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Abstract

This paper investigates the short and long run relationships between energy consumption and real GDP in Switzerland. We apply cointegration and error correction models to data covering a long period, from 1950 to 2009, and distinguish between different energy sources. Our results show that there is a separate long run relationship from real GDP to energy consumption of heating oil, fuel and electricity. Conversely, we do not find any significant relationship from energy consumption towards GDP. Energy abatement policies are therefore not expected to have a negative impact on the growth of the Swiss economy.

Keywords Energy – GDP relationship; energy policy; fractional integration

JEL Classification: Q43, C32, O13

1. Introduction

Potential climate change threats and energy supply security concerns rank high in the priorities of international agendas. Energy is a necessary production factor and is thought to be intimately related with development (e.g. see Goldemberg, 1996). Therefore, policies attempting to curb down energy consumption and production could have a negative impact on development and economic growth. However, if energy costs are relatively low, energy and GDP could be de-linked or the causal relationship could go from GDP to energy (see Ghali & El-Sakka, 2004). In this case, energy abatement policies would not impact negatively economic growth.

Given its political relevance, there are several studies quantifying the relationship between energy and GDP. Chontanawat et al. (2006) summarise the results of 46 studies and show that there is no consensus on the direction of the energy-GDP nexus, if any. This is not surprising, given the variety of countries and periods under analysis, and the different empirical approaches used in the literature. Chontanawat et al. (2008) test for causality between energy and GDP for 30 OECD countries and 78 non-OECD countries. They find that causality from energy to GDP is more prevalent in the OECD countries compared to non-OECD. Other outstanding studies include Bowden & Payne (2009), who compute sector specific causalities for the US; Huang et al. (2008), who introduce the possibility of non-linear relationships; and Lee et al. (2008), who control for differences in capital stocks. Focusing on nuclear energy consumption and using a panel cointegration test for sixteen countries, Apergis & Payne (2010) find that there exists a bidirectional relationship with GDP in the short run, but a unidirectional causality running from nuclear energy consumption to economic growth in the long run. When looking separately at each country's relationship (see Wolde-Rufael & Menyah, 2010), it however becomes clear that even among high income countries, no general conclusion can be drawn on this issue, as each country displays different relationships.

In this paper, we investigate the relationship between energy consumption and GDP in Switzerland. This country is of interest because of the peculiarities of its economy, energy supply, and geographical characteristics. Moreover energy policy is at a crossroads and decisions on future energy supply and conservations programs are expected to be taken in the near future.

Switzerland is one of the richest countries in the world and two-thirds of its workers are employed in the service sector. Since the energy-intensity in the service sector is relatively low, one would expect Switzerland to be less energy dependant than other countries possessing larger manufacturing and agricultural sectors. Electricity supply is based on nuclear (about 40%) and hydropower (about 60%), and thus the greenhouse gas emissions from electricity generation are remarkably small. However the country has to decide which kind of large power plants need to be built, and whether nuclear and/or thermal plants are chosen, it will of course determine emission perspectives. Serious efforts in energy efficiency improvement are needed in any case. Currently, about one third of greenhouse gas emissions come from the transport sector, 20 percent each from households and the industry sector, 10 percent each from the agriculture, and the service sectors, and 5 percent from wastes. Concerning transport activities, Switzerland is also a special case, with a well- developed public transport system offering a very high quality service. It should however be noted that large parts of the country are mountainous regions, where there is no real alternative to private cars.

Although we are not aware of specific studies on the relationship between real GDP and energy consumption in Switzerland, Swiss data are available in some international databases and in several multi-country papers, results for Switzerland are reported separately. An overview of these results is given in Table 1.

Table 1: Results for the energy-GDP nexus in Switzerland, from multi-country studies

Studies	Data	Results
Total energy consumption (EC) – Real GDP		
Chontanawat et al. (2006)	1960-2000 (per capita)	Cointegrating equation, bidirectional causality
Lee (2006)	1960-2001	Unidirectional causality from EC to GDP
Huang et al. (2008)	1960-2002	Positive significant relationship from EC to GDP
Acaravci & Ozturk (2010)	1960-2005 (per capita)	Unidirectional causality from EC to GDP (and bidirectional short run causality)
Nerayan et al (2010)	1980-2006	Positive bidirectional causal relationship
Electricity (ELC) or nuclear energy consumption (NEC) – Real GDP		
Narayan & Prasad (2008)	1960-2002, ELC	Cointegrating equation, but no causality
Yoo & Ku (2009)	1969-2005, NEC	Not cointegrated but bidirectional causality
Wolde-Rufael & Menya (2010)	1971-2005, NEC	Negative unidirectional causality from NEC to GDP

