oil.
[3] 7,500,000 tons is less than one day's world production (which is 11,000,000 tons).

Figure 3.2: Energy Intensities in Europe

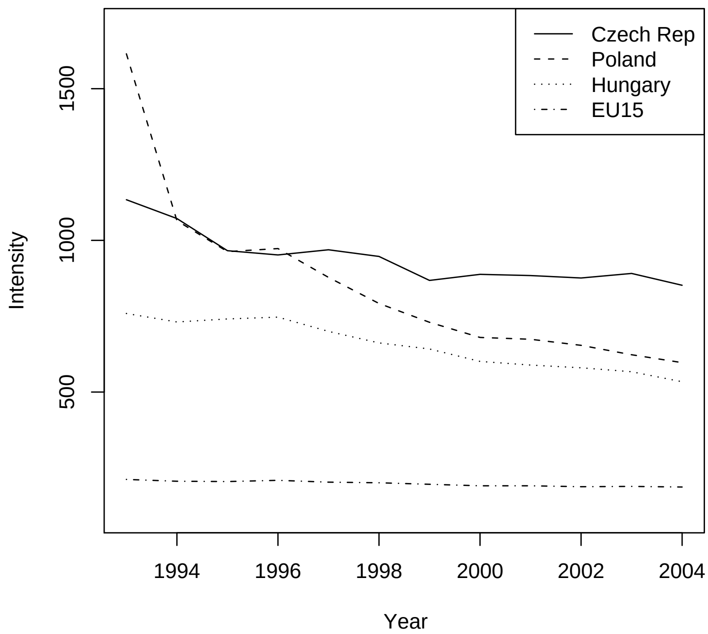


A. PPS based (2005) B. Exchange rates (2005 and 1995)

Note: The energy intensity of the economy is expressed in kg of oil equivalent per 1000 EUR GDP (exch. rate or PPS).

Source: Eurostat, own calculations.

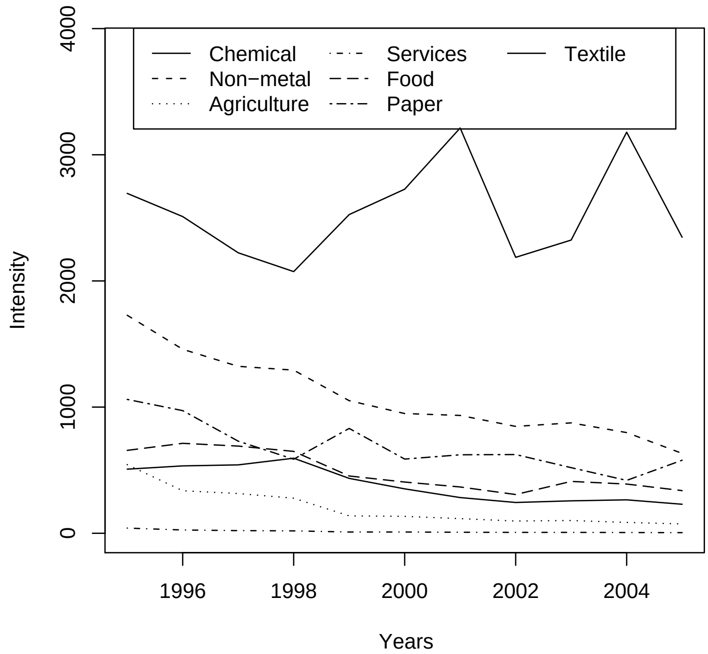
Figure 3.3: Energy Intensity Development – International Comparison



Note: The energy intensity of the economy is expressed in kg of oil equivalent per 1000 EUR GDP (exch. rate or PPS).

Source: Eurostat.

Figure 3.4: Intensities per Industry



Note: The energy intensity of the economy is expressed in kg of oil equivalent per 1000 EUR GDP (exch. rate or PPS).
Source: Czech Statistical Office.

Czech oil supply comes from Russia. The typical type of oil for Czech refineries is therefore heavy (high viscosity and density) and sour (high share of sulfur), i.e., of lower quality.

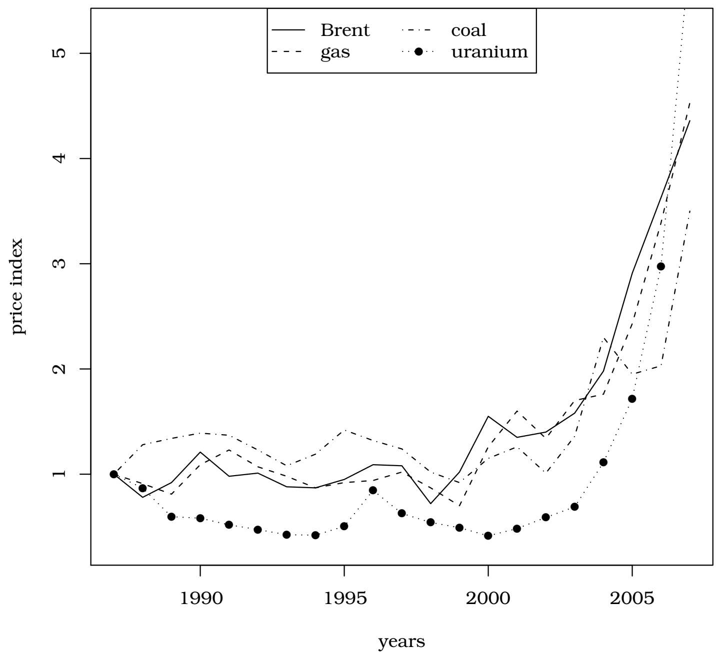
Table 3.4: Origins of Petroleum and Petroleum Product Imports in 2006 (Thousands of Tons)

	Crude oil	Motor gasoline	Diesel oil
Russia	5225	—	—
Azerbaijan	1935	—	—
Algeria	50	—	—
Libya	161	—	—
Austria	—	84	101
Germany	—	141	378
Slovakia	—	366	710
Other	396	24	65
Total	7767	615	1254

Source: Czech Statistical Office.

An additional 265,000 tons (of high quality oil) is produced in the Czech Republic, which makes the share of domestic production equal to 3.3%. The country exports negligible amounts of crude oil (42,000 tons in 2006). The rest, plus some stocks from the previous year (together

Figure 3.5: Price Development of Main Primary Energy Sources [index, 1986=1]



Source: BP Statistical Review of World Energy, June 2007.

7,866,000 tons[4] in 2006), goes to local refineries. The refineries lose some tons in the refining process (56,000 tons in 2006) and add some additives (oxygenates, other hydrocarbons, totaling 371,000 tons) and produce a set of basic finished petroleum products (8,181,000 tons in 2006). Table 3.5 gives detailed information on the products created by refineries. Crude oil is mainly transformed into motor gasoline and diesel.

Table 3.5: Products of Refineries in 2004, 2005 and 2006

	Refinery gas	LPG	Naphtha	Motor gasoline	Jet fuel	Diesel
2004	1.74%	2.59%	8.02%	18.42%	2.10%	31.96%
2005	1.67%	2.26%	8.68%	18.04%	1.62%	35.99%
2006	1.83%	2.49%	8.65%	19.51%	1.48%	36.76%
	Heating oil	Fuel oils	Lubricants	Bitumen	Other	**TOTAL (mil. tons)**
2004	6.23%	5.63%	1.79%	6.69%	14.84%	6999
2005	1.72%	7.14%	1.71%	6.59%	14.56%	8132
2006	1.48%	4.66%	1.37%	6.06%	15.71%	8181

Source: Czech Statistical Office.

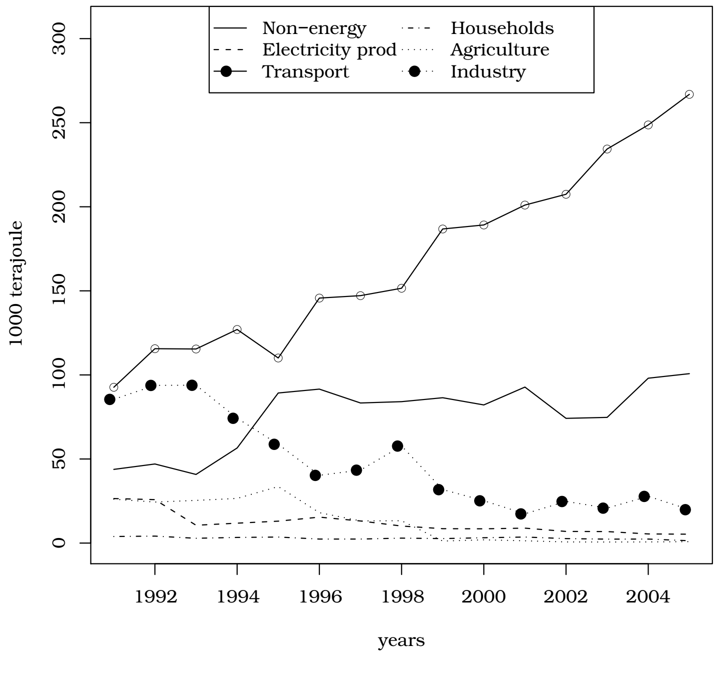
Additional petroleum products are imported mainly from neighboring countries (2,843 tons in 2006) and some of the home refined products are exported (1134,000 tons). The Czech Republic

[4] 7866=7767+265-42-124, where -124 is the change of stocks.

exports mainly motor gasoline (293,000 tons), diesel (358,000 tons), and asphalt (135,000 tons). The major items of imported refined products are again motor gasoline (615,000 tons), diesel (1,254 tons), and asphalt (242,000 tons).

The structure of oil product use by industries is depicted in Figure 3.6. The share of transport has been increasing and today forms the bulk of oil product use. Note that the use of oil products in transportation also includes private car use by households. So, the households' share only covers direct use for heating and so on and has therefore been negligible lately. The use of oil *for energy* by industry has been decreasing, probably due to its price and substitutability by other energy-producing raw materials. The non-energy consumption is mainly due to the chemical industry (more than 50%). Non-energy oil consumption increased in the first part of the 1990s and has been stable since then.

