

# Elasticities of Gasoline Demand in Switzerland\*

Andrea Baranzini<sup>‡</sup> and Sylvain Weber<sup>§</sup>

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- ‡: Geneva School of Business Administration (HEG Ge), University of Applied Sciences Western Switzerland (HES SO), 7 route de Drize, 1227 Carouge, Switzerland. [andrea.baranzini@hesge.ch](mailto:andrea.baranzini@hesge.ch)
- §: Corresponding author, University of Neuchâtel, Institute of Economic Research, Pierre-à-Mazel 7, 2000 Neuchâtel, Switzerland. [sylvain.weber@unine.ch](mailto:sylvain.weber@unine.ch). This paper was written while Sylvain Weber was at the Department of Economics of the University of Geneva (Switzerland).

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Working Paper

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## ***Abstract***

Using co-integration techniques, we investigate the determinants of gasoline demand in Switzerland over the period 1970-2008. We obtain a very weak price elasticity of -0.09 in the short run and -0.34 in the long run. For fuel demand, i.e. gasoline plus diesel, the corresponding price elasticities are -0.08 and -0.27. The rich dataset allows working with quarterly data and with more explicative variables than usual in this literature. In addition to the traditional price and income variables, we account for variables like vehicles stocks, fuel prices in neighbouring countries, oil shocks and fuel taxes. All of these additional variables are found to be significant determinants of demand.

***Keywords:*** Gasoline demand, Price elasticity, Income elasticity, Cointegration, Error correction model.

***JEL codes:*** C32, Q41, R41.

## 1. Introduction

Measuring the determinants of gasoline demand is essential to understand the evolution of energy consumption in the transport sector and to judge the impacts of economic and environmental policies. In Switzerland, transport is one of the major contributors to CO<sub>2</sub> emissions and the environmental objectives (e.g. in terms of emissions or noise) are particularly difficult to attain. For instance, the Swiss Federal CO<sub>2</sub> Law aims at decreasing emissions of the transport sector by 8 percent with respect to their 1990 level, over the period 2008-2012. This objective is currently not achieved since emissions in 2009 are 12.9 percent larger than in 1990 (FOEN, 2011). Implementing policy instruments, like CO<sub>2</sub> taxes, requires information on the price sensitivity of gasoline demand.

The objective of this paper is to investigate the determinants of gasoline demand in Switzerland, and to assess their impact on consumption. Among others, we focus on the impact of prices and measure the price elasticities of demand in the short and in the long run. Thanks to the rich dataset we built, we are able to use several additional covariates. Contrarily to what is usually done in typical studies on gasoline demand, not only price and income are considered as determinants, but also vehicles stocks, gasoline prices in neighbouring countries, oil shocks, and fuel taxes. All of these additional variables are found to be significant drivers of gasoline demand.

Different approaches to analyse automobile gasoline demand are found in the literature. A first distinction can be made between studies using disaggregate versus aggregate data. The use of micro-level data allows modelling individual and household behaviour more precisely (see for example Eltony, 1993; Hensher et al., 1992; Nicol, 2003; and Rouwendal, 1996). However, given the data available in Switzerland (see below) and like the vast majority of gasoline demand studies, our paper is based on aggregate data. At the aggregate level, models can be distinguished by the type of data: time series, cross-section, or pooled cross-section time series data. Because no data are available at the regional level in Switzerland, our choice is constrained to time series models.

A number of surveys provide summaries of the results on gasoline demand elasticities, such as Blum et al. (1988), Dahl & Sterner (1991), Graham & Glaister (2002), and Lipow (2008). These traditional literature surveys are complemented by meta-analyses. Brons et al. (2008) perform a meta-analysis on a dataset composed by 312 elasticity estimates from 43 primary studies. The estimates of the short run price elasticity of gasoline demand fall between -1.36 and 0.37 and are in general lower in absolute value than the long run estimates, which fall between -2.04 and -0.12. The mean price elasticity of gasoline demand is -0.34 in the short run and -0.84 in the long run. Brons et al. (2008) also identify the characteristics driving different results. They show in particular that USA, Canada and Australia display a lower price elasticity; that price elasticity increases over time; and that time-series studies and models with dynamic specification report lower elasticity estimates (in absolute value). Generally, price elasticities are lower than the corresponding values of income elasticities both in the short and in the long run (see Dahl & Sterner, 1991; Graham & Glaister, 2002).

