Inflation and Broadband Revisited: Evidence from an OECD Panel. A replication study of Yi and Choi (*Journal of Policy Modeling*, 2005)

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Data Availability: The raw data used for this replication are available from various web sources, mainly the Worldbank `http://data.worldbank.org`. A detailed description of the variables and the access to data is given in the Appendices A and B of this paper.
To facilitate replication the analysis data set, the Stata do-files and the log-files are available from the website of the journal `www.iree.eu`.

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Abstract
This note revisits the conjecture that the use of broadband internet lowers transaction costs and thereby inflation. Using a macro-economic panel of OECD countries, it replicates and expands previous estimations by Yi and Choi (2005). We confirm the direction of the results, but also highlight a series of conceptual and econometric issues in the original contribution that need to be addressed.

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1 Introduction

The use of telecommunication services has promoted economic growth and productivity (Khalil et al. 2009; Hardy 1980; Röller and Waverman 2001). Especially broadband internet is regarded as a general purpose technology that not only allows firms to explore new markets and distribution channels, but also lowers transaction costs economy-wide (Clarke, Qiang, and Xu 2015; Norton 1992). This affects multiple economic variables, including consumer price inflation. There are several channels through which broadband internet can affect price dynamics. For instance, broadband-based services may dampen price increases through cost savings. This is, markets become more transparent (e.g., due to platforms allowing users to easily compare prices) and therefore more competitive for suppliers (Litan and Rilvin 2001).

It has been argued that a higher internet penetration rate significantly reduces the inflation rate (Yi and Choi 2005). This finding relies on older data, covering a period when internet connection speeds were substantially slower than today, and many of the modern applications did not exist. Re-addressing the question in a contemporary context is important against the background of the current debate about the economic effects of the "digitization". This led to a renewed macroeconomic interest in the relationship between price developments (and other variables) and broadband internet.[1]

This note revisits previous findings by Yi and Choi (2005), which support the conjecture that widely available internet access reduces inflation. However, we argue that these estimates suffer from econometric and conceptual issues, which this note addresses using a sample of OECD countries. We expand the statistical work, and validate these previous results with more elaborate econometric techniques and with the next generation of data transmission technology, broadband internet. We support the notion that higher internet penetration rates reduce inflation. The magnitude of the estimated coefficient is roughly comparable with the results reported by Yi and Choi (2005), even though we find a significantly smaller range of the effect. We thereby contribute to the literature on the economic effects of the use of broadband, and add an instrument to the toolbox of macro-economic policy makers.

2 Previous findings

Yi and Choi (2005) estimated the effect of internet on inflation in a worldwide panel of 207 countries for the period from 1991 to 2007. The estimates explained the consumer price index (CPI) inflation rate as a function of internet penetration rates (the ratio of internet users to total population, in logs) as the main explanatory variable. In addition, the regressions considered the oil price as the percentage change in the West Texas Intermediate, the unemployment rate and the growth rate of the sum of money and quasi-money (M2) as control variables. In a series of regressions, the Yi and Choi (2005) uncovered the expected negative signs of the coefficients, arguing that when the internet penetration rate increases, the inflation drops by 0.04 to 0.13 percentage points.

We replicate the key specifications with the present sample, even though there are issues with the data availability of the money supply indicator (M2). The results of these specifications find coefficients for broadband internet which are substantially lower than those reported by Yi and Choi (2005), ranging between -0.1 and -0.4 compared to -4.3 and -10.1 in the original paper. The effect becomes statistically insignificant in the random effects specifications (to keep the present

[1] A related micro-economic question concerns the adequacy of price measures, since it could be argued that price indices do not adequately capture the effects of online services, because many transactions occur "out of market". This discussion is beyond the scope of this article, however.

contribution concise, the replicated results are provided in the Appendix D). Both the unemployment rate and changes in the oil price are statistically insignificant, supporting the findings of the original article. Yet, it is striking that the coefficients of the growth of quasi-money are much larger in the replication than in the original article, and that the effect of money growth is larger than the effect of the internet penetration indicator. The opposite was found in the original contribution, where internet use was found to have a stronger effect than the growth of quasi-money. This might be due to the use of a different sample. We use OECD countries only, whereas Yi and Choi (2005) rely on a total 207 countries, considering both developed and developing economies. It is therefore likely that there are great differences in the macroeconomic environment across the countries in the original sample. However, fixed effects at the country level have not been controlled for by Yi and Choi (2005).