Figure 3.6: Oil Product Use by Industry



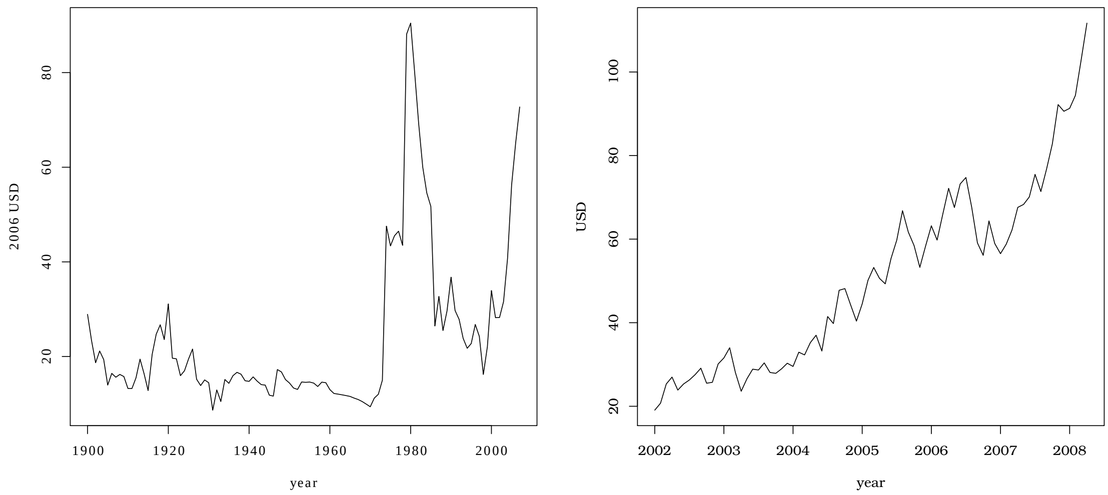
Source: Czech Statistical Office.

For modeling purposes, we can conclude as follows. The Czech Republic imports all its crude oil needs. A negligible share is used for electricity and heat production; the rest is transformed to oil products, which form around 70% of the oil products on the market (the rest is imported from neighboring countries). The oil products are used for two main purposes: transport and non-energy use in the chemical industry. Other sub-items are either negligible or are becoming negligible at a high pace.

3.3 The Price of Oil and its Decomposition

In our analysis we concentrate on the period 2002–2007. Primarily, we want to see how a change in the world oil price affects domestic oil prices and the production of oil-consuming industries. For a basic idea about the development of the oil price, we include Figure 3.7, which depicts the development of the world market since 1900 and shows in detail how the price nearly quadrupled between 2002 and 2007.

Figure 3.7: Oil Price Development (Price per Barrel of Brent)



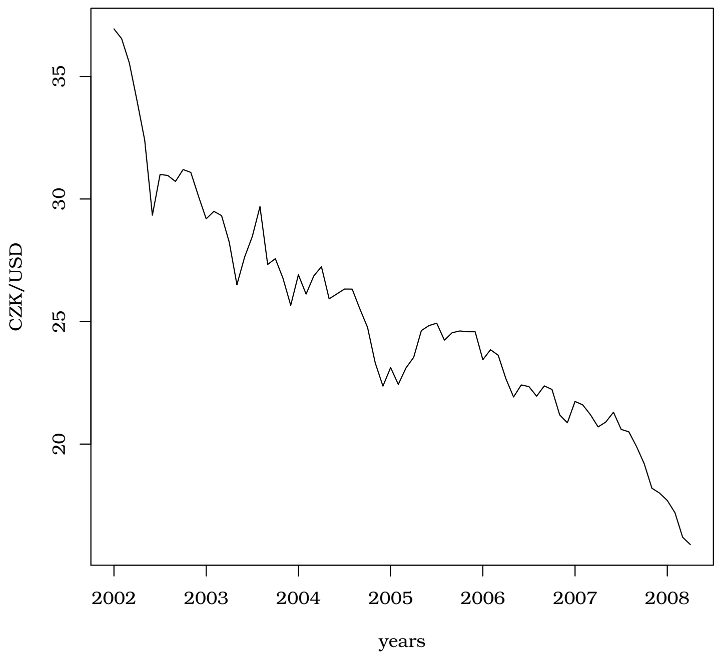
Source: BP Statistical Review of World Energy, June 2007.

Movements in world oil prices translate into domestic prices of producers as well as consumers. Since residents are interested in prices in the domestic currency, the development of the exchange rate is of major interest, i.e., an appreciating exchange rate could be a stabilizing factor for increasing oil prices. To be more specific, especially during the second half of the period considered here, the fluctuations in the barrel price in CZK are dampened heavily as a result of CZK appreciating against USD. Nevertheless, the appreciation of CZK against USD only partly offset the price increases in USD.

It is worth mentioning that due to price regulation of selected goods and services the final impact of potential oil price changes on producers and consumers might differ. To be more specific, the prices of electricity, heating, transportation, etc. for households are regulated by the government. But those prices are not regulated for producers. The following regressions demonstrate the relationship between growth of the Brent price in CZK and growth of the producer price index (PPI), prices of industrial producers (IPI), manufacturing producer prices (MANUF), and the consumer prices of oil-based fuels (PETROL), respectively. All the variables are year-on-year relative changes in current prices from 1/2001 to 7/2007. Apart from the growth of the CPI, all the variables are stationary at the 10% significance level. The CPI growth is not stationary, but does not display any upward or downward trend over the whole period.

$$\Delta \log \mathrm{PPI}_t \;=\; \underset{(5.01)}{1.08} + \underset{(0.004)}{0.006}\,\Delta \log \mathrm{brent}_{t-1} + \underset{(0.05)}{0.95}\,\Delta \log \mathrm{PPI}_{t-1} + \epsilon_t$$

Figure 3.8: CZK/USD Exchange Rate since 2002



Source: Czech National Bank.

$$\begin{aligned}
\Delta \log \mathrm{IPI}_t &= \underset{(23.48)}{35.13} + \underset{(0.010)}{0.018}\, \Delta \log \mathrm{brent}_{t-1} + \underset{(0.23)}{0.63}\, \Delta \log \mathrm{IPI}_{t-1} + \epsilon_t \\
\Delta \log \mathrm{MANUF}_t &= \underset{(31.87)}{46.61} + \underset{(0.013)}{0.023}\, \Delta \log \mathrm{brent}_{t-1} + \underset{(0.32)}{0.52}\, \Delta \log \mathrm{MANUF}_{t-1} + \epsilon_t \\
\Delta \log \mathrm{PETROL}_t &= \underset{(5.27)}{35.49} + \underset{(0.017)}{0.19}\, \Delta \log \mathrm{brent}_{t-1} + \underset{(0.06)}{0.44}\, \Delta \log \mathrm{PETROL}_{t-1} + \epsilon_t
\end{aligned}$$

Indeed, the impact of CZK Brent prices on producer prices is most visible in petrol-related industries. As the oil intensity of the industry in question decreases, we observe a lower impact of oil prices on the price of its output. In manufacturing, the short-run elasticity decreases to 2.3%, since manufacturing includes many industries that use very little oil as an input. As we proceed to a more aggregate level (industry as a whole and the whole economy), the impact of the price of oil declines even more.

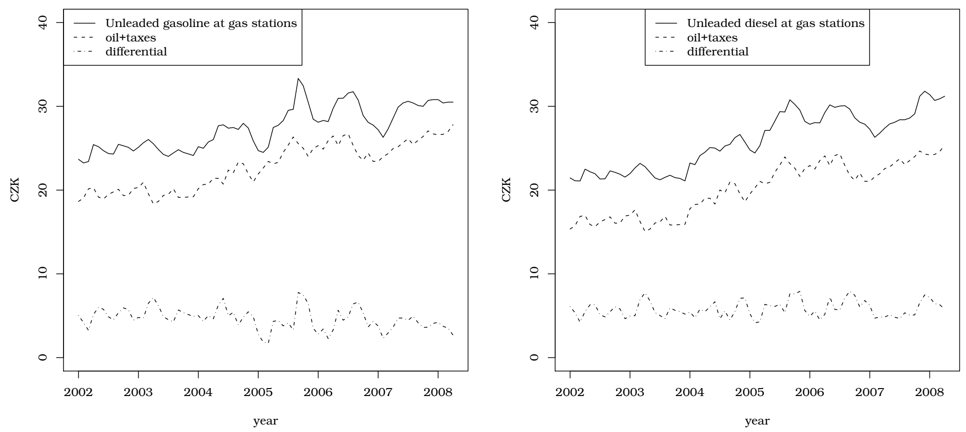
Price regulation alters the relation between oil import prices and domestic consumer prices. This is reflected by the fact that we found only a weak relationship between the domestic CPI and the price of Brent oil in CZK.

$$\Delta \log \mathrm{CPI}_t = \underset{(3.73)}{8.55} + \underset{(0.002)}{0.004}\, \Delta \log \mathrm{brent}_{t-1} + \underset{(0.036)}{0.91}\, \Delta \log \mathrm{CPI}_{t-1} + \epsilon_t \qquad (3.1)$$

These results are obviously based on very simple models. A serious econometric analysis would require the use of a VAR model.

The following example demonstrates the impact of additional factors such as taxes and menu costs on final consumer prices. Figure 3.9 shows the price of Natural 95 unleaded motor gasoline and diesel at Czech gas stations since 2002.

Figure 3.9: Unleaded Gasoline and Diesel Price Decomposition



Source: Czech Ministry of Finance, Czech Statistical Office, own calculations.

We can easily see that the price volatility at gas stations is much lower than the volatility of world prices[5]. The difference is caused by:

1. Appreciation of CZK against USD. Measured in USD, Czech gas prices more than doubled between 2002 and 2007.

2. The rest of the difference is caused by taxation. There are two taxes on gasoline and diesel: *consumption tax* and the standard *value added tax*, which is also levied on the consumption tax part of the price. The consumption tax is a quantity tax (per liter, see Table 3.6), independent of the current price of oil. The consumption tax has a moderating effect on the gasoline price fluctuations. Figure 3.9 also shows how the "oil converted to CZK + taxes" price of Czech gasoline would look. The difference between this price and the observed price covers labor costs, refining costs, company profits, and other items. The important thing is that this residual is a stationary time series in the studied period.

3. The price margin of gasoline suppliers absorbs the oil price shocks. We have regressed the price residual to changes of the total costs of refined oil to a gas station. The resulting equation

$$\pi_t = \underset{(0.13)}{4.91} - \underset{(0.16)}{1.10}\,\Delta p_{t,oil} + \epsilon_t$$

   shows that we cannot reject the hypothesis that the Δp_{oil} coefficient is equal to -1, so we can say that a 1 CZK increase in the total costs of refined gasoline is fully absorbed by the residual price margin in the running month. It can be argued that refineries and gas stations absorb short-run fluctuations of the oil price in their margins.

[5] The variation coefficient (the std. deviation divided by the mean) of the price of fuel at Czech gas stations is 0.1. The variation coefficient of USD Brent prices is 0.37.

Table 3.6: Consumption Tax and VAT on Gasoline and Diesel since 1995 [CZK/liter]

period	Gasoline	Diesel	VAT
1995	7.62		22%
1996-97	8.68		22%
1998-6/99	9.71		22%
7/99-2003	10.84	8.15	22%
2004-	11.74	9.95	19%

Source: Ministry of Finance.