Notes: EC: energy consumption, ELC: electricity consumption, NEC: nuclear energy consumption, GDP: real GDP

The five papers in the top panel of Table 1 find that total energy consumption has a significant effect on GDP. However, the first and the last study find a bidirectional causality between energy and GDP, while the other studies show causality from energy to GDP only. Focusing on electricity consumption, Narayan & Prasad (2008) find a cointegrating vector and hence a long run relationship between electricity consumption and GDP. They could however not identify any causal relationship. Focusing on nuclear energy production, Yoo & Ku (2009) find a bidirectional causality, while with a very similar dataset but using a modified version of Granger causality tests and introducing physical capital and labour as additional variables, Wolde-Rufael & Menya (2010) surprisingly find a negative effect of nuclear energy consumption on real GDP. They argue that this negative effect might be due to production shifting towards less energy intensive sectors or to excessive nuclear energy consumption in unproductive sectors. This finding suggests that energy conservation policies would mitigate the negative effect of nuclear energy on economic growth.

It is somehow surprising to observe such different results for the same country. Contrary to previous studies, the present paper investigates the energy – GDP relationship in more details, by focusing on Switzerland only. The novel features are the use of a very long time period including most recent data (1950-2009), that we allow for fractional integration and that we are investigating different energy sources separately. The structure of the paper is the following. Section 2 presents the empirical approach and the data. Section 3 discusses the results, while Section 4 concludes.

2. Data and empirical approach

We use annual data from 1950 to 2009. Table A1 in Appendix shows descriptive statistics of the variables. Figure 1 displays the evolution of Swiss real GDP per capita in Swiss Francs (CHF)[3] and per capita total energy consumption. We use per capita values in order to abstract from changes in the population size. Total energy grew relatively fast from 1950 until the first oil shock, then less rapidly until 1990, and it eventually stabilised in the last couple of decades.

In Figure 2, total energy consumption is further decomposed into different energy sources. This Figure shows in particular that the evolution of total energy consumption since 1970 is mostly driven by the steady and regular decrease in heating oil consumption, in combination with the steady increase in fuel and electricity.