Some studies on gasoline demand are available for Switzerland. Those using time-series are based on rather old data, while the more recent use alternative methodologies (i.e. surveys) or are limited to some parts of Switzerland. Wasserfallen & Güntensperger (1988) adopt a partial equilibrium model that explains the demand for gasoline and the total stock of motor vehicles simultaneously. Using annual data from 1962 to 1985, they estimate a short run price elasticity between -0.3 and -0.45, and find that demand has become more price sensitive after the first oil shock in 1973. They obtain an income elasticity of 0.7. Using a model merging econometric and engineering approaches, Carlevaro et al. (1992) explain the evolution of energy consumption in Switzerland using annual data from 1960 to 1990. They obtain a very weak short run price elasticity of -0.06. Paying particular attention to the problem of non-stationarity, Schleiniger (1995) uses cointegration techniques to estimate the demand for gasoline over the period 1967-1994.

Surprisingly, he finds that only income per capita has a significant impact, while price changes do not explain any variation in gasoline demand. Using a stated preference approach (survey), Erath and Axhausen (2010) obtain gasoline price elasticity estimates between -0.04 and -0.17 in the short run and -0.34 in the long run. Banfi, Filippini & Hunt (2005) and Banfi et al. (2010) focus on gasoline demand in the Swiss border regions to study the so-called “tank tourism” phenomena. Their results indicate that price elasticity in the Swiss border regions is about -1.5 with respect to Swiss gasoline prices. This value is much stronger than all other estimates, since car drivers can easily refuel in a neighbouring country if they live close to the border and the price is cheaper abroad.

The remainder of the paper is structured as follows. We present the empirical approach in Section 2, and the data in Section 3. Section 4 discusses the results and Section 5 concludes.

## 2. Empirical approach

Our empirical approach is constrained by the data available in Switzerland. Gasoline consumption and prices are collected at the country level only and we cannot observe regional quantities and prices (e.g. for the Cantons). Our study thus uses the econometrics of time-series.<sup>1</sup> Like the vast majority of the literature, we assume a log-linear demand of the form:<sup>2</sup>

$$\ln Q_t = \beta_0 + \beta_1 \ln P_t + \beta_2 \ln Y_t + \beta_3 \ln V_t + z_t, \quad (1)$$

where  $Q_t$  is gasoline consumption per capita in period  $t$ ,  $P_t$  is real gasoline price,  $Y_t$  is real income per capita, and  $V_t$  is the number of vehicles per driver. In addition to gasoline demand, we also estimate a demand for automobile fuel, i.e. the sum of gasoline and diesel consumption, using a similar equation.

Based on the seminal approach of Engle and Granger (1987), equation (1) is interpreted as a long run relationship. If a cointegration relationship is identified, the short run dynamic can then be investigated through an error correction model:

$$\Delta \ln Q_t = \alpha_0 + \alpha_1 \Delta \ln P_t + \alpha_2 \Delta \ln Y_t + \alpha_3 \Delta \ln X_t + \gamma \hat{z}_{t-1} + \varepsilon_t, \quad (2)$$

where  $X_t$  is a matrix of variables having an impact in the short run, but not in the long run, such as an increase in automobile fuel taxes or an oil crisis. The vehicles stock is not included in (2) because it is not supposed to have a short run impact.

Because all variables are in logarithms, the coefficients can be interpreted directly as elasticities. Long run elasticities are given by the  $\beta_i$  parameters in equation (1), while short run elasticities are given by the  $\alpha_i$  parameters in equation (2). The parameter  $\gamma$  can be interpreted as the “adjustment speed” to the long run equilibrium given by (1).

## 3. Data

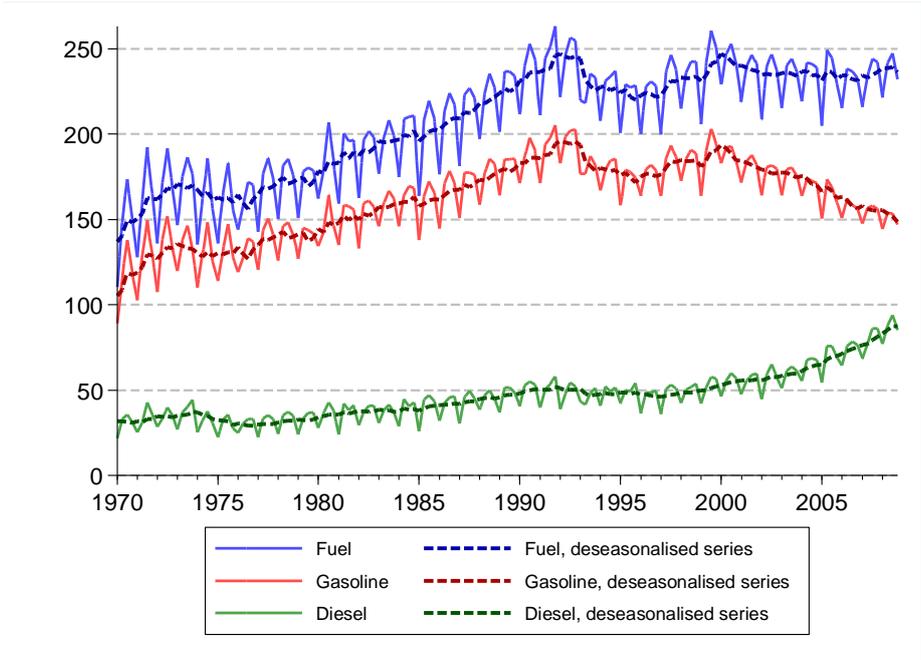
In the literature on gasoline consumption, samples are typically small and they contain annual data. Consequently, gasoline demand studies include a limited number of explicative variables, often merely fuel price and GDP per capita (as a proxy for income). We have been able to collect data at a higher frequency, and found monthly information on quantities of gasoline and diesel and on prices since 1970. Swiss GDP is however available on a quarterly basis only and the vehicles stocks are measured once a year. Hence, we decided to transform all the series in quarterly data by summing the monthly quantities, averaging the prices, and linearly interpolating the vehicles stocks. Our workable dataset spans the period 1970 to 2008, and contains 156 quarterly observations.