4. A General Equilibrium Model of the Czech Economy

In this section we present model simulation outcomes of oil price changes under several scenarios. As mentioned already, the future energy intensity development in the Czech Republic is hard to predict. On the one hand there is a sizeable gap between the current Czech energy intensities and those of the EU15. This suggests that the Czech economy might be able to catch up within the not too distant future. On the other hand, the past development (see Figure 3.3) shows that the intensity decline has been rather slow during the last decade (on average 2% p.a.) and even decelerating in the last 5 years.

Also, there is substantial uncertainty about the impact of oil prices on the Czech Republic's trade partners, especially the EU. Therefore, in our simulations we concentrate on different assumptions about the development of technology and world demand.

We first simulate the impact of an oil price change under the assumption of no change in oil intensity (pessimistic scenario), assuming that the impact on the Czech Republic's trade partners will be in line with the literature results summarized in Section 5.

Then we compare the results with other simulations where we assume no impact of the oil price shock on economies other than the Czech one. At first sight, this seems to be an unrealistic assumption. But taking into account the relatively low energy intensity of the EU15 economies (by far the greatest trade partners of the Czech Republic), we could argue that the oil price effect on them is of a limited extent and importance for our calculations.

In the third simulation we compare the results of the first simulation with the same simulation under the assumption of reaching the EU15 energy intensity levels in 10 years.

Our general conclusion is that regardless of alternative simulation assumptions, the effects of oil price increases are rather small, though rather bigger than the impacts suggested, for example, by equation (3.1) in the empirical part of this paper.

4.1 Oil Price Shock in the Model

Before running the simulations, it is worthwhile to review the structure of the model from the point of view of the shock that is to be studied. This section describes how oil price shocks disseminate through the model. A more complete description of the model is presented in Appendix B.

To capture the propagation mechanism of an oil price shock, we start with equation

$$P^m_{c,t} = \mathrm{ER}_t(1+\tau^m_{c,t})P^w_{c,t}, \tag{4.2}$$

where $P^m_{c,t}$ represents the import price of commodity c at time t in CZK including import tariffs, ER_t is the exchange rate, $\tau^m_{c,t}$ stands for the rate of tariffs, indirect taxes, transport, and other import-related costs, and $P^w_{c,t}$ denotes the world price in foreign currency. The world price is assumed exogenous to the model, since we model a small open economy. The development of the exchange rate is also assumed to be exogenous. It is worth stressing that equation (4.2) is the only one where the world oil price explicitly enters the model.

Import prices directly influence prices of intermediates, which are both imported and produced domestically. We assume that firms have to import a certain share of their intermediates from abroad (Leontief production structure). The price of intermediates paid by industry i is defined as a weighted average of the domestic and import prices of the intermediate commodities.

$$P^{int}_{i,t} = \frac{\sum_c \left(P^d_{c,t}\mathrm{INT}^d_{i,c,t} + P^m_{c,t}\mathrm{INT}^m_{i,c,t}\right)}{\sum_c INT_{i,c,t}} \tag{4.3}$$

The intermediate price enters the price of domestic production

$$P^{dom}_{i,t} = (1+\mathrm{markup_i})\frac{w_{i,t}L_{i,t} + r_tK_{i,t} + P^{int}_{i,t}\mathrm{INT}_{i,t}}{Q^{dom}_{i,t}}, \tag{4.4}$$

where $P^{dom}_{i,t}$ represents the unit price of domestic producers, markup stands for the profit margin, $w_{i,t}$ denotes the wage level, $L_{i,t}$ is employment in industry i, r_t is the real interest rate, $K_{i,t}$ is the capital stock, $\mathrm{INT}_{i,t}$ is intermediate consumption, and $P^{int}_{i,t}$ is its price. Together, import prices and domestic producer prices determine the price level $\mathrm{CPI_t}$ on the Czech market.

Contrary to firms, households are assumed to be able to substitute imported goods for domestic ones and vice versa if relative prices change.

$$\frac{C^{dom}_{c,t}}{C^m_{c,t}} = \left(\frac{\alpha_c}{1-\alpha_c}\frac{P^m_{c,t}}{P^{dom}_{c,t}}\right)^{\frac{1}{1+\sigma_c}} \tag{4.5}$$

Here, $C_{c,t}$ is the household consumption of commodity c at time t, α_c is a calibrated coefficient, and σ_c is the relative price elasticity of household demand (we set σ_c around 2 for most commodities).

The CPI is influenced by both domestic and import prices.

$$\mathrm{CPI}_t = \frac{\sum_c \left(P^{dom}_{c,t} C^{dom}_{c,t} + P^{m}_{c,t} C^{m}_{c,t}\right)}{\sum_c \left(C^{dom}_{c,t} + C^{m}_{c,t}\right)} \tag{4.6}$$

An increase in the price level puts pressure on wages. The wage equation is a fundamental building block of the model. It says that

$$\Delta \log w_{i,t} = \Delta \log \mathrm{CPI_t} + \Delta \log h_{i,t} - \frac{\lambda_i}{u_t}, \tag{4.7}$$

where $h_{i,t}$ is the productivity level in industry i, u_t is the unemployment rate, and $\lambda_i > 0$. The wage equation says that wages reflect price and productivity developments but get moderated if unemployment starts to grow (Phillips curve effect). When consumer prices change, wages change ceteris paribus by the same relative amount. Prices of domestic producers are affected again by a wage level change.

We assume that Czech producers do not price discriminate between the Czech and foreign market, thus the export price is just the domestic price converted to foreign currency:

$$P^{exp}_{c,t} = \mathrm{ER_t} P^{dom}_{c,t} \tag{4.8}$$

The external demand for Czech products is influenced by the ratio of world prices to Czech export prices, i.e.

$$\Delta \log \mathrm{EXP}_{c,t} = \Delta \log \mathrm{GDP^{world}_t} + \sigma^{\epsilon}_{\mathrm{c}} \left[\Delta \log \mathrm{P^{world}_{c,t}} - \Delta \log \mathrm{P^{exp}_{c,t}}\right] \tag{4.9}$$

where σ^{ϵ}_{c} is around 1.7 for most commodities.

Indeed, as the domestic export price rises, the competitiveness of the economy deteriorates. It follows that real exports and thereby aggregate demand for Czech production decrease.

The production side of the economy is hit by the cost shock in several ways

1. Prices of intermediate goods increase. In the model intermediate goods cannot be substituted for labor and capital.
2. The increased wages push up labor costs.
3. Prices of capital goods grow as well (by the same mechanism as prices of intermediates) and the decreased demand for domestic production leads to a fall in the optimal capital stock. This leads to lower investment and a further demand decline.

All in all, demand for domestic output decreases and firms adjust their labor force. The resulting unemployment leads to wage moderation (see equation (4.7)) and a decrease in production costs. In the long run, Czech production becomes competitive again, but the cost structure changes. The cost share of imported goods increases and the share of labor costs decreases. The terms of trade deteriorate and real household income is lower in the new equilibrium. In quantities, we will import less and export more, keeping a roughly stable current account balance in the long run. The loser in this scenario is households, whose incomes are cut in order to regain competitiveness.

4.2 Presentation of Simulation Results

The simulation results are presented in Tables 4.1, 4.2, and 4.3. Each table presents eight economic indicators. Except for the CPI, all the variables are given in real terms (fixed prices). The last two rows represent the cumulative present value loss of GDP and household consumption over 1, 3, and 5 years and the infinite horizon expressed as a percentage of GDP and household consumption respectively in the first year. To compute the cumulative losses we apply a 3% p.a. discount rate. The cumulative present value consumption loss is therefore defined by $L_c = \frac{1}{C_1^{\text{base}}} \sum_{t=1}^{+\infty} \frac{C_t - C_t^{\text{base}}}{(1+0.03)^t}$. The expression for the cumulative present value GDP loss is analogous.

A series of four permanent oil price shocks enters the model in years 1, 2, 3, and 4. The tables present the results in years 1, 3, and 5 and in the long run (column $+\infty$). The precise definitions of the alternative simulations are provided in the respective subsections.

The presented figures denote a difference from the baseline. The baseline always equals 100. So, for example, 99.2 in the upper-right corner of Table 4.1 means that in Simulation 1 real GDP will be 0.8% lower in the long run than it would be if no price shock occurred.

Similarly, in the fourth row, first column of Table 4.1 the figure 99.6 indicates that in the first simulation real exports will be 0.4% lower in the first year of the shock compared to the baseline.

4.3 Simulation 1: Overall Increase in Oil Prices

In this simulation we assume that import prices of oil and oil products *in Czech koruna* increase by 5% a year during the upcoming 4 years, i.e., by 20% over this horizon. In all following years the price of oil stays at the level of year 4. Since the oil price has increased by around 50% in the last five years (see Figure 3.9), this shock seems to be within realistic bounds. The related prices of imported chemical products are assumed to increase by 0.8% a year during the four years. In this scenario, the oil price shock hits both the Czech economy and its trade partners, therefore world market prices of all goods are assumed to increase. Aggregate world demand (i.e., also world demand for Czech goods) is also assumed to decrease. Within this scenario, no oil intensity improvement is taken into account, either in the Czech Republic or abroad.

Since the model is not a two-country model, the assumptions about the impact of oil prices on the Czech Republic's trade partners are bound to be arbitrary. We assume a world price increase due to an oil price shock in the range of 0 to 1% in the long run, depending on the characteristics of the goods traded. Furthermore, we assume that the oil price shock cuts aggregate world demand by around 0.2%. This is roughly in line with the literature (see, for example, the survey by Kingma and Suyker (2004)). Alternative sensitivity scenarios suggest that the results are not significantly affected by assuming a higher impact on foreign economies[6] (see Table A.4).

It is worth emphasizing that the impact on the foreign country has two effects on the Czech Republic, which can be of opposite sign. First, the decrease in world demand is simply a

[6] An alternative scenario assuming a 1% foreign demand decrease instead of the original 0.2% decrease was simulated.

Table 4.1: Results of Simulation 1: Overall Increase in Oil Price

	1	3	5	$+\infty$
GDP	99.5	98.8	98.5	99.2
Household consumption	99.6	99.0	98.8	97.5
Gross investment	98.3	96.4	96.6	98.3
Export	99.6	98.7	98.3	101.4
Import	99.4	98.7	98.5	98.9
Employment	99.1	97.8	97.7	100.2
CPI	100.4	101.5	102.1	99.5
Gross wage	100.1	100.2	100.2	96.1
$\text{GDP}_{\text{cumul}}$	-0.5	-2.5	-5.3	-40.8
$\text{Household consumption}_{\text{cumul}}$	-0.4	-2.1	-4.2	-78.3

Note: Column "1" corresponds to the first year of the shock, "3" to the third year of the shock, "5" to the fifth year (one year after the shock) and "$+\infty$" to the long-run result. The presented figures are index numbers where the baseline scenario equals 100. The last two rows report the cumulative present value loss of GDP and household consumption as percent of GDP and household consumption, respectively, in the base year. A 3% discount rate is used.
Source: Own calculations.

negative shock for the Czech economy. Second, the world price level increase would ceteris paribus have a positive impact on Czech competitiveness. But at the same time higher import prices increase domestic costs and price levels. The net effect depends on the relation of imports to exports in each commodity group.