Figure 1: Evolution of GDP and energy consumption, 1950-2009

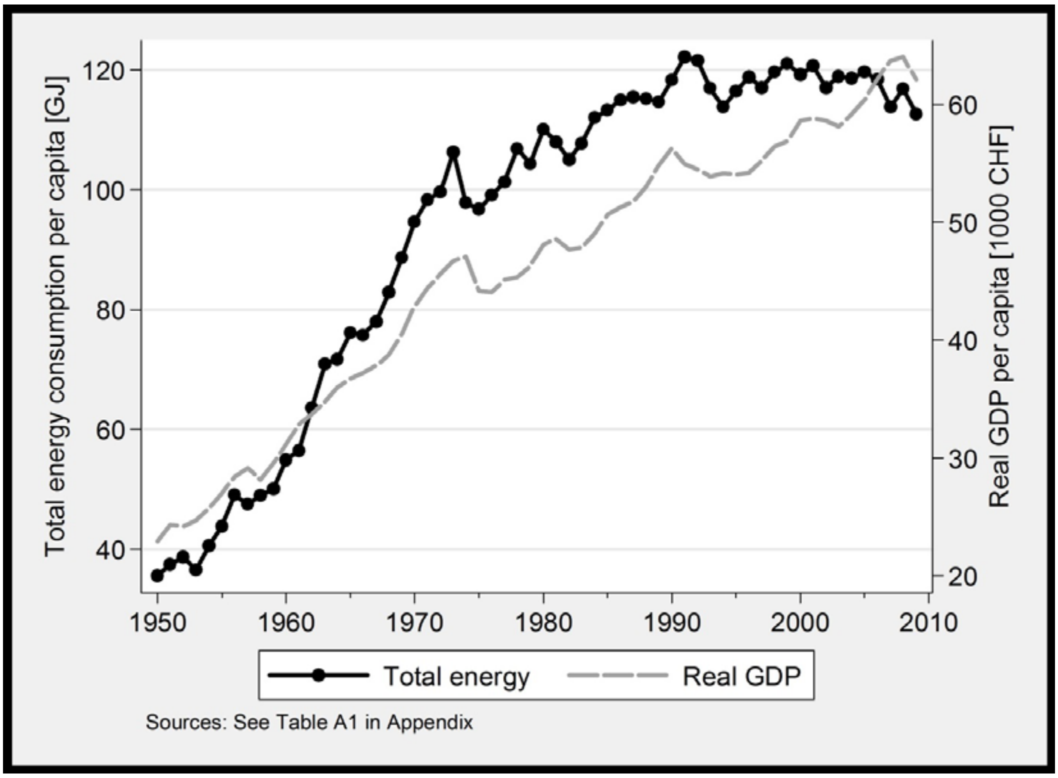
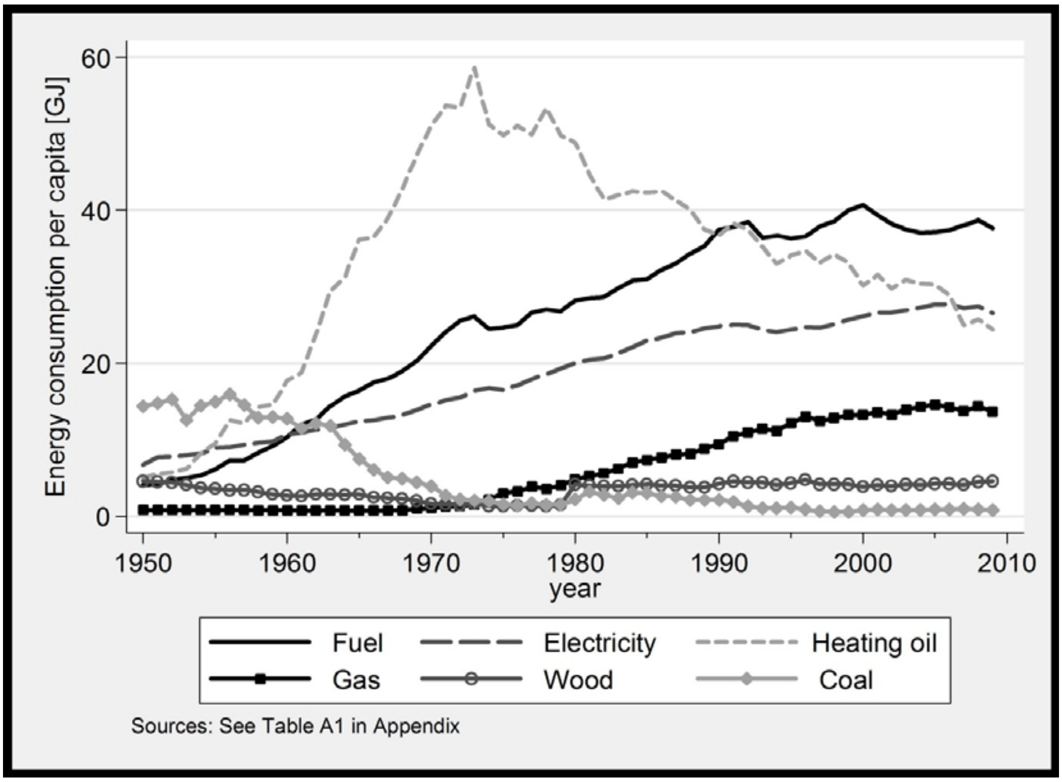


Figure 2: Evolution of energy consumption by energy source, 1950-2009



Stern (2000) points out that substitution from lower (e.g. coal) to higher quality energy sources (e.g. electricity) may take place during the growth process. Such substitution is important for countries like Korea (see Oh & Lee, 2004) but not for Switzerland, given the rather limited substitution possibilities. Indeed, in Switzerland, heating oil is used for heating and fuel for transport, while electricity is mostly used for the remaining activities. The only substitution takes place in the heating of houses from heating oil towards electricity. Since our analysis is not only performed on the aggregate (Joules) measure of energy use, but also individually for the most important energy sources, those substitution phenomena, if any, will show up in the separate analyses.