Hence, it is seems that these previous estimates suffer from both econometric and conceptual shortcomings. First, there are econometric issues with regard to the estimation technique, and the choice to estimate the key variables in levels. Especially internet penetration rates have increased steadily over time, thereby causing non-stationarity and autoregression issues. Also, the chosen estimation techniques were OLS and panel random effects. Specification tests are not reported, however.

Second, the control variables only partly capture inflation dynamics. For instance, money growth is an indicator for monetary policy, but does not capture the policy intention to affect real interest rates. Similarly, the oil price is an important indicator for commodity price developments, but is only a single measure that does not capture price developments of other raw materials. In addition, including unemployment is questionable, since its coefficient is typically found to be statistically insignificant.

3 *Empirical results*

We estimate panel regressions to analyze the effect of broadband on annual inflation rates. We use an unbalanced macro-economic panel of thirty OECD countries for the period 1996–2014 (see Appendix A for the country coverage, Appendix B for the data and variable definition, and Appendix C for descriptive statistics).

The dependent variable is the annual change of the consumer price index (CPI), a measure for the inflation rate. The main explanatory variable is the fixed broadband penetration rate - that is, fixed broadband subscriptions as a share of the total population. Fixed broadband services are part of the basket of consumer goods, but can be regarded as exogenous due to their negligible share in the basket. An unconditional correlation coefficient indicates a negative relationship between the two main variables CPI and fixed broadband penetration (ρ: -0.15, p-value: 0.002).

We control for other price developments affecting the inflation rate, and thus capture both global and country specific dynamics. The control variables reduce a possible bias of the estimates by including time-varying macroeconomic effects derived from the literature. We also add structural aspects in the robustness checks (Aisen and Veiga 2008, 2006). It is possible that inflation rates not only differ from country to country, but that these differences are to a certain extent constant. Hence, the bulk of the specifications of the present contribution control for time-invariant, country-level fixed-effects.

We use the output-gap as a relative measure of demand and supply conditions of the domestic economy. The output-gap is defined as the difference between an economy's actual output and its potential, maximum output. If the output-gap is negative, the economy operates below its capacity;

if it is positive, it outperforms expectations. The output-gap is a particularly useful indicator for monetary policies. It mirrors the real interest rate gap, which is the difference between the observed real interest rate – that is, the nominal short-term interest rate minus expected inflation – and the natural rate of interest. Hence the output-gap provides a measure for monetary policy, and is therefore preferable to other cyclical measures such as GDP growth (Cúrdia 2015; Cúrdia et al. 2015). Since higher inflation rates are associated with poor macro-economic performance, we expect a positive relationship between the output-gap and inflation (Fischer, Sahay, and Végh 2002).

Next, we control for openness to trade by the merchandise trade share in percent of GDP, whose effect might be ambiguous. While countries that are more open to trade may be more exposed to external price shocks which potentially increase inflation rates, they might also be better able to absorb such shocks. The control variables capturing international markets comprise two price indices. We control for the price of commodities by an index provided by the Hamburgisches WeltWirtschaftsInstitut (HWWI). The index is derived from world market prices of various commodities such as crude oil, cotton, coffee or sugar. It therefore covers a variety of raw materials. It allows for an analysis beyond oil prices, which was used in the original article by Yi and Choi (2005). This seems appropriate because oil has lost of its importance in recent years. In addition, the HWWI commodity index has been linked to inflation dynamics (Breitung and Roling 2015). We expect the raw material index to be positively associated with consumer price inflation, because price increases on international markets are typically passed on to the consumers.