The oil price shock first hits domestic oil importers. Simultaneously, all other domestic importers face higher prices due to the oil-induced price level increase abroad. Both groups of importers pass on the increased costs to their prices, which in turn increases the costs (and prices) of their customers and the prices of final goods. The simulated price level impact of the oil price shock is rather moderate: the CPI gap is 0.4% in the first year and 2.1% after 5 years. This amounts to an average oil shock net impact of around 0.4 p.p. extra inflation in the first 5 years.

The higher level of domestic prices has a negative effect on both international competitiveness and domestic demand. GDP will be roughly 1.5% lower in the fifth year, i.e., after the whole shock is realized. So in the short run, average domestic economic growth slows down by 0.3% per year. Lower economic performance and higher nominal wages are accompanied by a drop in aggregate employment by 2% in the short run.

As already mentioned in Section 4.1, in the first years real wages are not strongly affected by the decrease in employment. On the contrary, real wages increase slightly in reaction to productivity increases triggered by the employment cuts. Later on, the bargaining power of employees deteriorates, which leads to a real wage decrease. This allows cost and price cuts, more employment and restoration of the competitive position of the economy. Exports rise above their pre-shock levels, while imports remain low. In the nominal terms this leads to an equilibrium balance of payments under the new (worse) terms of trade. The burden of the shock is borne by households, whose income is cut in order to regain competitiveness. This mechanism is reflected in the cumulative household consumption loss being much higher than the cumulative loss of GDP.

Compared to the baseline, the CPI decreases in the long run as a result of the wage cuts. The simulated long-run effect on the GDP level seems to be rather limited, at around -0.8%. The long-run model outcomes reflect the restored competitiveness and employment.

The impact of the oil price change partly depends on the reaction of the government. We assume that the government does not try to keep the budget balanced in the years of the shock. Later (after 10 years) it cuts down its consumption to reach public finance sustainability. Other assumptions about the government reaction are introduced in the form of a robustness check in the Appendix (see Table A.4).

4.4 Simulation 2: Isolated Increase in Oil Price

In this simulation we again assume that import prices of oil and oil products *in Czech koruna* increase by 5% a year during the upcoming 4 years, i.e., by 20% over this horizon. The related prices of imported chemical products are assumed to increase by 0.8% a year during the four years. In this simulation we still assume that the intensity of oil use does not change beyond the (rather limited) substitution possibilities assumed in the production structure of our model. The difference from the base simulation is that we assume that the oil price increase hits the Czech economy only. The aim of this simulation is to show which part of the result of Simulation 1 is caused by the assumptions about the foreign reaction. For another simulation which considers a larger impact on foreign economies, see the robustness analysis in the Appendix.

Table 4.2: Results of Simulation 2: Isolated Increase in Oil Price

	1	3	5	$+\infty$
GDP	99.6	98.8	98.5	99.2
Household consumption	99.7	99.0	98.8	97.5
Gross investment	98.6	96.6	96.7	98.3
Export	99.6	98.7	98.2	101.4
Import	99.5	98.7	98.5	98.8
Employment	99.2	97.9	97.6	100.2
CPI	100.3	101.2	101.7	99.0
Gross wage	100.1	100.2	100.2	96.1
GDP_{cumul}	-0.4	-2.4	-5.2	-41.3
Household $consumption_{cumul}$	-0.4	-1.9	-4.1	-79.3

Note: Column "1" corresponds to the first year of the shock, "3" to the third year of the shock, "5" to the fifth year (one year after the shock) and "$+\infty$" to the long-run result. The presented figures are index numbers where the baseline scenario equals 100. The last two rows report the cumulative present value loss of GDP and household consumption as percent of GDP and household consumption, respectively, in the base year. A 3% discount rate is used.
Source: Own calculations.

The difference between Simulation 1 and Simulation 2 is apparent in the development of inflation. In the long run the price level is 1% below the baseline scenario. In Simulation 1 it was 1.5% below. Concerning GDP, the difference between the two scenarios is very limited and present only in the very short run. We conclude that taking into account the reactions of the rest of the world to an oil price shock increases the impact on the domestic price level, but does not influence aggregate economic activity.

All in all, the results of Simulations 1 and 2 are rather similar. This is due to the contradictory impact of the foreign demand drop and the foreign price increase on Czech competitiveness.

4.5 Simulation 3: Increase in Oil Price under Energy Intensity Improvement

In this simulation we again assume that import prices of oil and oil products *in Czech koruna* increase by 5% a year during the upcoming 4 years, i.e., by 20% over this horizon. The related prices of imported chemical products are again assumed to increase by 0.8% a year during the four years. The difference from Simulation 1 is that the oil use intensity is assumed to improve by 5.5% a year between years 1 and 10. Over the 10 years, the intensity is thus assumed to improve by 71%, which would close the gap between the EU15 and the Czech energy intensity levels (see Figure 3.3). In other words, this simulation assumes that the Czech Republic converges to the EU15 rather rapidly in terms of energy intensity.

Table 4.3: Results of Simulation 3: Increase in Oil Price under Energy Intensity Improvement

	1	3	5	$+\infty$
GDP	99.6	99.1	99.0	99.4
Household consumption	99.7	99.3	99.2	98.3
Gross investment	98.7	97.5	97.7	98.8
Export	99.7	99.1	98.9	100.9
Import	99.5	99.0	99.0	99.2
Employment	99.3	98.5	98.4	100.1
CPI	100.3	101.1	101.6	99.8
Gross wage	100.1	100.2	100.1	97.4
GDP_{cumul}	-0.4	-1.8	-3.7	-27.2
Household $consumption_{cumul}$	-0.3	-1.5	-3	-53.8

Note: Column "1" corresponds to the first year of the shock, "3" to the third year of the shock, "5" to the fifth year (one year after the shock) and "$+\infty$" to the long-run result. The presented figures are index numbers where the baseline scenario equals 100. The last two rows report the cumulative present value loss of GDP and household consumption as percent of GDP and household consumption, respectively, in the base year. A 3% discount rate is used.
Source: Own calculations

Intuitively, thanks to the lower oil use intensity, the impact of the oil price shock on the Czech economy is less pronounced. Otherwise, the mechanisms described in Simulation 1 still apply.

To interpret the results of this simulation it is necessary to emphasize that the reduction in oil intensity is assumed to be compensated by an increase of use of other inputs, whose prices increase much less. In other words, importing less oil means importing (and paying) more of some other input in order to produce the same amount of output.

The most pronounced improvements compared to Simulation 1 can be observed in household consumption and wages. As described in Section 4.1, households bear the final burden of the price shock, since their employment (in the short run) and wages (in the long run) decrease. The dampening of the shock via technological progress is therefore beneficial to them.

The decrease in real wages is much smaller than in Simulation 1 (2.6% against 3.9% in the long run). Households enjoy higher real income and therefore spend more on imported goods. Real exports increase less than without the technological progress and imports are higher, therefore the exports deteriorate compared to Simulation 1. The final effect on GDP is therefore less pronounced than the effect on domestic demand and wages.

5. Impact of Oil Price Shock in Other Models

During recent years several institutions have carried out analyses of oil price changes on prices and economic activity using their economic models. Such analyses have been undertaken by institutions such as the ECB (AWM model), the IMF (Multimod model), the EC (QUEST model), the OECD (Interlink model), and the NIESR (NiGEM model), to name but a few. Indeed, it should be borne in mind that each model is partly based on different assumptions and possibly stresses the role of alternative factors and relationships. Regardless of such differences, the simulation outcomes point in same direction and the main conclusions seem to be robust to the modeling practices applied.[7]

Table 5.1: Model Comparison

	Inflation		GDP growth	
	Year 1	Year 3	Year 1	Year 3
ECB AWM	0.5	0.1	-0.1	-0.1
EC QUEST	0.4	0.1	-0.6	-0.1
NiGEM	0.3	0.0	-0.8	0.1
IMF Multimod	1.6	0.5	-0.1	0.1
Our model	0.8	0.9	-1.0	-1.0

Note: Reaction to a 50% permanent oil price increase.

The European Commission QUEST model does not treat oil as a separate commodity. The oil price shock is simulated indirectly via an increase in import prices, using the relative importance of net imports of oil in total imports. The simulated impact on inflation is 0.4 p.p. above the baseline in the first year and 0.1 p.p. in the third year in reaction to a permanent increase in oil

[7] For a more detailed comparison of oil price change simulations on prices and economic activity, see, for example, ECB (2004).

prices of 50%. The impact on GDP growth under the same assumptions was simulated to be -0.6 and -0.1 p.p. lower relative to the base scenario. The simulation outcomes of the NIGEM model are relatively close to the QUEST outcomes in suggesting an increase in inflation of 0.3 and 0.0 p.p. in the first and third year, respectively. The impact on GDP growth is -0.8 and 0.1 p.p. compared to the baseline scenario.

The AWM model estimates suggest that a permanent 50% rise in oil prices adds to overall inflation by 0.5 p.p. within the first year. After three years overall inflation would be 0.1 p.p. higher compared with the situation of unchanged oil prices. Regarding economic activity, the AWM model suggests that a 50% increase in oil prices would lead to real GDP growth declining by 0.1 p.p. in the first year. Likewise, this model predicts an impact of -0.1 p.p. in the third year.

The IMF Multimod is driven mainly by longer-term relationships. That is probably why the model yields stronger effects than the other models. The impact of a 50% oil price shock is simulated to be 1.6 and 0.5 p.p. on inflation and -0.1 and 0.1 p.p. on GDP growth in the first and third year, respectively.

As already mentioned, our model puts more weight on the detailed structure of the economy while leaving out some important dynamic features such as expectations and intertemporal optimization. The lack of intertemporal smoothing leads to higher effects of shocks in the short run, as can be seen in the effect on GDP in comparison with other models. There are several other reasons why our model reports higher deviations from the baseline scenario in the short run. Firstly, the absolute size of the 50% is much higher in our simulation, as the oil price in our baseline reflects the recent high oil prices. Secondly, in the other models oil-exporting countries are assumed to spend most of their oil profits on imports from the simulated countries. That is how the GDP effect can turn out positive after three years. Thirdly, the Czech energy intensity *is* higher than that of the EU and the US, so we do expect higher effects. Anyway, the main conclusions of our analysis seem to be in line with the outcomes of the models mentioned above.