The above mentioned papers using Swiss data apply error correction models as proposed by Engle & Granger (1987) or a modified version of it (for example Wolde-Rufael & Menya, 2010). To apply these estimating techniques, all series should be integrated of order I(1). Hence, the existing studies fail to consider that energy consumption might be a fractionally integrated process, in the sense that it might have long memory. Lean & Smith (2009), Akinboade et al. (2008), Amusa et al. (2009), Elder & Serletis (2008) and Wolde-Rufael (2010) apply a more general setting in the energy context and prove its relevance. Using an unrestricted error correction model (UECM) to test cointegration between two series has the following advantages. First, the bounds test procedure proposed by Pesaran et al. (2001) and Narayan (2005) is applicable whether the variables are integrated of order I(0) or I(1). Second, the approach is not sensitive to the size of the sample and can therefore be applied to datasets having a small number of observations. Third, it can be used even if some regressors are endogenous. The proposed approach provides unbiased long run estimates and valid t-statistics. It does however not allow for I(2) variables, and series must therefore be tested for unit roots.

The estimated UECM is given by:

$$\Delta y_t = \alpha + \sum_{i=1}^{m} \beta_i \Delta y_{t-i} + \sum_{i=0}^{n} \lambda_j \Delta x_{t-i} + \phi y_{t-1} + \delta x_{t-1} + \eta_t \qquad (1)$$

Where Δ is the first-difference operator; *t* is the time index; *m* and *n* indicate the number of lags; *y* stands for the dependent variable of the model (i.e. ln(GDP per capita) or ln(energy consumption per capita)), *x* for the independent variables; *α, β, λ, φ* and *δ* are parameters to be estimated; and *η* is the error term. To test for the existence of a cointegration relationship, the F-statistic from the test of H_0: $\varphi = \delta = 0$ (against H1: $\varphi \neq 0$ *or* $\delta \neq 0$) is compared with the bottom and top critical values computed by Pesaran et al. (2001) and Narayan (2005). If the F-statistic is lower than the bottom critical value from the table, then there is no cointegrating relationship between the series. If the F-statistic is between the bottom and the top critical value, no conclusion can be drawn. If the F-statistic is larger than the top critical value, then there is a cointegrating relationship between the series.

If a cointegrating relationship is obtained, then an autoregressive distributed lag model (ARDL) can be used to establish short and long run elasticities. The long run model is given by the following equation in levels:

$$y_t = \theta + \sum_{i=1}^{p} \sigma_i y_{t-i} + \sum_{i=0}^{q} \kappa_i x_{t-i} + \varepsilon_t \qquad (2)$$

Where *p* and *q* are the number of lags, θ, σ and *κ* are parameters to be estimated and ε is the error term. To obtain the long run elasticity, we use the delta method (see Greene 2003). Concretely, we let $y = y_t = y_{t-i}$ and $x = x_t = x_{t-i}$ and are thus able to compute the long run elasticity using the transformed equation.[4]

Using the lagged residuals $\hat{\varepsilon}_{t-1}$ from the long run relationship, the short run relationship is then given by:

$$\Delta y_t = \mu + \sum_{i=1}^{r} \pi_i \Delta y_{t-i} + \sum_{i=0}^{s} \omega_i \Delta x_{t-i} + \tau \hat{\varepsilon}_{t-1} + \upsilon_t \qquad (3)$$

Where τ measures the speed of adjustment. When the model is shocked, convergence towards equilibrium takes place at a rate of τ % per year.

Following the literature, we use the Augmented Dickey-Fuller (ADF) and the Phillips-Perron test to identify the order of integration of the time series. The number of lags included is determined using the usual information criteria: Akaike (AIC), Schwarz Bayesian (SBIC) and Hannan Quinn (HQIC), which confirm the same number of lags to be included for the integration test of each series. In Table 2, we report this set of results. It can be observed that the ADF and the Phillips-Perron tests cannot reject the null of a unit root for the series in levels but can reject it for the series in first differences. The only exception is heating oil, where the ADF rejects the H_0 of a unit root also for the variable in levels. KPSS tests are used to check for stationarity under the null hypothesis (H_0). Evidence thus implies that stationarity can be rejected for all variables in levels. In first differences stationarity cannot be rejected except for heating oil and very weakly for fuel. Hence the series seem to be generally stationary in first differences with a minor doubt for heating fuel. Table A2 in Appendix reports tests for long memory and fractional integration. The H_0 of no long range dependence (i.e. series have no long memory) is rejected for all variables in levels. This is a strong argument to proceed with the bounds test proposed by Pesaran et al. (2001) and Narayan (2005).