A second index controls for the real effective exchange rate. Following the same pass-through logic and the scaling of the index, we expect the exchange rate index to be negatively associated with inflation (Aisen and Veiga 2006; Campa and Goldberg 2005). In addition, we include global developments by time dummies for five periods (1995-1997, 1998-2000, 2001-2003, 2004-2006, 2007-2009, 2010-2012 and 2013-2014). All specifications consider an outlier dummy for the UK in 2007 due to an erratic spike in the broadband series, which is sample specific.

To address possible concerns about non-stationarity, the inflation rate, fixed broadband penetration and the control variables are estimated in first-differences (see Appendix C for illustrations of both key variables). To examine whether there is non stationarity in the presently used data set, we implemented Fisher-type panel unit-root tests, which allow for unbalanced panels. The data used is unbalanced because the broadband penetration ratios are missing in some countries in the earlier years of the sample. The non-stationarity test involves fitting an augmented Dickey-Fuller regression for each panel. The null hypothesis is that all panels contain a unit root, which is rejected by the results (Choi 2001). We therefore support the notion obtained by the graphical illustrations of the key variables (see Appendix C).

We implement four different regression techniques to examine the effect of broadband on inflation. The first two regressions are fixed-effects specifications controlling for unobserved time-invariant, country-specific effects. The first regression leaves out fixed broadband (1) which is added in the second specification (2). This allows examining the effect of broadband on the explanatory power of the model, the within-R^2. The third specification is a random effects estimator (3), which is implemented because a Hausman specification test does not reject random effects (p-value: 0.990). The standard errors of these specifications are bootstrapped with 2,000 repetitions. To determine the minimum number of repetitions, we implement on procedure proposed by Andrews and Buchinsky (2000), which aims at a high level of accuracy of the bootstrapped standard errors. Accuracy is defined as the maximum percentage deviation between the bootstrap statistic and the ideal bootstrap where the number of repetitions converges towards infinity. We allow for a maximum deviation of five percent, and obtain a minimum number of bootstraps of 1,505 (Poi 2004; Andrews and Buchinsky 2000).

The next regressions consider potential disturbances due to a possibly autoregressive lagged dependent variable. A Wooldridge test does not reject the null-hypothesis that there is no first-order autocorrelation in the error term (p-value: 0.130). However, the p-value is close to being statistically significant, which is why specification (4) is a fixed-effects and specification (5) a random-effects model with a first-order autoregressive disturbance term. The Baltagi-Wu locally best invariant test statistic and the Durbin-Watson statistic do not indicate serial correlation in either of these specification (Baltagi and Wu 1999; Wooldridge 2010; Baltagi and Li 1995; Drukker and others 2003).

The regression results indicate a statistically significant, negative effect of fixed broadband penetration on the inflation rate. The estimated elasticity ranges between -0.09 and -0.10. Including the broadband indicator improves the within R^2 of the fixed effects specification by 7.6 percentage points. The control variables largely perform as expected (see Table 1).

Table 1: Estimation results for fixed broadband penetration on inflation (CPI)

	1	2	3	4	5
Estimator	FE	FE	RE	FE (AR1)	RE (AR1)
Broadband, fixed		-0.1048***	-0.0868**	-0.0959**	-0.0871**
		(0.038)	(0.036)	(0.043)	(0.039)
Output gap	0.0442	0.0879	0.0863*	0.0996***	0.0936***
	(0.065)	(0.056)	(0.052)	(0.038)	(0.036)
Trade openness	0.0226	0.0300	0.0254	0.0221	0.0210
	(0.018)	(0.024)	(0.018)	(0.017)	(0.014)
Raw materials	0.0362***	0.0339***	0.0344***	0.0339***	0.0340***
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
FX	-0.0570**	-0.0476*	-0.0476**	-0.0431***	-0.0462***
	(0.027)	(0.028)	(0.023)	(0.016)	(0.014)
Time dummies	-0.6110***	-0.4764***	-0.5003***	-0.4585***	-0.4767***
	(0.103)	(0.092)	(0.092)	(0.151)	(0.134)
Observations	472	387	387	357	387
R^2	0.326	0.402	0.402	0.428	0.401