<sup>1</sup> For a detailed presentation of cointegration techniques, see for example Maddala & Kim (1998).

<sup>2</sup> Among the studies using cointegration techniques for the estimation of gasoline demand, see for instance: Akinboade et al. (2008), Alves & Bueno (2003), Bentzen (1994), Crôte et al. (2010), Eltony & Al-Mutairi (1995), Polemis (2006), Rao & Rao (2009), Sentenac-Chemin (2012), Samimi (1995), and Schleiniger (1995).

Figure 1 shows the evolution of gasoline, diesel, and fuel consumptions. The original series display substantial seasonal variations, and we deseasonalise the data before the analysis (thick lines in Figure 1).<sup>3</sup> Quantities grew regularly until the beginning of the 1990's. Since 2000, gasoline consumption is however clearly decreasing, while diesel consumption is on the rise. Compared to other European countries (cf. EEA, 2012), the share of diesel in total fuel consumption is still relatively weak in Switzerland, as it only represents about one-third of the total amount of transport fuels.

**Figure 1: Consumption of fuel, gasoline, and diesel, 1970-2008**



Note: Fuel quantities are given by the sum of gasoline and diesel quantities.

Several types of gasoline were delivered in Switzerland over the period 1970-2008.<sup>4</sup> To analyse gasoline consumption over the whole period, we aggregate the different types in a single series, and we define gasoline price ( $P_G$ ) as the following weighted average:

$$P_G = \frac{Q_U \cdot P_U + Q_L \cdot \frac{P_R + P_S}{2}}{Q_U + Q_L} \tag{3}$$

where  $Q_U$  ( $P_U$ ) is the quantity (price) of unleaded gasoline,<sup>5</sup> and  $Q_L$  is the quantity of leaded gasoline, which is either regular gasoline with price  $P_R$  or super gasoline with price  $P_S$ . This price

<sup>3</sup> We used the command ESMOOTH in the software RATS to deseasonalise the series. An alternative strategy to analyse series showing seasonality would be to keep the raw data and introduce seasonal dummies. This does not alter our results significantly (available upon request). Apart the deseasonalisation, all the empirical analyses have been conducted in Stata.

<sup>4</sup> “Regular” leaded gasoline was available in Switzerland until December 1984. Between October 1977 and December 1999, another type of leaded gasoline, called “Super”, was also available. Unleaded gasoline was introduced in January 1985. The standard type of unleaded gasoline has 95 research octane number (RON). Since May 1993, 98 RON is also available as a more expensive option. We do not have separate data series for the quantities of 95 RON and 98 RON, but it is well-known that consumption of 98 RON is much lower.