Table 2: Stationarity tests
(all variables in logs and per capita)

	Lags[A]	ADF		Phillips-Perron		KPSS	
		Levels	Diff	Levels	Diff	Levels	Diff
Real GDP	AIC: 3 SBIC: 3 HQIC: 3	-2.01	-3.12***	-1.74	-5.10***	B: 0.26*** Q: 0.52***	B: 0.05 Q: 0.05
Total Energy	AIC: 1 SBIC: 1 HQIC: 1	-0.90	-3.93***	-0.90	-6.41***	B: 0.27*** Q: 0.55***	B: 0.79 Q: 0.06
Heating oil	AIC: 3 SBIC: 3 HQIC: 3	-4.31***	-2.34**	-2.51	-5.39***	B: 0.26*** Q: 0.53***	B: 0.16** Q: 0.20**
Fuel	AIC: 1 SBIC: 1 HQIC: 1	-2.45	-2.52***	-1.73	-3.86***	B: 0.26*** Q: 0.53***	B: 0.11 Q: 0.12*
Electricity	AIC: 1 SBIC: 1 HQIC: 1	0.87	-3.40***	-0.51	-7.00***	B: 0.28*** Q: 0.57***	B: 0.08 Q: 0.05

Notes:

[A] Results with Lütkepohl statistics (excluding the constant term from the likelihood) give the same results.
AIC: Akaike's Information Criterion ; SBIC: Schwarz's Bayesian Information Criterion ; HQIC: Hannan Quinn Information Criterion
ADF: Augmented Dickey-Fuller Test with trend on levels, and with drift and constant in first differences. H_0: unit root, 5% critical values: in levels: -3.496, in first differences: -1.677
Phillips-Perron Test with trend in levels, H_0: unit root, 5% critical values in levels: -3.49, in first differences: -2.92.
KPSS-test: H_0: stationarity, 5% critical value: 0.146, autocovariances weighted by Bartlett kernel (B) and quadratic spectral kernel (Q).

3. Results and discussion

Table 3 reports the results for the UECM estimations and the corresponding bounds tests. The selection of the lag length is based on the AIC. Results show that the H_0 of no long run relationship can be rejected for heating oil, fuel and electricity as functions of real GDP. More precisely, results show that GDP is a significant driver of each one of the three main energy sources in the long run. On the contrary, the H_0 cannot be rejected for total energy, which means that there is no long run causality running from GDP to total energy.

We highlight that none of the models tested with GDP as a function of energy consumption depicts a statistically significant relationship. However, the causality is unidirectional from economic growth to the consumption of the three main sources of energy. In other words, economic growth induces more demand for energy, but the consumption of energy does not stimulate economic growth.

These results have important policy implications: they indicate that reducing energy consumption would have little or no adverse effect on economic growth. In the current context where climate policies aim at reducing greenhouse gas emissions, our finding is of utmost importance. Based on this analysis, policies aiming at cutting energy consumption can be implemented in Switzerland without fear of harmful effects on long run economic growth.

Table 3: UECM estimations

	F-stat on long run relationship	Adjusted R-squared	Ramsey-Reset test: F-stat (p-value)
Total energy=f(GDP)	4.55	0.29	0.71 (0.55)
Heating oil =f(GDP)	11.42***	0.52	1.41 (0.25)
Fuel=f(GDP)	14.33***	0.58	0.3 (0.83)
Electricity=f(GDP)	8.85***	0.48	1.33 (0.27)
GDP=f(Total energy)	3.95	0.31	0.62 (0.61)
GDP=f(Fuel, heating oil, electricity)	1.39	0.54	4.33 (0.01)
GDP=f(Fuel)	1.11	0.39	0.17 (0.91)
GDP=f(Heating oil)	0.70	0.38	0.78 (0.51)
GDP=f(Electricity)	3.10	0.41	1.12 (0.35)

Notes: Critical values for I(0) and I(1) with intercept and no trend from Narayan (2005) for 60 observations at 1%: 1 regressor: 7.400/8.510 and for 3 regressors: 4.748/6.188, */**/*** : significant at 10/5/1%.