6. Concluding Remarks

The paper was motivated by the dramatic increases in oil prices recorded in the course of 2002 up to the end of 2007. The USD price of one barrel of Brent oil increased during the analysed period more than five times. This has triggered a debate among Czech economists about the possible impacts of such a price shock on the Czech economy. In our study we use several approaches to show that the impact of such a shock is not dramatic. Our arguments can be summarized as follows.

First, the structure of energy use in the Czech Republic reflects the fact that some energy sources (e.g. coal) are abundant in the Czech Republic. This results in low overall energy dependence. On the other hand, the energy intensity of the Czech economy is much higher than that in the EU15. The USD price of a barrel of Brent is not the only determinant of the price paid by the Czech consumer. The price can be moderated by appreciation of CZK, which has been the case in recent years. The volatility of the oil price is also restricted by the construction of the consumption tax system.

Second, reduced-form regressions of different price measures on the oil price confirm that Czech prices react very little to oil price developments. The long-run effect of an oil price increase of 1% on the PPI was estimated to be 0.12%. For the CPI the figure is 0.044%. The estimated elasticity of the CPI is lower due to energy price regulation and the absorption of short-run oil price fluctuations by producers.

Third, structural CGE model simulations indicate that the impact of oil prices on both nominal and real variables is not too high, although the effects are higher than those reported for the EU and the USA in the literature. We present three alternative simulations. In the base simulation, both the Czech Republic and its trade partners are hit by the shock. In the second scenario, only the Czech Republic is hit by the shock. In the third scenario, the impact of the shock is mitigated by technological improvement.

On basis of these simulations we predict that a 20% rise in the price of oil in Czech koruna would slow economic growth down by around 0.4 p.p. per year in the first years after the shock. The shock would decrease the long-run GDP level by around 0.7%. In the short run, inflation would also increase by around 0.4 p.p. per year. In the long run, the price level would actually decline compared to the scenario without a shock. This decrease is caused by wage cuts necessary to restore international competitiveness.

To check the robustness of the results we performed several alternative simulations. The results of these simulations indicate that our results are reasonably robust.

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Appendix A

Robustness Check

The results reported in tables 4.1, 4.2, and 4.3 depend on a set of assumptions and parameter values discussed in appendix B. Here we discuss the parameters and assumptions that might be important for the results and perform the respective robustness checks.

In table A.1, the effect of changes of the Phillips curve parameter (λ in Appendix B) is studied. The Phillips curve parameter is responsible for the link between unemployment and wages. If the parameter is high, unemployment leads to a bigger decrease of the bargaining power of employees and real wages decrease faster. Assuming less flexibility leads to higher inflation and less economic growth. In the table we report simulations where the Phillips curve parameter is halved (compared with the simulations presented in sections 4.3 to 4.5). The scenario includes higher inflation and less growth, but the impact is moderate.

Other parameters of interest are import and export elasticities. Export elasticities describe the sensitivity of foreign demand to Czech price setting. Import elasticities describe the reactions of Czech private consumption demand to changes in foreign prices. The results for doubled and halved elasticities are reported in tables A.2 and A.3 for export and import, respectively. The effect of assumptions about import elasticities on our results is negligible. The export elasticities tend to be more important. In each simulation, the economy adjusts the level of real wages to reestablish competitiveness. When the export elasticities are lower wages must be cut more, which leads to the negative effects observed in table A.2.

Further, in line with the model results of other institutions (see table 5.1), we assumed that the effect of oil prices on foreign GDP (i.e., aggregate world demand) would be negligible after three years. These model results seem to be very optimistic. Therefore, as a robustness check, we also report results based on a long-run aggregate world demand decrease of 1% (instead of 0.2% in the base simulation), much above any published estimate. The result given in the second block of table A.4 indicates that the simulation result is not overly sensitive to this parameter.

Another possible uncertainty is about the role of the government budget. In any case, the government must sooner or later balance its budget, so a certain amount of restriction is inevitable. In the base simulation we assume that the government postpones stabilization of its budgets by 10 years so that the primary negative effects of the shock phase out, and then it slowly decreases its consumption to attain a balanced budget. As a robustness check we run simulations where income tax and VAT are increased instead of the consumption cuts. The income tax increases have relatively negative effects on overall economic activity, while the VAT closure increases the negative impact on the price level. The results are given in table A.4.

Table A.1: The Robustness Results with Respect to the Relationship between Wage Bargaining Power and Unemployment

		Oil price increase only in CZ				Oil price increase everywhere and tech. improvement				Oil price increase everywhere			
		1	3	5	$+\infty$	1	3	5	$+\infty$	1	3	5	$+\infty$
Base	GDP	99.6	98.8	98.5	99.2	99.6	99.1	99	99.4	99.5	98.8	98.5	99.2
	Household consumption	99.7	99	98.8	97.5	99.7	99.3	99.2	98.3	99.6	99	98.8	97.5
	Gross investment	98.6	96.6	96.7	98.3	98.7	97.5	97.7	98.8	98.3	96.4	96.6	98.3
	Export	99.6	98.7	98.2	101.4	99.7	99.1	98.9	100.9	99.6	98.7	98.3	101.4
	Import	99.5	98.7	98.5	98.8	99.5	99	99	99.2	99.4	98.7	98.5	98.9
	Employment	99.2	97.9	97.6	100.2	99.3	98.5	98.4	100.1	99.1	97.8	97.7	100.2
	CPI	100.3	101.2	101.7	99	100.3	101.1	101.6	99.8	100.4	101.5	102.1	99.5
	Gross wage	100.1	100.2	100.2	96.1	100.1	100.2	100.1	97.4	100.1	100.2	100.2	96.1
Phillips effect halved	GDP	99.6	98.7	98.3	98.8	99.6	99.1	98.8	99.3	99.5	98.7	98.3	98.9
	Household consumption	99.6	99.1	99	97.6	99.6	99.3	99.3	98.3	99.6	99.1	99.1	97.6
	Gross investment	98.6	96.6	96.6	98.2	98.6	97.4	97.6	98.7	98.3	96.4	96.6	98.1
	Export	99.6	98.5	97.8	101	99.6	99	98.5	100.7	99.5	98.5	97.8	101
	Import	99.5	98.7	98.4	98.7	99.5	99	98.9	99.1	99.4	98.6	98.4	98.7
	Employment	99.2	97.7	97.3	99.7	99.2	98.4	98.2	99.8	99	97.7	97.4	99.7
	CPI	100.4	101.3	102	99.3	100.4	101.3	101.9	100	100.4	101.6	102.4	99.8
	Gross wage	100.1	100.5	100.7	96.5	100.1	100.3	100.5	97.6	100.2	100.5	100.8	96.5
Phillips effect doubled	GDP	99.6	99	98.8	99.2	99.7	99.3	99.3	99.5	99.6	99	98.9	99.2
	Household consumption	99.6	98.9	98.6	97.6	99.6	99.1	99	98.4	99.6	98.8	98.5	97.7
	Gross investment	98.7	96.7	96.9	98.4	98.7	97.6	97.8	98.9	98.3	96.6	96.8	98.4
	Export	99.7	99.1	99	101.2	99.8	99.5	99.5	100.8	99.7	99.2	99.2	101.1
	Import	99.5	98.8	98.6	98.9	99.6	99.1	99.1	99.2	99.5	98.7	98.7	98.9
	Employment	99.3	98.2	98.3	100.2	99.3	98.7	98.9	100.1	99.1	98.2	98.3	100.2
	CPI	100.3	100.8	101	99.2	100.3	100.9	101.1	100	100.3	101.1	101.4	99.7
	Gross wage	100	99.8	99.2	96.3	100	99.7	99.3	97.5	100	99.7	99.2	96.4

Table A.2: The Robustness Results with Respect to Price Elasticities of Export

		Oil price increase only in CZ				Oil price increase everywhere and tech. improvement				Oil price increase everywhere			
		1	3	5	+∞	1	3	5	+∞	1	3	5	+∞
Base	GDP	99.6	98.8	98.5	99.2	99.6	99.1	99	99.4	99.5	98.8	98.5	99.2
	Household consumption	99.7	99	98.8	97.5	99.7	99.3	99.2	98.3	99.6	99	98.8	97.5
	Gross investment	98.6	96.6	96.7	98.3	98.7	97.5	97.7	98.8	98.3	96.4	96.6	98.3
	Export	99.6	98.7	98.2	101.4	99.7	99.1	98.9	100.9	99.6	98.7	98.3	101.4
	Import	99.5	98.7	98.5	98.8	99.5	99	99	99.2	99.4	98.7	98.5	98.9
	Employment	99.2	97.9	97.6	100.2	99.3	98.5	98.4	100.1	99.1	97.8	97.7	100.2
	CPI	100.3	101.2	101.7	99	100.3	101.1	101.6	99.8	100.4	101.5	102.1	99.5
	Gross wage	100.1	100.2	100.2	96.1	100.1	100.2	100.1	97.4	100.1	100.2	100.2	96.1
Export elasticities halved	GDP	99.7	99.3	99.1	98.6	99.7	99.4	99.3	99	99.6	99.2	99.1	98.6
	Household consumption	99.8	99.4	99.4	96.3	99.7	99.5	99.6	97.3	99.6	99.4	99.3	96.2
	Gross investment	99.2	98.2	98.3	97	99	98.5	98.7	97.9	98.7	97.9	98.1	96.9
	Export	99.8	99.3	99	101.6	99.7	99.4	99.2	101.1	99.7	99.2	98.9	101.6
	Import	99.7	99.3	99.3	98	99.7	99.4	99.4	98.5	99.6	99.2	99.2	97.9
	Employment	99.5	98.7	98.6	100.2	99.4	99	99	100.2	99.3	98.6	98.5	100.2
	CPI	100.4	101.3	101.8	97.5	100.4	101.3	101.7	98.5	100.5	101.6	102.3	97.8
	Gross wage	100	100.2	100.2	94.2	100	100.1	100.2	95.7	100	100.2	100.2	94
Export elasticities doubled	GDP	99.4	98.1	97.6	99.3	99.6	98.8	98.6	99.6	99.4	98.3	97.8	99.4
	Household consumption	99.4	98.4	98	97.9	99.6	98.9	98.7	98.7	99.5	98.5	98.2	98.1
	Gross investment	98	94.6	94.3	98.7	98.4	96.4	96.5	99.1	97.9	94.7	94.5	98.7
	Export	99.4	98	97	101.4	99.6	98.9	98.5	100.9	99.5	98.3	97.5	101.4
	Import	99.3	97.8	97.3	99.1	99.5	98.7	98.5	99.5	99.3	98	97.6	99.2
	Employment	98.9	96.8	96.3	100.1	99.1	97.9	97.8	100.1	98.8	96.9	96.6	100.1
	CPI	100.3	100.9	101.5	99.6	100.3	101	101.4	100.3	100.3	101.2	101.8	100.1
	Gross wage	100	100.2	100.1	96.8	100	100.1	99.9	98	100.1	100.2	100.2	97.1