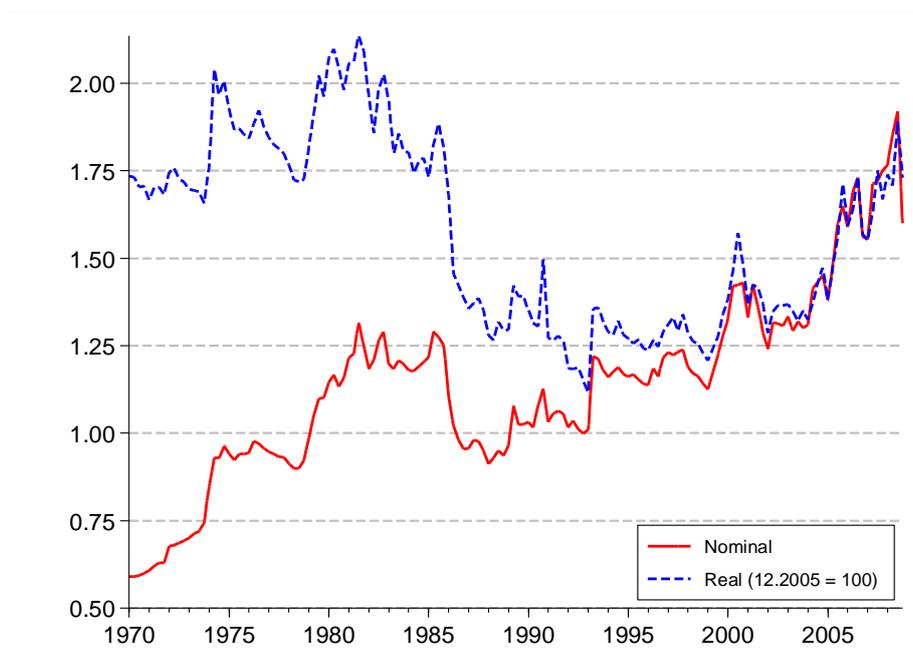
<sup>5</sup> The price of 95 RON alone is taken as the price of unleaded gasoline ( $P_U$ ), since the quantity of 98 RON is negligible. We do not have separate data for regular and super gasoline quantities and we consider the unweighted average of their prices ( $P_R$  and  $P_S$ ) in the gasoline price (3). Over the

is then deflated using the consumer price index (CPI) in December 2005 CHF.<sup>6</sup> Figure 2 displays the evolution of nominal and real gasoline prices since 1970. Over the observation period, the mean real gasoline price was CHF 1.6 per litre, with a maximum at 2.1 (1981Q3) and a minimum at 1.1 (1993Q1). We point out the relatively high prices during the two oil shocks of 1973 and 1980, and the sharp increase since 2005, with a peak in summer 2008. It is to note that the 2008 real prices remained lower than those in 1973 and 1980.

Diesel prices are collected since 1993 only and nothing more than a production price index exists over the whole period 1970-2008. It is thus not possible to estimate a separate demand for diesel alone. Moreover, correlation between real gasoline prices and values of the diesel real price index is almost perfect (0.96), which prevents us from using both prices in the same regression. When estimating a total fuel demand, i.e. the sum of gasoline and diesel, we include gasoline prices only and leave aside all measures of diesel prices.

We also consider gasoline prices in foreign countries. This allows accounting for the “tank tourism” phenomena, which is relatively important in Switzerland (Banfi et al., 2005). We consider prices in the border regions of Germany, Italy, France and Austria. These prices are converted in Swiss francs using the corresponding exchange rates and then deflated using the Swiss CPI.<sup>7</sup> We aggregate border prices in a single variable by taking the average price, weighted by the kilometres of border with the neighbour countries.<sup>8</sup> Gasoline prices in the foreign border regions are generally higher than in Switzerland. Over the observation period, the mean foreign price was CHF 1.9 per litre of gasoline.

**Figure 2: Nominal and real gasoline prices, 1970-2008**



Following the existing literature, we use GDP per capita as a proxy for income. Of course, in the context of a demand function, it would have been preferable to use disposable income, but in Switzerland, this variable is available since 1990 only.

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period when both gasoline types are in the market (1977-1984), the price difference is very small and amounts to 2 cents in average.

<sup>6</sup> In December 2005, CHF1 = US\$0.77 = €0.65.

<sup>7</sup> Before January 2002, the exchange rates of the different national currencies (DEM, ITL, FRF, and ATS) against CHF were used to convert the prices. Since January 2002, all Switzerland's neighbours use the Euro, so that this single exchange rate was used thereafter.

<sup>8</sup> Results are quantitatively similar if we define foreign gasoline price as the simple (non-weighted) average of the prices in the foreign countries (available on request).

In the long run, we expect gasoline and fuel demands to depend on the number of vehicles. We have a measure for the total stock of vehicles (including trucks and motorbikes), and separate measures for the vehicles stocks by fuel type (gasoline, diesel, electric, and others). We divide vehicles stocks by the number of individuals aged 20-76 years old, which seems a legitimate approximation for the number of drivers.<sup>9</sup> The number of vehicles per 1000 drivers was about 722 in average over the period, with a maximal value of 928. The number of gasoline-powered passenger cars per 1000 drivers was on average 553, with a maximum of 653. Pock (2010) shows that using total stock of vehicles in the estimation of gasoline demand leads to an overestimation of the price, income and vehicles stock elasticities. Therefore, we use the stock of gasoline-powered passenger cars per driver in the gasoline demand, while we include the total stock of vehicles per driver in the estimation of fuel demand.