Note: This table describes the regression results for fixed broadband penetration on the annual change of the consumer price index (in percent) for 30 OECD countries in the period 1996-2014. The results show an inflation reducing effect of fixed broadband usage. All variables are estimated in first differences. Regressions (1), (2) and (4) are fixed-effects estimations (FE), and regressions (3) and (5) are estimated as random-effects (RE). Bootstrapped standard errors with 2000 replications are reported in parentheses are used in specifications (1), (2) and (3); specification (4) and (5) use a first-order autoregressive disturbance term (AR1). All estimations include time effects and an outlier dummy taking on a value of 1 for the UK in 2007, and 0 otherwise (see Appendix C). The raw material index and the FX index use 2005 as the base year. The number of observations varies due to lacking data about broadband penetration ratios in the earlier years and methodological reasons in specification (4). Standard errors in parentheses. *** Statistically significant at 1% significance level,** at 5% significance level, and *** at 10% significance level, respectively.

We perform several robustness checks ensuring the structural validity of the key finding (see Appendix D). Both significance levels and the magnitude of the estimated coefficient for broadband penetration remain qualitatively the same across these specifications:

- Implementing a dynamic panel estimator: A lagged dependent variable estimation with a small-sample bias-control with bootstrapped standard errors (Bun and Kiviet 2003). The results show a statistically insignificant autoregressive term (p-value: 0.355); the one-step Sargan statistic indicates that the overidentifying restrictions used by the underlying Blundell-Bond specification are not satisfied (see also Bruno 2005). Statistical insignificant lagged dependent variables have been reported before in inflation estimates (Aisen and Veiga 2008; Castro and Veiga 2004).
- Using a different set of control variables. Instead of the output-gap, we include other explanatory variables that are also commonly used in inflation estimates. The alternative control variables used are real annual GDP growth, GDP per capita in constant prices (base year 2005), the GDP share of agriculture and the regulatory quality from the World Governance Indicators as a proxy for pro-market regulations. This set of variables mainly controls for characteristics that are more relevant to developing countries, which are, however, hardly represented in the present sample. (Veiga and Aisen 2006).
- Estimating the regression with inflation rates (annual change of CPI in percent) as the dependent variable instead of using their first differences, or estimating the model with a crisis dummy instead of time effects. The crisis dummy takes on the value 1 for years after 2008 and 0 otherwise.
- Dropping outliers, i.e. the top and bottom one-percentile of the CPI indicator, and dropping the observations for the UK due to spike in the broadband indicator.
- The number of observations drops because broadband penetration ratios are missing for some countries in the earlier years of the sample. We asked if the missing information of the key variable leads to a systemic bias. Hence, we replaced all missing values by zeros, and created a dummy variable taking on the value of one if there is a missing, and zero otherwise. We re-run the estimations, and found that the dummy for the missing values to be insignificant. The other results remained qualitatively unchanged.

The present analysis focuses on fixed broadband usage rates. Data for mobile broadband is poorly available, since its deployment began at the end of the period analyzed. Estimates including mobile broadband point towards a negative effect on inflation. However, the coefficient is statistically insignificant and less pronounced than for fixed broadband.

4 Conclusion

This note revisited the inflation reducing effect of internet using broadband penetration rates. We confirm this conjecture in a panel of OECD countries, and address both measurement and econometric issues of previous estimations (Yi and Choi 2005). The results of the original paper suggest that an increase in the internet penetration ratio (internet users to total population) by one percentage point leads to a decrease in consumer price inflation rates by 0.04% and 0.13%. The coefficients obtained by the enhanced estimation methods which this paper proposed range from -0.11 to -0.09, and are directly comparable with the estimates by Yi and Choi (2005). Hence, the estimated coefficients resemble the magnitude of the original findings, but are in a more narrow range.

The findings suggest that the continuing deployment of broadband internet, which is in many countries promoted by infrastructure and economic policies, will reduce consumer price inflation rates. This finding contributes to research on the economic effects of broadband, and also adds to macro-economic policy tools.

5 References

Aisen, Ari, and Francisco José Veiga (2006). Does Political Instability Lead to Higher Inflation? A Panel Data Analysis. *Journal of Money, Credit, and Banking*, 38 (5): 1379-1389.