For the three equations where a long run relationship is established, we investigate in more detail the long run and the short run effects using the ARDL framework proposed above. The lag length is determined using the AIC and the specification tests. Table 4 reports the results for the long run relationship.

The ARDL model confirms the results we obtain with the UECM concerning the long run relationship between electricity consumption and GDP. We obtain a significant long run elasticity of 0.9, indicating that each time real GDP increases by 1%, electricity consumption increases by 0.9%. An elasticity lower than unity could indicate that electricity consumption is getting more efficient when there is economic growth.

The results in Table 4 however cast some doubts about the relationship between fuel and GDP or between heating oil and GDP identified with the UECM. Current real GDP is a statistically significant determinant of fuel and heating oil consumption, but the long run elasticities are insignificant and even negative. The point estimates of the long run elasticities thus tend to show that economic growth would have a negative effect on the consumption of fuel and heating oil. This might indicate a possible substitution from non-renewable towards renewable energy sources (e.g. solar), electricity or a shift towards increased energy efficiency in the growth process, which would somewhat be similar to the substitution from lower to higher quality energy sources identified by Stern (2000). Assessing this potential substitution is however beyond the scope of this paper, also because more detailed data are not available over the whole sample period.

Table 4: ARDL long run estimations

	energy(-1)	energy(-2)	energy(-3)	GDP	GDP(-1)	GDP(-2)	LR elasticity[A]
Fuel=f(GDP)	0.977***			0.553**	-0.345	-0.263	-2.359
	(0.036)			(0.210)	(0.317)	(0.204)	(7.250)
Heating oil =f(GDP)	0.840***	0.362**	-0.240*	-0.170***			-4.474
	(0.123)	(0.164)	(0.121)	(0.063)			(1.44)
Electricity= f(GDP)	0.890***	0.060		0.448***	-0.403***		0.898**
	(0.109)	(0.102)		(0.107)	(0.364)		(0.424)

Notes: standard errors in parenthesis, [A] standard errors estimated with delta method.

Table 5 reports the estimations for the short run relationships. Real GDP is found to increase fuel and electricity consumption significantly, while its effect is also positive but statistically insignificant for heating oil consumption. In all three cases, the coefficients on the lagged residuals have the expected negative sign and are highly significant. If there is a shock in the long run relationship, 35% (fuel), 52% (electricity) and 90% (heating oil) of the disequilibrium will be filled in during the first year.

Table 5: ARDL short run estimations

	Δenergy(-1)	Δenergy(-2)	ΔGDP	EC(-1)	Tests	Adj R^2
ΔHeating oil =f(ΔGDP)	0.577***	0.345***	0.479	-0.897***	BP: 4.82 (0.03)	0.51
	(0.159)	(0.108)	(0.453)	(0.204)	Reset: 1.22 (0.31)	
					ARCH: 0.04 (0.85)	
ΔFuel=f(ΔGDP)	-	-	1.146***	-0.354**	BP: 2.37 (0.12)	0.48
			(0.227)	(0.166)	Reset: 1.32 (0.28)	
					ARCH: 0.07 (0.80)	
ΔElectricity= f(ΔGDP)	0.447**		0.424***	-0.524**	BP: 0.71 (0.40)	0.38
	(0.182)		(0.113)	(0.220)	Reset: 2.09 (0.11)	
					ARCH: 1.70 (0.19)	

Notes: Standard errors in parenthesis; BP: Breusch-Pagan/Cook-Weisberg test for heteroskedasticity, H_o: constant variance, reported values: chi-square (p-value); Reset: Ramsey Reset test, H_o: no omitted variables, reported values: F-statistic (p-value); ARCH: LM test for ARCH, H_o: no ARCH effects, reported values: chi-square (p-value). To test for parameter stability, the cumulative sum of recursive residuals (cusum) and the cusum of squares (cusumsq) tests were applied. Results are available upon request. The stability tests are passed except for the case of fuel, cusumsq stability is borderline. For this regression, a dummy takes into account the introduction of unleaded fuel since 1985.