Table A.3: The Robustness Results with Respect to Price Elasticities of Import for Final Use

		Oil price increase only in CZ				Oil price increase everywhere and tech. improvement				Oil price increase everywhere			
		1	3	5	$+\infty$	1	3	5	$+\infty$	1	3	5	$+\infty$
Base	GDP	99.6	98.8	98.5	99.2	99.6	99.1	99	99.4	99.5	98.8	98.5	99.2
	Household consumption	99.7	99	98.8	97.5	99.7	99.3	99.2	98.3	99.6	99	98.8	97.5
	Gross investment	98.6	96.6	96.7	98.3	98.7	97.5	97.7	98.8	98.3	96.4	96.6	98.3
	Export	99.6	98.7	98.2	101.4	99.7	99.1	98.9	100.9	99.6	98.7	98.3	101.4
	Import	99.5	98.7	98.5	98.8	99.5	99	99	99.2	99.4	98.7	98.5	98.9
	Employment	99.2	97.9	97.6	100.2	99.3	98.5	98.4	100.1	99.1	97.8	97.7	100.2
	CPI	100.3	101.2	101.7	99	100.3	101.1	101.6	99.8	100.4	101.5	102.1	99.5
	Gross wage	100.1	100.2	100.2	96.1	100.1	100.2	100.1	97.4	100.1	100.2	100.2	96.1
Import elasticities halved	GDP	99.6	98.8	98.5	99.2	99.6	99.1	99	99.4	99.5	98.8	98.5	99.2
	Household consumption	99.7	99	98.8	97.4	99.7	99.3	99.2	98.3	99.6	99	98.8	97.5
	Gross investment	98.7	96.7	96.8	98.3	98.7	97.5	97.7	98.8	98.3	96.5	96.7	98.3
	Export	99.6	98.7	98.2	101.4	99.7	99.1	98.9	101	99.6	98.7	98.3	101.4
	Import	99.5	98.7	98.5	98.8	99.5	99	98.9	99.2	99.4	98.6	98.5	98.9
	Employment	99.2	97.9	97.7	100.2	99.3	98.5	98.5	100.1	99.1	97.9	97.7	100.2
	CPI	100.3	101.2	101.7	99	100.3	101.1	101.6	99.8	100.4	101.5	102.1	99.5
	Gross wage	100.1	100.2	100.2	96	100.1	100.2	100.1	97.3	100.1	100.2	100.2	96.1
Import elasticities doubled	GDP	99.6	98.7	98.4	99.2	99.6	99.1	99	99.5	99.5	98.7	98.5	99.2
	Household consumption	99.7	98.9	98.8	97.5	99.7	99.3	99.2	98.3	99.6	98.9	98.8	97.6
	Gross investment	98.6	96.5	96.6	98.3	98.6	97.4	97.6	98.8	98.3	96.3	96.6	98.3
	Export	99.6	98.7	98.2	101.3	99.7	99.1	98.9	100.9	99.6	98.8	98.3	101.3
	Import	99.5	98.7	98.5	98.8	99.5	99	99	99.2	99.4	98.7	98.5	98.8
	Employment	99.2	97.8	97.6	100.2	99.2	98.4	98.4	100.1	99	97.8	97.6	100.2
	CPI	100.3	101.2	101.7	99	100.3	101.1	101.6	99.9	100.4	101.5	102.1	99.5
	Gross wage	100.1	100.2	100.2	96.1	100.1	100.2	100.1	97.4	100.1	100.2	100.2	96.3

***Table A.4:* The Robustness Results with Respect to Reactions of the Government**

		Oil price increase only in CZ				Oil price increase everywhere and tech. improvement				Oil price increase everywhere			
		1	3	5	$+\infty$	1	3	5	$+\infty$	1	3	5	$+\infty$
Base	GDP	99.6	98.8	98.5	99.2	99.6	99.1	99	99.4	99.5	98.8	98.5	99.2
	Household consumption	99.7	99	98.8	97.5	99.7	99.3	99.2	98.3	99.6	99	98.8	97.5
	Gross investment	98.6	96.6	96.7	98.3	98.7	97.5	97.7	98.8	98.3	96.4	96.6	98.3
	Export	99.6	98.7	98.2	101.4	99.7	99.1	98.9	100.9	99.6	98.7	98.3	101.4
	Import	99.5	98.7	98.5	98.8	99.5	99	99	99.2	99.4	98.7	98.5	98.9
	Employment	99.2	97.9	97.6	100.2	99.3	98.5	98.4	100.1	99.1	97.8	97.7	100.2
	CPI	100.3	101.2	101.7	99	100.3	101.1	101.6	99.8	100.4	101.5	102.1	99.5
	Gross wage	100.1	100.2	100.2	96.1	100.1	100.2	100.1	97.4	100.1	100.2	100.2	96.1
Foreign demand decline 1 %	GDP	99.6	98.8	98.5	99.2	99.5	98.9	98.8	99.3	99.4	98.6	98.3	99.1
	Household consumption	99.7	99	98.8	97.5	99.5	99.2	99	98	99.4	98.9	98.7	97.2
	Gross investment	98.6	96.6	96.7	98.3	98.1	97	97.4	98.6	97.7	95.9	96.3	98
	Export	99.6	98.7	98.2	101.4	99.5	98.9	98.6	101	99.4	98.5	98	101.4
	Import	99.5	98.7	98.5	98.8	99.3	98.8	98.7	99	99.2	98.4	98.3	98.7
	Employment	99.2	97.9	97.6	100.2	98.9	98.1	98.2	100.1	98.8	97.5	97.5	100.2
	CPI	100.3	101.2	101.7	99	100.3	101.1	101.6	99.5	100.4	101.4	102.1	99.2
	Gross wage	100.1	100.2	100.2	96.1	100.1	100.2	100.1	96.9	100.1	100.4	100.2	95.7
Income tax closure	GDP	99.6	98.8	98.5	98.8	99.6	99.1	99	99.2	99.5	98.8	98.5	98.8
	Household consumption	99.7	99	98.8	96.7	99.7	99.3	99.2	97.8	99.6	99	98.8	96.8
	Gross investment	98.6	96.6	96.7	98.1	98.7	97.5	97.7	98.6	98.3	96.4	96.6	98
	Export	99.6	98.7	98.2	99.7	99.7	99.1	98.9	99.8	99.6	98.7	98.3	99.7
	Import	99.5	98.7	98.5	98.4	99.5	99	99	98.9	99.4	98.7	98.5	98.4
	Employment	99.2	97.9	97.6	99.3	99.3	98.5	98.4	99.5	99.1	97.8	97.7	99.3
	CPI	100.3	101.2	101.7	100.4	100.3	101.1	101.6	100.7	100.4	101.5	102.1	100.8
	Gross wage	100.1	100.2	100.2	98	100.1	100.2	100.1	98.7	100.1	100.2	100.2	98.2
VAT closure	GDP	99.6	98.8	98.5	99.3	99.6	99.1	99	99.5	99.5	98.8	98.5	99.3
	Household consumption	99.7	99	98.8	96.7	99.7	99.3	99.2	97.8	99.6	99	98.8	96.8
	Gross investment	98.6	96.6	96.7	98.3	98.7	97.5	97.7	98.8	98.3	96.4	96.6	98.3
	Export	99.6	98.7	98.2	100.5	99.7	99.1	98.9	100.4	99.6	98.7	98.3	100.5
	Import	99.5	98.7	98.5	98.5	99.5	99	99	99	99.4	98.7	98.5	98.6
	Employment	99.2	97.9	97.6	100.1	99.3	98.5	98.4	100.1	99.1	97.8	97.7	100.1
	CPI	100.3	101.2	101.7	101.6	100.3	101.1	101.6	101.5	100.4	101.5	102.1	102
	Gross wage	100.1	100.2	100.2	95.4	100.1	100.2	100.1	96.9	100.1	100.2	100.2	95.5

Appendix B

Model Structure

In order to analyze the impact of oil price changes on the Czech economy, we implement a model with a detailed sectoral structure. Unfortunately, the detailed sectoral structure is used at the cost of simplified dynamics. Thus, our model is not comparable to standard DSGE models since intertemporal optimization by economic agents is not taken into account. On the other hand, DSGE models are typically limited to aggregate relationships. It is apparent that we face a tradeoff between detailed sectoral analysis and advanced dynamics in applied economic modeling. Since the goal of our analysis lies in using detailed sectoral information and input-output tables, we decided to adopt a more detailed CGE framework. Our model is inspired by the Dutch sector model Athena, developed and used by the Netherlands Bureau for Policy Analysis (see Smid (2006)).

We calibrate the model using a Social Accounting Matrix (SAM) based on Czech National Accounts data from 1995 to 2003. This data is used to fix most of the parameters of the model. In Table B.2 we report some of the important parameters that were estimated or calibrated in another way.

The structure of our SAM table corresponds to the structure of the theoretical CGE model. Following the standard approach to SAM construction, we introduce blocks of production, income, institutions, demand, and supply. The production block consists of data on value added, taxes on value added, intermediate consumption, and overall production of 18 types of activities and 18 types of commodities. The income block comprises three types of income: labor, capital, and mixed income. In addition, taxes related to different types of income are introduced. There are four institutions in the SAM/CGE model, i.e., enterprises, households, government, and rest of the world. The block of institutions reflects data on all types of transfers between these institutions, including direct taxes and subsidies. The demand block comprises data on intermediate consumption, public and private final consumption, investment, and change in stock. Since aggregate demand must equal aggregate supply, data on production, commodity taxes, trade and transport margins, exports, and imports are also used.

Since it is not possible to solve the CGE model algebraically, we have to use numerical software to run simulations of oil price shocks. Our software was GAMS, one of the standard packages used for CGE modeling.

There are four economic agents in our model: households, firms, the public sector, and foreign agents.

Firms

Firms can be owned by households, the government, and foreigners. The sector of firms is further decomposed into 18 industries, which produce 18 goods. These are:

Agriculture	Crude Petroleum	Mining products
Food and tobacco	Textile and leather	Wood and paper
Chemical products	Basic metals	Machinery
Cars	Electricity, water, gas	Construction
Trade	Transport	High tech services
Public services	Other services	Financial services

Each of the 18 industries uses labor, capital, infrastructure, and materials in order to produce its products. Labor and capital are hired from households, government or foreigners. On the one hand, we assume a certain level of substitutability between labor and capital. But on the other hand, materials (also called intermediate inputs) are assumed to be used in fixed proportions to production. A difference is made between materials that have to be imported (such as oil) and materials that can be purchased domestically. There are separate input-output matrices for imported and domestic materials. Infrastructure (or government capital) is important for production, but exogenous to the private sector. Capital depreciates and has to be renewed by investment, and the investment level is based on the idea of closing the gap between current and optimal capital, the optimal one being derived from the production function.