#### 4. Results

We consider two demand equations: one for gasoline and another for total fuel (gasoline and diesel together). For both demands, we use the following long run relationship:

$$\ln Q_t = \beta_{01} + \beta_{02} I_{t\tau} + \beta_1 \ln P_t + \beta_2 \ln Y_t + \beta_3 \ln V_t + \beta_4 \ln PF_t + \beta_5 t + z_t, \quad t = 1, \dots, n. \quad (4)$$

where  $Q_t$  is gasoline (or fuel) consumption per capita in quarter  $t$ ,  $P_t$  is real gasoline price,  $Y_t$  is GDP per capita,  $V_t$  is the stock of gasoline-powered passenger cars (or of motor vehicles) per driver,  $PF_t$  is real gasoline price in the foreign border areas, and  $t$  is a linear trend, normalised from 0 (for  $t = 0$ ) to 1 (for  $t = n$ ), that captures technical progress.

All the variables included in (4) were found to be stationary in first difference on the basis of the tests proposed by Dickey and Fuller (1979), Phillips and Perron (1988), and Kwiatkowski et al. (1992). The stationarity tests are available in Appendix.

$I_{t\tau}$  is included in (4) to account for potential breaks in the long run relationships, following the procedure by Gregory & Hansen (1996a, b).  $I_{t\tau}$  is the dummy variable:

$$I_{t\tau} = \begin{cases} 0, & \text{if } t \leq [n_\tau] \\ 1, & \text{if } t > [n_\tau] \end{cases}$$

where the unknown parameter  $\tau \in (0, 1)$  denotes the timing of the break point (relative to the observation period) and  $[ \cdot ]$  denotes integer part. Our estimations show that there is a level shift (change in the constant) in both fuel and gasoline demands in the last quarter of 1990. We also tested for regime shifts (changes in both the constant and the slopes), but the results are inconclusive.

A regression over the entire period 1970Q1-2008Q4 yields much larger residuals for the first 6 observations (1970Q1-1971Q2) than for later observations. This may indicate a first break point in 1971. Unfortunately, we lack observations prior to 1970 to rigorously test for it.<sup>10</sup> For this

<sup>9</sup> Schmalensee & Stoker (1999) highlight that, in the context of gasoline consumption, it is more relevant to consider the number of car drivers as a determinant instead of total population, because this allows avoiding demographic effects. Notably, using the former heavily reduces estimates of income elasticity. We do not observe the number of drivers directly, and we follow here Pock (2010) by considering individuals in a reasonable age range to approximate the number of car drivers.

<sup>10</sup> Gregory & Hansen (1996a, b) indicate that at least 15% of the observations are required on each side of the break point to permit the computation of all the necessary statistics. In our case, it means we can test for shifts over the period 1975Q5-2002Q4 only. Interestingly, Wasserfallen & Güntensperger (1988), who analyse annual Swiss data over the period 1962-1985, find a break in the price coefficient between 1973 and 1974. However, they contend this may be due to a low variability in gasoline prices before 1973, which makes it difficult to identify the true parameter in the data.

reason, we discard the first 6 observations (1970Q1-1971Q2), and perform our analysis over the reduced period 1971Q3-2008Q4.

Table 1 reports the results of the estimations for the gasoline and fuel cointegration relationships (equation 4). The estimated coefficients correspond to long run elasticities. As expected, the price elasticity of gasoline demand is relatively low in Switzerland (-0.34), even in the long run. The price elasticity of fuel demand is lower in absolute value (-0.27) than those for gasoline. An explanation is that substitution possibilities for gasoline are higher (e.g. switch to diesel) than for total fuel, which already includes diesel. Similar estimates of price elasticities were found for countries like the USA, Canada and Australia (see Section 1). As mentioned by Brons et al. (2008), in those countries and in Switzerland, consumers could be less sensitive to price, because their income is relatively high and fuel prices relatively low. Our estimates are remarkably close to those of other studies about gasoline demand in Switzerland. Although using a completely different methodology based on stated preferences, Erath & Axhausen (2010) find a value of exactly -0.34 for the price elasticity of gasoline demand. Banfi et al. (2010), focusing on “tank tourism”, find that the price elasticity is about -1.5 in the Swiss border regions, but that it falls to -0.3 farther than 30 kilometres away from the border.