4. Conclusions

This paper investigates the relationship between energy consumption and real GDP per capita in Switzerland over the period 1950-2009. We find that there exist a separate long run relationship between GDP and fuel, heating oil and electricity. Causality is unidirectional and runs from GDP towards consumption of energy only. We do not find any long run relationship from energy consumption to GDP. This indicates that energy consumption does not have any statistical impact on GDP. From our analysis, we can thus deduce that there is no risk that energy abatement policies would impede economic growth. In the current context where CO_2 regulation is being largely discussed and where nuclear is getting bitterly debated, these findings appear as encouraging.

Following economic growth, electricity consumption increases due to an increasing demand, but the long run elasticity is relatively weak (0.9). Therefore, electricity efficiency seems to weakly increase in the growth process. On the other hand, GDP variations seem to leave fuel and heating oil unaffected. If any, the measured long run elasticities for fuel and heating oil with respect to GDP appear to be negative, which would indicate a reduction in those energies consumption in the growth process. This might be explained by a substitution from these non-renewable energy sources towards cleaner energy sources (e.g. solar, electricity), and increased energy efficiency.

Because this paper focuses on energy use and GDP, it leaves aside any other potentially important variable such as prices (see Baranzini et al. 2009). Further research should investigate how the relationship is affected when other relevant variables are introduced. Moreover it might be of interest to further decompose the large energy use aggregates and obtain additional insights from different energy user groups. In particular, disaggregating the electricity energy source into its components (60% hydropower and 40% nuclear in Switzerland) appears an important exercise. One could indeed imagine that hydropower and nuclear energy have different effects on economic growth, which cannot be investigated at the aggregate level.

References

Acaravci A. & I. Ozturk (2010), "On the relationship between energy consumption, CO2 emissions and economic growth in Europe", Energy, 35(12): 5412-5420.

Akinboade O.A., Ziramba E. & W.L. Kumo (2008), "The demand for gasoline in South Africa: an empirical analysis using co-integration techniques", *Energy Economics*, 30(6): 3222-3229.

Amusa H., Amusa K. & R. Mabugu (2009), "Aggregate demand for electricity in South Africa: an analysis using the bounds testing approach to cointegration", *Energy Policy*, 37(10): 4167-4175.

Apergis A. & J.E. Payne (2010), "A panel study of nuclear energy consumption and economic growth", *Energy Economics*, 32(3): 545-549.

Baranzini A., Weber S. & D. Neto (2009), "Price elasticity of fuel demand in Switzerland", report for the SFOE, publication 290036.

Bowden N. & J.E. Payne (2009), "The causal relationship between U.S. energy consumption and real output: a disaggregated analysis", *Journal of Policy Modeling*, 31(2): 180-188.

Chontanawat J., L.C. Hunt & R. Pierse (2006), "Causality between Energy Consumption and GDP: Evidence from 30 OECD and 78 Non-OECD Countries", Surrey Energy Economics Discussion Paper.

Chontanawat J., L.C. Hunt & R. Pierse (2008), "Does energy consumption cause economic growth?: Evidence from a systematic study of over 100 countries." *Journal of Policy Modeling*, 30(2): 209-220.

Elder J. & A. Serletis (2008), "Long memory in energy future prices", *Review of Financial Economics*, 17(2): 146-155.

Engle, R.F. & C.W.J. Granger (1987), "Cointegration and error-correction: Representation, estimation, and testing", *Econometrica,* 55(2): 251-276.

Ghali K.H. & M.I.T. El-Sakka (2004), "Energy use and output in Canada: a multivariate cointegration analysis", *Energy Economics*, 26(2): 225-238.

Goldemberg, J. (1996): *Energy, Environment and Development*. London: Earthscan.

Greene, W. H. (2003), Econometric Analysis, 5th ed., pp. 913f.

Huang B.-N., M.J. Hwang & C.W. Yang (2008), "Does more energy consumption bolster economic growth? An application of the non-linear threshold model", *Energy Policy*, 36(2): 755-767.

Lean H.H. & R. Smyth (2009), "Long memory in US disaggregated petroleum consumption: evidence from univariate and multivariate LM tests for fractional integration", *Energy Policy*, 37(8): 3205-3211.

Lee C.-C. (2006), "The causality relationship between energy consumption and GDP in G-11 countries revisited", *Energy Policy*, 34: 1086-1093.

Narayan P. K., Narayan S. & S. Popp (2010), "A note on the long-run elasticities from the energy consumption-GDP relationship", *Applied Energy*, 87(3): 1054-1057.