The price-setting is cost-based. The costs include a very detailed tax structure (VAT, tariffs, subsidies, consumption taxes) and trade and retail margins.

Households

The household sector consumes, supplies labor, and owns the firms. It pays all kinds of taxes and social insurance and it receives social benefits depending on the unemployment rate. It saves money using a rule of thumb which depends on income and interest rates.

The consumption of different commodities depends on income and on relative prices. In contrast to firms, which have to import some materials, households can easily replace imported consumption by domestic consumption and vice versa.

The labor supply of households is determined by a wage equation. The wage equation includes inflation- indexing (a CPI increase translates to wages), productivity indexing (a productivity increase is translated to wages), and a Phillips curve effect. The bargaining power of employees (and therefore the earned wage) decreases when unemployment increases. This is an important compensating mechanism in the model.

Government

The government redistributes public revenues. On the one hand, the government collects taxes, tariffs, and social contributions. On the other hand, the government purchases commodities and pays out production subsidies, social benefits of all kinds, and interest on public debt. Next, it builds infrastructure, which enters the production functions of firms. The government budget is closed by assuming that it remains nominally constant.

Rest of the World

Both foreign prices and aggregate world demand are exogenous in the model. The demand from the rest of the world depends on the relation between Czech and foreign prices. The substitution elasticity is assumed to be 2 (which is reasonably common in models of other small open economies, such as the Netherlands).

B.1 List of Equations

In Table B.1 we present the list of equations of the CGE model. The list is almost complete, leaving out some very obvious identities. The description of the equations, which is in the right part of the table, should also be sufficient to understand the symbols used in the equations. The most common subscripts and superscript are

c	…	commodity	i	…	industry
t	…	period	s	…	sector
m	…	import	d	…	domestic
ex	…	export	h	…	household
Gov	…	government			

The parameters of the equations are either calibrated from the national accounts data from 2000–2003 or based on literature, expert opinions or simple econometrics. A list of the most important parameters and their values is given in Table B.2.

Table B.1: Equations in the Firm Block

Price-setting equations	
$\mathrm{Costs}_{ti} = \mathrm{CapCosts}_{ti} \cdot \mathrm{Cap}_{ti} + w_{ti}\mathrm{Lab}_{P}ti + \mathrm{PrInter}_{ti}\mathrm{Interm}_{ti}$	The total costs of production in industry i are determined by capital costs, labor costs, and intermediate costs.
$\mathrm{UC}_{ti} = \frac{\mathrm{Costs}_{ti}}{y_{ti}}$	Costs per unit of output
$\mathrm{PrBa}^{d}_{ti} = (1 + \mu^{m}_{i} + \mu^{p}_{i})(1 + \tau_i)\mathrm{UC}_{ti}$	The basic price of production of industry i is determined by putting a markup μ on costs per unit of output. The markup is partly to generate mixed income and partly to generate profit. The basic price also includes some production-related taxes and subsidies.
$\mathrm{PrComVat}^{d}_{tc} = (1 + \text{cons. tax}_{tc} + \text{subsidy}^{d}_{tc} + \text{trade margins}^{d}_{tc} + \text{transport costs}^{d}_{tc})\mathrm{PrBa}^{d}_{tc}$	Consumption priced of domestically produced goods excluding VAT are the basic prices plus other taxes and costs.
$\mathrm{PrCo}^{d}_{tc} = (1 + \mathrm{vat}_{tc})\mathrm{PrComVat}^{d}_{tc}$	Consumption prices of domestically produced goods including VAT
$\mathrm{PrCo}^{\mathrm{ex}}_{tc} = \mathrm{PrComVAT}^{d}_{tc}$	The export prices of firms are assumed to be equal to domestic prices. VAT is not included in exports.

$\mathrm{PrBa}^m_{tc} = (1 + \overline{\Delta \mathrm{PrBa}^m_{t-1,c}})\mathrm{PrBa}^m_{t-1,c}$	The basic import price is assumed to grow exogenously
$\mathrm{PrComVat}^m_{tc} = (1 + \text{tarrifs}_{tc} + \text{subsidy}_{tc} + \text{trade margins}_{tc} + \text{transport costs}_{tc})\mathrm{PrBa}^d_{tc}$	Consumption c.i.f. price of imported goods excluding VAT
$\mathrm{PrCo}^m_{tc} = (1 + \mathrm{VAT}_{tc})\mathrm{PrComVat}^m_{tc}$	Consumption price of imported goods including VAT
$\mathrm{PrImport}_t = \frac{1}{\mathrm{Import}_t} \sum_c \mathrm{PrComVAT}^m_{tc}\mathrm{Import}_{tc}$	Import price index (excluding VAT)
$\mathrm{Pr}^{\mathrm{ex}}_t = \frac{1}{\mathrm{Export}_t} \sum_c \mathrm{PrCo}^{\mathrm{ex}}_{tc}\mathrm{Export}_{tc}$	Export price index
$\mathrm{CPI}_t = \frac{\sum_c \mathrm{PrCo}^d_{tc}\mathrm{Cons}^d_{tc} + \mathrm{PrCo}^m_{tc}\mathrm{Cons}^m_{tc}}{\sum_c \mathrm{Cons}^d_{tc} + \mathrm{Cons}^m_{tc}}$	The CPI is a weighted average of domestic and import prices.
Production equations	
$\mathrm{Export}_t = \sum_c \mathrm{Export}_{tc}$	Definition of total exports as a sum of exports per commodity. In fixed prices.
$\mathrm{Interm}_{tc} = \sum_i \mathrm{Interm}_{tci}$	Total use of good c as an intermediate input is the sum of uses in all industries
$\mathrm{Interm}^d_{tc} = \sum_i \mathrm{Interm}^d_{tci}$	Total use of domestically produced good c as an intermediate input is the sum of uses in all industries
$\mathrm{Interm}^m_{tc} = \sum_i \mathrm{Interm}^m_{tci}$	Total use of imported good c as an intermediate input is the sum of uses in all industries
$\mathrm{Interm}^d_{tci} = \mathrm{iocoef}^d_{ci}\mathrm{Interm}_{ti}$	The intermediate use of domestically produced good c in industry i is determined by the input-output coefficients and total intermediate use by the industry
$\mathrm{Interm}^m_{tci} = \mathrm{iocoef}^m_{ci}\mathrm{Interm}_{ti}$	The intermediate use of imported good c in industry i
$\mathrm{ExpProd}_{ti} = (1 + \varsigma_i)\mathrm{Prod}_{t-1,i}$	The expected growth per industry is exogenous and industry specific
$Y_{ti} = \left(\alpha_{Ki}\mathrm{Cap}_{ti}^{\sigma_i^P} + \alpha_{Li}\mathrm{Lab}_{ti}^{\sigma_i^P} + \alpha_{Gi}\mathrm{Cap}_{ti}^{G\sigma_i^P}\right)^{\frac{1}{\sigma_i^P}}$	The production function of industry i. The production factors are private capital, labor, and public capital (exogenous). The sum of the α's is one. σ_i^P is the factor substitution elasticity. In addition, intermediate goods must be bought in fixed proportions (see other equations).
$\mathrm{ExpProd}_{ti}^{\sigma_i^p} - \alpha_{Gi}\mathrm{Cap}^G_{t-1}{}^{\sigma_i^p} = \left(\alpha_{Ki} + \alpha_{Li}\left[\frac{\alpha_{Li}}{\alpha_{Ki}}\mathrm{LE}_{ti}\frac{\mathrm{CapCosts}_{ti}}{w_{it}}\right]^{\sigma_i^{PR}-1}\right) \cdot \mathrm{Cap}^{*\,\sigma_i^p}_{ti}$	The optimal capital Cap^* is determined by the expected production and the available public capital Cap^G_{t-1}, taking into account the price of capital.
$Y_{tc} = \mathrm{Interm}^d_{tc} + \mathrm{Cons}^d_{tc} + G^d_{tc} + \mathrm{GFCF}^d_{tc} + \mathrm{Export}_{tc}$	The demand for domestic production is a sum of intermediate, household, public, and export demand plus gross fixed capital formation.
$\Delta \log w_{ti} = \Delta \log \mathrm{CPI}_t + 0.25\Delta \log h_{ti} + 0.25\Delta \log h_{t-1,i} + 0.25\Delta \log h_{t-2,i} + 0.25\Delta \log h_{t-3,i} + 0.5\Delta \log \mathrm{TaxWedge}_t + \frac{\lambda_i}{u_t}$	The wage equation of the nominal wage. The nominal wage is fully inflation indexed. Labor productivity h is projected into the wage with a lag. An increase in taxes leads to higher wage demand. Unemployment reduces the bargaining power of employees (Philips curve effect).
$\alpha_{Li}\left(\mathrm{LE}_{ti}\mathrm{Lab}_{ti}\right)^{\sigma_i^p} = y_{ti}^{\sigma_i^p} - \alpha_K\mathrm{Cap}_{t-1,i}^{\sigma_i^p} - \alpha_H\mathrm{Cap}^G_{t-1,i}{}^{\sigma_i^p}$	Labor demand based on the production function and the given amount of capital and government capital. LE_{ti} is the (exogenous) labor efficiency or in other words technological progress.
$\mathrm{Lab}_t = \sum_i \mathrm{Lab}_{ti}$	Aggregate employment is the sum of employments over industries

$\mathrm{NetProfit}_{ti} = \frac{\mathrm{PrBa}^d_{ti} y_{ti}}{(1+\tau_i)} - \mathrm{Costs}_{ti} - \mathrm{Mixed}_{ti}$	Net profit is determined as the value of production in basic prices minus production taxes, costs, and mixed income.
$\mathrm{GDP}_{ti} = y_{ti} - \mathrm{Interm}_{ti}$	Real value added per industry.
$h_{ti} = \frac{\mathrm{GDP}_{ti}}{\mathrm{Lab}_{ti}}$	Labor productivity in industry i
$\mathrm{GDP}_t = \sum_i \mathrm{GDP}_{ti}$	GDP is a sum of value added per industry in fixed prices