**Table 1: Long run cointegration relationships**

	<b>lnQ of Gasoline</b>	<b>lnQ of Fuel</b>
<b>lnP</b>	-0.339 (0.027)	-0.267 (0.022)
<b>lnY</b>	0.673 (0.085)	0.755 (0.071)
<b>lnV</b>	0.803 (0.028)	0.559 (0.027)
<b>lnPF</b>	0.101 (0.032)	0.125 (0.026)
<b>Trend</b>	-0.559 (0.042)	-0.397 (0.038)
<b>I<sub>1990:4</sub></b>	0.066 (0.009)	0.046 (0.008)
<b>Constant</b>	-1.381 (0.279)	-0.064 (0.235)
<b>Adjusted R<sup>2</sup></b>	0.969	0.983
<b>Observations</b>	150	150
<b>Period</b>	1971Q3-2008Q4	1971Q3-2008Q4

Note: standard errors in parenthesis.

Income elasticity is +0.67 for gasoline and +0.76 for fuel. In accordance with the literature, gasoline and fuel are found to be first necessity goods: an increase in income implies an increase in quantity less than proportional. We then obtain that an increase by 1% of the gasoline-powered cars stock per driver increases gasoline consumption by 0.8%, while an increase by 1% of the vehicles stock per driver increases fuel consumption by about 0.6%. The estimated elasticity of gasoline or fuel demand with respect to the prices in the foreign border regions is +0.1. An increase by 1% of real gasoline prices in the foreign border areas thus increases gasoline and fuel consumptions in Switzerland by 0.1%. This elasticity seems relatively weak. However, we emphasize that the impact is measured with respect to gasoline or fuel consumption over the

whole Swiss territory. In fact, our result is perfectly consistent with the price elasticity of 1.2 measured by Banfi et al. (2010) when limited to Swiss border regions.<sup>11</sup>

The trend coefficient is negative in both demands, which can be explained by an increase in gasoline and fuel efficiency use. The trend values are normalised between 0 and 1, so that its coefficient can be interpreted as the percentage variation in consumption between the beginning and the end of the period, all other factors remaining constant. If no factor considered in the demand equations had changed between 1971 and 2008, gasoline consumption would have decreased by 43% and fuel consumption by 33%.<sup>12</sup>

The dummy variable  $I_{1990:4}$  accounts for the structural break observed between 1990Q4 and 1991Q1 in the gasoline and fuel cointegration relationships. It takes the value 0 until the 4<sup>th</sup> quarter 1990 and the value 1 since the 1<sup>st</sup> quarter 1991. The coefficients associated to this variable are positive. Since 1991, demand for gasoline has increased by 6.8% and demand for fuel by 4.7%, all other things being equal. We emphasize that the breaks in cointegration relationships are found by statistical investigation only, and they do not inform on any underlying economic reason. Some caution is moreover needed in the interpretation of the break points, especially when samples are relatively small (see Hassler, 2003; Kim et al. 2004; Tsay & Chung, 2000). It is however not surprising to find a shift at the end of 1990 if we go back to Figure 1, where we observe a clear change in the evolution of gasoline and fuel consumptions.

To investigate the short run dynamics, we estimate the following error correction model:

$$\Delta \ln Q_t = \alpha_0 + \alpha_1 \Delta \ln P_t + \alpha_2 \Delta \ln Y_t + \alpha_3 \Delta \ln PF_t + \alpha_4 \text{Shock1973} + \alpha_5 \text{Shock1979} + \alpha_6 D1985 + \alpha_7 \text{Tax1993} + \alpha_8 D2000 + \sum_{i=1}^m \alpha_{9i} \Delta \ln Q_{t-i} + \gamma \hat{Z}_{t-1} + \varepsilon_t, \quad (5)$$

where  $Q_t$ ,  $P_t$ ,  $Y_t$ , and  $PF_t$  are defined as before. They are taken in first-differences (indicated by  $\Delta$ ) to make them stationary. Shock1973 and Shock1979 are dummy variables accounting for the impact of the first and second oil shocks. Shock1973 takes the value 1 between 1973Q4 and 1974Q3 included, while Shock1979 is 1 between 1978Q4 and 1979Q4 included. Those periods have been chosen by inspection of the gasoline price variations in Switzerland (see Figure 2). The dummy variable D1985 takes the value 1 starting in 1985Q1 and accounts for the introduction of unleaded gasoline in the Swiss market. The dummy variable D2000 takes the value 1 starting in 2000Q1 and accounts for the abolition of leaded gasoline. The dummy variable Tax1993 takes the value 1 for 1993Q2 only. This variable accounts for a possible impact of the mineral oil tax increase of about 25 cents per gross 100 Kg introduced in March 1993.  $\hat{Z}_{t-1}$  represents the error correction term and is estimated by the lagged residuals of the long run cointegration relationship (4). Lags in the endogenous variable ( $\Delta \ln Q_{t-i} = \ln Q_{t-i} - \ln Q_{t-i-1}$ ) are introduced to eliminate autocorrelation. Estimations show that it is necessary to include 5 lags. Relation (5) does not include the vehicles stock, since it can be considered as fixed in the short run.<sup>13</sup>

We tried various short run models, also including additional explicative variables such as meteorological variables (e.g. rain, temperature) or prices indexes for various goods, but they were not statistically significant. Table 2 reports the results for our preferred estimation.