Narayan P.K. & A. Prasad (2008), "Electricity consumption-real GDP causality nexus: evidence from bootstrapped causality test for 30 OECD countries", *Energy Policy*, 36(2): 910-918.

Narayan P.K. (2005), "The saving and investment nexus for China: evidence from cointegration tests", *Applied Economics*, 37(17): 1979-1990.

Oh W. & K. Lee (2004), "Causal relationship between energy consumption and GDP revisited: the case of Korea 1970-1999", *Energy Economics*, 26(1): 51-59.

Pesaran M.H., Shin Y. & R.J. Smith (2001), “Bounds testing approaches to the analysis of level relationships” *Journal of Applied Econometrics*, 16(3): 289-326.

Stern, D.I. (2000), "A multivariate cointegration analysis of the role of energy in the US macroeconomy", *Energy Economics*, 22(2): 267-283.

Wolde-Rufael Y. & K. Menyah (2010), “Nuclear energy consumption and economic growth in nine developed countries”, *Energy Economics*, 32(3): 550-556.

Wolde-Rufael Y. (2010), “Bounds test approach to cointegration and causality between nuclear energy consumption and economic growth in India”, *Energy Policy*, 38(1): 52-58.

Appendix

Table A1: Variables and data sources, 1950-2009

Description	Source	Unit	Mean	Std. Dev.	Min	Max
Real GDP	SECO	Mio CHF	298’460	108’653	108’176	492’934
Total energy consumption	SFOE	TJ	616’724	237’934	167’700	899’880
Fuel	SFOE	TJ	172’082	91’747	19’070	297’970
Heating oil	SFOE	TJ	216’518	92’924	23’670	371’150
Electricity consumption	SFOE	TJ	123’228	56’951	31’780	211’420
Population	SFSO	Mio	6.344	0.816	4.717	7.786

Note:
For all variables we have 60 observations
SFSO: Swiss Federal Statistical Office
SFOE: Swiss Federal Office of Energy
SECO: State Secretariat of Economic Affairs

Table A2: Tests for long memory and fractional cointegration

Variables	Modified Gewerke/Porter Hudak, d(t(d=0)/z(d=1))	Robinson semi-parametric estimate, d(t(d=0))	Lo’s Modified R/S test H_0: not long range dependent
Levels			
Real GDP	1.62 (13.11***/6.07***)	0.77 (20.40***)	2.99***
Total Energy	1.24 (7.82***/2.34**)	0.81 (16.95***)	4.89***
Heating oil	1.59 (12.09***/5.78***)	0.84 (14.76***)	2.78***
Fuel	1.31 (19.42***/2.99***)	0.82 (25.77***)	3.71***
Electricity	1.09 (8.36***/0.90)	0.76 (21.80***)	4.03***
First Differences			
Real GDP	0.35 (2.56**/-6.36***)	0.25 (2.18**)	1.48
Total Energy	-0.19 (-1.38/-11.60***)	0.02 (0.15)	1.95**
Heating oil	0.01 (0.07/-9.60***)	0.15 (1.19)	1.71
Fuel	0.25 (1.67/-7.28***)	0.33 (2.50**)	1.49
Electricity	0.19 (1.13/-7.87***)	0.11 (0.85)	1.93**

Notes:
Used power: 0.9 (Robinson 1995)
Modified Gewerke/Porter Hudak test proposed by Philips (1999),
Lo’s modified rescaled range test for long range dependence, 95% critical values: 0.809/1.862 (Hurst-Mandelbrot classical R/S test would lead to similar results)

Endnotes:

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[2] The opinions expressed in this article are those of the authors only. Any errors or emissions remain the responsibility of the authors.

[3] As of 12.4.2011 CHF 1 = EUR 0.7699 = USD 1.1146

[4] If (2) is given by: $y_t = \theta + \sigma_1 y_{t-1} + \sigma_2 y_{t-2} + \kappa_0 x_t + \kappa_1 x_{t-1}$, in the long run we get: $y = \theta + (\kappa_0 + \kappa_1)/(1 - \sigma_1 - \sigma_2)x$. The long run elasticity is then given by (with *x* and *y* in logarithms): $(\kappa_0 + \kappa_1)/(1 - \sigma_1 - \sigma_2)$.

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