Investment, capital, and depreciation

$\mathrm{Depr}_{tsi} = \delta_{is} K_{t-1,s,i}$	The depreciation in all industries is driven by a per industry and sector depreciation coefficient, which is calibrated from the data of the base year
$\mathrm{Depr}^{\mathrm{priv}}_t = \mathrm{Depr}_{t,\mathrm{Firms},i} + \mathrm{Depr}_{t,\mathrm{Households},i}$	Depreciation in the private sector, which consists of the firm and household sectors.
$\mathrm{Dept}_{ti} = \sum_s \mathrm{Depr}_{tsi}$	Depreciation per industry, aggregated over sectors
$\mathrm{Invest}^{\mathrm{Priv}}_{ti} = \epsilon_i \left(\mathrm{CAP}^*_{ti} - \mathrm{CAP}_{ti} - \mathrm{Invest}^{\mathrm{Gov}}_{ti}\right)$	Private net investment per industry. The investment depends on the difference between the optimal capital and the available capital (taking into account the behavior of the government)
$\mathrm{Invest}^{\mathrm{Firms}}_{ti} = \mathrm{Invest}^{\mathrm{Priv}}_{ti}$	All private net investment is assumed to be made by enterprises. Households' capital (very small) therefore remains constant.
$\mathrm{Invest}_{ti} = \mathrm{Invest}^{\mathrm{Priv}}_{ti} + \mathrm{Invest}^{\mathrm{Gov}}_{ti}$	The net investment per industry is a sum of private and government investment
$\mathrm{GrossInv}_{tsi} = \mathrm{Invest}_{tsi} + \mathrm{Depr}_{tsi}$	Gross investment is a sum of net investment and depreciation
$\mathrm{GrossInv}_{ti} = \mathrm{Invest}_{ti} + \mathrm{Depr}_{ti}$	Gross investment is a sum of net investment and depreciation
$\mathrm{GrossInv}_t = \sum_i \mathrm{GrossInv}_{ti}$	The aggregate (gross) investment is the sum of investment in all industries
$\mathrm{PrmVAT}^{\mathrm{Cap}}_{ti} \sum_c \mathrm{InvMatrix}_{ci} \left[\frac{\alpha_c}{\mathrm{PrComVAT}^{\mathrm{d}}_{\mathrm{tc}}} + \frac{1-\alpha_c}{\mathrm{PrComVAT}^m_{tc}}\right] = 1$	The price of capital in sectors that do not pay VAT (enterprises, foreign)
$\mathrm{PrVAT}^{\mathrm{Cap}}_{ti} \sum_c \mathrm{InvMatrix}_{ci} \left[\frac{\alpha_c}{\mathrm{PrCo}^{\mathrm{d}}_{\mathrm{tc}}} + \frac{1-\alpha_c}{\mathrm{PrCo}^m_{tc}}\right] = 1$	The price of capital in sectors that do pay VAT
$\mathrm{CapCosts}_{ti} = \mathrm{Pr}^{\mathrm{Cap}}_{ti} (\delta_i + \mathrm{IR}_t)$	Capital costs are determined by depreciation and interest rates and the price of capital goods.
$\mathrm{Cap}_{ti} = \mathrm{Cap}_{t-1,i} + \mathrm{Invest}_{ti}$	The capital stock is equal to the capital stock in the previous period plus net investment

The household block

$U_H(\mathrm{Cons}_t) = \prod_{c=1}^{C} (\mathrm{Cons}_{tc} - \overline{\mathrm{Cons}}_{tc})^{\mathrm{shC0_c}}$	The utility of households is based on consumption of different types of goods i. The minimum consumption is $\overline{\mathrm{Cons}_i}$. The weight of i in the consumption basket is $\mathrm{shC0}_i$.
$\overline{\mathrm{Cons}}_{tc} = \mathrm{shMinCons}_c \cdot \mathrm{Cons}_{t-1,c}$	The minimum consumption level of good c in a given year is a fixed share of its actual consumption level in the previous year
$\overline{\mathrm{ConsExp}}_t = \sum_c \mathrm{PrCo}_{tc} \overline{\mathrm{Cons}}_{tc}$	The minimum consumption expenditure of households

$\text{NetHHIncome}_t = \text{NetProfit}_t + \text{MixedIncome}_t + \text{WageBill}_t + \text{InterestIncome}_t - \text{SocContrib}_t - \text{IncomeTax}_t + \text{SocBen}_t + \text{OtTrans}_t$	Net household income is the sum of income from shares, being self-employed, wages, interest minus social contributions and taxes, plus social benefits and other transfers
$\text{NetHHLending}_t = \text{shSAV}\left(\text{NetHHIncome}_t - \overline{\text{ConsExp}_t}\right)$	Net savings of households are a fixed share of their net income after minimum consumption
$\text{ConsExp}_t = \text{NetHHIncome}_t - \text{NetHHLending}_t$	Consumption expenditure is the difference between net income and savings.
$\text{Cons}_{tc} = \overline{\text{Cons}}_{tc} + \text{shC0}_c \frac{\text{ConsExp}_t - \overline{\text{ConsExp}_t}}{\text{PrCo}_{tc}}$	The consumption demand for good c is determined by the minimum consumption, the available income after minimum consumption needs, and the price of the good.
$\frac{\text{Cons}^d_{tc}}{\text{Cons}^m_{tc}} = \left(\frac{\alpha^h_c}{1-\alpha^h_c}\right)^{\frac{1}{1+\sigma^h_c}} \cdot \left(\frac{\text{PrCo}^m_{tc}}{\text{PrCo}^d_{tc}}\right)^{\frac{1}{1+\sigma^c_h}}$	The distribution of consumption between domestic and imported goods depends on the ratio of domestic and import prices and the elasticities of consumer demand.
$\text{Cons}_{tc} = \left(\alpha^h_c \text{Cons}^{\sigma^c_h}_{tc,d} + (1-\alpha^h_c)\text{Cons}^{\sigma^c_h}_{tc,m}\right)^{\frac{1}{\sigma^c_h}}$	The total consumption of good c is a CES aggregate of domestic and imported goods
$u_t = \frac{\overline{\text{LS}} - \text{Lab}_t}{\overline{\text{LS}}}$	The unemployment rate is the gap between the exogenous labour supply and endogenous labour demand

Government expenditure

$\text{GovCon}_{tc,d} = (1+\Delta\text{GDP})\text{GovCon}_{t-1,c,d}$	The domestic consumption of the government grows with GDP
$\text{GovCon}_{tc,m} = (1+\Delta\text{GDP})\text{GovCon}_{t-1,c,m}$	Imports for the government grow with GDP
$\text{Invest}^{\text{Gov}}_{ti} = \text{exogenoust}$	Government net investment per industry is assumed to be exogenous
$\text{Subs}_t = -\sum_c \text{subsidy}_{c,d}\text{PrCo}_{tc,d}y_{tc} + \text{subsidy}_{tc,m}\text{PrBa}_{tc,m}\text{Import}_{tc}$	The subsidies on products are determined by the value of production and imports and exogenous commodity-specific subsidy rates, which reflect the situation in the base year
$\text{GovExp}_t = \text{Subs}_t + \text{GovCon}_t + \text{Invest}^{\text{Gov}}_t + \text{OtTrans}^{\text{Gov}}_t + \text{InterestPay}^{\text{Gov}}_t$	The total expenditure of the government
$\text{Cap}^{\text{Gov}}_{it} = (1-\delta^{\text{Gov}}_K)\text{Cap}^{\text{Gov}}_{i,t-1} + \text{Invest}^{\text{Gov}}_{ti}$	The capital of the government (infrastructure) is used in the enterprises' production function.

Government income

$\text{VAT}_t = \sum_c \text{vat}_{tc,d}\text{PrBa}_{tc,d}(\text{GovCon}_{tc,d} + \text{Cons}^d_{tc}) + \text{vat}_{tc,m}\text{PrBa}_{tc,m}(\text{GovCon}_{tc,m} + \text{Cons}^m_{tc})$	The VAT collected. VAT rates are goods-specific, levied only on final consumption of households and the government.
$\text{TAR}_t = \sum_c \text{tarrifs}_{tc}\text{PrBa}_{tc,m}\text{Import}_{tc}$	Collection of tarrifs
$\text{GovInc}_t = \text{NetProfit}^{\text{Gov}}_t + \text{VAT}_t + \text{TAR}_t + \text{IncomeTax}_t + \text{SocContrib}_t$	The composition of government income

Budget balance

$\text{NetLending}^{\text{Gov}}_t = \text{GovInc}_t - \text{GovExp}_t$	The net lending of the government

Export/Import equations

$\text{Export}_{tc} = \varpi_c \text{FD}_{tc}\left(\frac{\text{Pr}^m_{tc}}{\text{Pr}^e_{tc}}\right)^{\sigma^e_c}$	The export demand from abroad is determined by an exogenous trend FD and the ratio of export prices to world prices. σ^e_c is the price elasticity of exports.

$\text{Import}_{tc} = \text{Interm}^m_{tc} + \text{Cons}^m_{tc} + G^m_{tc} + \text{GFCF}^m_{tc}$	The demand for imported goods is a sum of intermediate, household, and public demand plus gross fixed capital formation.
$\text{FD}_{tc} = (1 + \overline{\Delta\text{FD}}_c)\text{FD}_{t-1,c}$	The autonomous foreign demand for Czech goods increases exogenously by $\overline{\Delta\text{FD}}_c$ % a year.
$\text{CA}_t = \sum_c \text{PrCo}^e_{tc}\text{Export}_{tc} - \text{PrBa}^m_{tc}\text{Import}_{tc}$	The current account balance is defined as the difference between the value of exports and the value of imports

Table B.2: The Key Parameters of the Model

Parameter	Description	Typical value
μ_i	The profit margins firms put on top of the unit costs of production	0.08
τ_i	The subsidy/tax on production of industry i	± 0.03
cons.tax^d_{tc}	The consumption tax on good c	0.075 in food 0.090 in chemicals
$\text{trademargins}^d_{tc}$	The wholesale and retail margins on domestically produced goods	0.03–0.1
subsidy^d_{tc}	Subsidies on domestically produced commodities	0.014 on food 0.04 on transport
ς_i	Expected production growth, the technological growth of the economy	3 % p.a.
FD_{tc}	Expected foreign demand growth	3 % p.a.
σ_{ip}	The elasticity of substitution between production factors	0.5
—	The capital:labor:infrastructure ratio in the production function	0.3:0.6:0.1
λ_i	The Phillips curve effect, the impact of unemployment on wages	0.01
δ_i	Depreciation of physical capital	0.06
σ^ϵ_c	The price elasticity of exports	1.7
σ^h_c	The price elasticity of imports for final consumption	2

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Czech National Bank
Economic Research Department
Na Příkopě 28, 115 03 Praha 1
Czech Republic
phone: +420 2 244 12 321
fax: +420 2 244 14 278
http://www.cnb.cz
e-mail: research@cnb.cz
ISSN 1803-7070