In the short run, price elasticity is estimated at -0.09 for gasoline demand and -0.08 for fuel demand. As expected theoretically, demands are more inelastic in the short than in the long run.

<sup>11</sup> Given that tank tourism accounts for 5% to 10% of overall gasoline consumption in Switzerland over the period 2001-2008 considered by Banfi et al. (2010), a price elasticity of 1.2 in border regions roughly corresponds to price elasticity between 0.06 and 0.12 in the entire country.

<sup>12</sup> Because gasoline and fuel are taken in logarithms, the effect of a change from 0 to 1 in the trend has to be computed as  $\exp(\beta_5) - 1$  (see Halvorsen & Palmquist, 1980).

<sup>13</sup> Moreover, we cannot use vehicles stocks in differences due to data limitations. Vehicles stocks are collected only once a year and we constructed quarterly values by linear interpolation. It would be meaningless to differentiate such a variable, since its growth rate is by definition constant within a year.

Price elasticities are very weak, since an increase of the price by 1% would decrease demand by less than 0.1%, all other things being equal. Such results are comparable to the value of -0.06 obtained in Carlevaro et al. (1992).

GDP per capita has no statistically significant impact in the short run. This was not unexpected, since consumers need time before reacting to income variations. In the short run, habits dictate the consumption path. The results also show that prices in the foreign border regions have a weak impact on short run gasoline demand and do not impact significantly short run fuel consumption. An increase by 1% of the gasoline price in the foreign border regions increases the Swiss gasoline demand by 0.07%. Once again, it is not surprising that this elasticity is lower than in the long run. Carlevaro et al. (1992) also find that cross-price elasticity between gasoline demands in Switzerland and Italy is very low (-0.07).

The 1993 increase of the mineral oil tax decreased gasoline demand by about 3.5% and fuel demand by about 3%. We emphasize that this impact comes in addition to the one from the price increase resulting from the tax. An increase in the mineral oil tax thus has two distinct impacts, both of which decrease demand: first, the price increase itself, then, an additional reaction by consumers, who know that this price increase is not a natural variation resulting from market forces. The fact that consumers' reaction depends on the source of price variation is a consistent finding in the literature. Davis & Kilian (2011) find that tax elasticity is much larger than price elasticity. Ghalwash (2007) also obtains differentiated effects, but his results on different types of goods are somewhat ambiguous. Li et al. (2012) find a much larger effect of tax increase and point to an interesting explanation: because gasoline tax changes are subject to public debates and attract a great deal of attention from the media, this could contribute to reinforce consumers' reaction. Scott (2012) finally finds consumers to be twice as responsive to tax-driven price changes as to market-driven price changes.

The two oil shocks have decreased fuel and gasoline demands: -1.8% in 1973 and -1.0% in 1979. In this case too, the short run impact has to be added to the effects of price variations that occurred during the oil shocks. Oil crisis also receive substantial media coverage. This gives credit to Li et al.'s (2012) argument that factors receiving high media coverage magnify consumers' reaction.

The abolition of leaded gasoline, represented by D2000, had a statistically significant negative impact on gasoline demand, but not on fuel. If fuel demand has not changed while gasoline demand decreased since 2000, this might indicate substitution effects between gasoline and diesel. When leaded gasoline was abolished, a number of drivers who possessed a leaded gasoline-powered car probably switched to a diesel-powered car, instead of buying a new (unleaded) gasoline-powered car.

The coefficients for the error correction terms are -0.27 for gasoline demand and -0.37 for fuel demand. This implies that 27% of disequilibrium in gasoline demand and 37% of disequilibrium in fuel demand is absorbed in one quarter. Therefore, the adjustment speed is relatively high, as more than 80% of deviations from long run equilibrium are absorbed after 1.5 years (gasoline) and 1 year (fuel).<sup>14</sup>

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<sup>14</sup> We check the robustness of the results using annual data. The results (available on request) are consistent with quarterly data.

**Table 2: Short run relationships**

	$\Delta \ln Q$ Gasoline	$\Delta \ln Q$ Fuel
$\Delta \ln P$	-0.092*** (0.028)	-0.082*** (0.025)
$\Delta \ln Y$	0.025 (0.107)	0.103 (0.093)
$\Delta \ln PF$	0.066** (0.033)	0.046 (0.029)
<b>Shock1973</b>	-0.018** (0.007)	-0.018*** (0.006)
<b>Shock1979</b>	-0.010* (0.006)	-0.011* (0.006)
<b>D1985</b>	-0.003 (0.003)	-0.003 (0.002)
<b>Tax1993</b>	-0.035** (0.014)	-0.029** (0.013)
<b>D2000</b>	-0.007** (0.003)	-0.003 (0.002)
$\hat{z}_{t-1}$	-0.271*** (0.058)	-0.374*** (0.060)
<b>Constant</b>	0.005** (0.002)	0.005** (0.002)
$\sum_{i=1}^5 \alpha_{9i} \Delta \ln Q_{t-i}$	.	.
<b>Adjusted R<sup>2</sup></b>	0.311	0.350
<b>Observations</b>	149	149
<b>Period</b>	1971Q4-2008Q4	1971Q4-2008Q4

Notes: standard errors in parenthesis; \*\*\*, \*\*, \*: statistically significant at 1%, 5% and 10%.

## 5. Summary and conclusions

In this paper, we analyse demands for gasoline and for fuel (gasoline and diesel together) in Switzerland. Using quarterly data from 1970 to 2008, we are able to investigate a larger number of explicative variables than most studies of the literature. Using Engle and Granger's (1987) cointegration approach, we establish a short and a long run relationship.

The main results are the following. In Switzerland, demands for gasoline and for fuel are weakly sensitive to price: price elasticities are about -0.3 in the long run. In the short run, demand is very price inelastic: estimates are -0.09 for gasoline and -0.08 for fuel.

The gasoline and fuel demands in Switzerland are sensitive to price variations in foreign countries. In the long run, an increase by 1% of gasoline prices in foreign border regions increases gasoline and fuel demands in Switzerland by about 0.1%. Those results refer to the whole Swiss market, which does not mean that foreign prices do not have a much stronger impact in regions close to borders.

Our results also show that the 1973 and 1979 oil shocks, as well as the 1993 increase of the mineral oil tax, possess an additional impact on gasoline and fuel demands on top of their direct impact due to price increase. For instance, leaving aside the price increase it provoked, the

increase in mineral oil tax per se decreased fuel demand by about 3% and gasoline demand by about 3.5%. In spite of this additional short run impact, our results show that the increase in price should be substantial in order to decrease fuel consumption and CO<sub>2</sub> emissions, which would in turn generate substantial fiscal revenues. In addition, significant distributive impacts might emerge due to diversity of the Swiss territory (urban, rural, mountain regions). This is subject for further research.

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### Appendix

**Table A.1: Stationarity tests**

Variable	ADF			Phillips-Perron			KPSS		
	T	lags	form	Z <sub>p</sub>	lags	form	t-stat	lags	form
lnQg	-1.66	0	c, no t	-2.50	0	c, no t	1.03***	9	no t
ΔlnQg	-12.41***	0	no c, no t	-152.28***	0	no c, no t	0.60**	12	no t
lnQtot	-0.96	0	c, t	-2.73	0	c, t	0.32***	9	t
ΔlnQtot	-13.25***	0	c, no t	-162.10***	0	c, no t	0.27	19	no t
lnP	-1.66	0	c, no t	-5.51	0	c, no t	0.81***	9	no t
ΔlnP	-5.99***	4	no c, no t	-148.82***	4	no c, no t	0.19	9	no t
lnY	-2.84	7	c, t	-16.31	7	c, t	0.09	9	t
ΔlnY	-5.198***	6	c, no t	-141.39***	6	c, no t	0.12	44	no t
lnPF	-2.55	1	c, no t	-8.43	1	c, no t	0.79***	9	no t
ΔlnPF	-7.83***	0	no c, no t	-99.41***	0	no c, no t	0.07	4	no t
lnV(gasoline-powered cars)	-2.44	1	c, t, t <sup>2</sup>	-2.42	1	c, t, t <sup>2</sup>	0.23***	9	t
ΔlnV(gasoline-powered cars)	-4.42***	0	c, t	-34.68***	0	c, t	0.03	3	t
lnV (vehicles)	-2.13	1	c, t, t <sup>2</sup>	-2.08	1	c, t, t <sup>2</sup>	0.35***	9	t
ΔlnV (vehicles)	3.51**	0	c, t	-23.96**	0	c, t	0.12	9	T

- Notes:
- \*\*\*/\*\*/\*denote a t-ratio significant at the 1/5/10% level.
  - For ADF and Phillips-Perron tests, the number of lags (with a maximum of 8) was selected on the basis of the AIC, BIC, and HQIC.
  - c = constant, t = linear trend, t<sup>2</sup> = quadratic trend.
  - Critical values for unit root test with quadratic trend are provided by Ayat & Burrige (2000, Appendix B).

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✉ [crag@hesge.ch](mailto:crag@hesge.ch)

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