— (2008). Political Instability and Inflation Volatility. *Public Choice*, 135 (3-4): 207-223.

Andrews, Donald WK, and Moshe Buchinsky (2000). A Three-Step Method for Choosing the Number of Bootstrap Repetitions. *Econometrica*, 68 (1): 23-51.

Baltagi, Badi H., and Qi Li (1995). Testing AR (1) against MA (1) Disturbances in an Error Component Model. *Journal of Econometrics*, 68 (1): 133-51.

Baltagi, Badi H., and Ping X. Wu (1999). Unequally Spaced Panel Data Regressions with AR(1) Disturbances. *Econometric Theory*, 15 (6): 814-823.

Breitung, Jörg, and Christoph Roling (2015). Forecasting Inflation Rates Using Daily Data: A Nonparametric MIDAS Approach. *Journal of Forecasting*, 34 (7): 588-603.

Bruno, Giovanni S.F. (2005). Approximating the Bias of the LSDV Estimator for Dynamic Unbalanced Panel Data Models. *Economics Letters*, 87 (3): 361-66.

Bun, Maurice J. G., and Jan F. Kiviet (2003). On the Diminishing Returns of Higher-Order Terms in Asymptotic Expansions of Bias. *Economics Letters*, 79 (2): 145-52.

Campa, Jose Manuel, and Linda S. Goldberg (2005). Exchange Rate Pass-through into Import Prices. *Review of Economics and Statistics*, 87 (4): 679-690.

Castro, Vítor, and Francisco José Veiga (2004). Political Business Cycles and Inflation Stabilization. *Economics Letters*, 83 (1): 1-6. DOI: 10.1016/j.econlet.2003.07.016.

Choi, In (2001). Unit Root Tests for Panel Data. *Journal of International Money and Finance*, 20 (2): 249-272.

Clarke, George R.G., Christine Zhenwei Qiang, and Lixin Colin Xu (2015). The Internet as a General-Purpose Technology: Firm-Level Evidence from around the World. *Economics Letters*, 135 (October): 24-27. DOI: 10.1016/j.econlet.2015.07.004.

Cúrdia, Vasco (2015). Why so Slow? A Gradual Return for Interest Rates. *FRBSF Economic Letter*, 2015: 32.

Cúrdia, Vasco, Andrea Ferrero, Ging Cee Ng, and Andrea Tambalotti (2015). Has U.S. Monetary Policy Tracked the Efficient Interest Rate? *Journal of Monetary Economics*, 70 (March): 72-83. DOI: 10.1016/j.jmoneco.2014.09.004.

Drukker, David M., and others (2003). Testing for Serial Correlation in Linear Panel-Data Models. *Stata Journal*, 3 (2): 168-177.

Fischer, Stanley, Ratna Sahay, and Carlos A. Végh (2002). Modern Hyper-and High Inflations. *Journal of Economic Literature*, XL (September): 837-80.

Hardy, Andrew P. (1980). The Role of the Telephone in Economic Development. *Telecommunications Policy*, 4 (4): 278-86.

Khalil, Mohsen, Philippe Dongier, Christine Zhen-Wei Qiang, and others (2009). Information and Communications for Development: Extending Reach and Increasing Impact. *World Bank*. handle: 10986/2636.

Litan, Robert E., and Alice M. Rilvin (2001). Projecting the Economic Impact of the Internet. *American Economic Review*, 91, 313-317.

Norton, Seth (1992). Transaction Costs, Telecommunications, and the Microeconomics of Macroeconomic Growth. *Economic Development and Cultural Change*, 41 (1): 175-96.

Poi, Brian P. (2004). From the Help Desk: Some Bootstrapping Techniques. *Stata Journal*, 4: 312-328.

Röller, Lars-Hendrik, and Leonard Waverman (2001). Telecommunications Infrastructure and Economic Development: A Simultaneous Approach. *American Economic Review*, 91 (4): 909-923.

Veiga, Francisco José, and Ari Aisen (2006). Political Instability and Inflation Volatility. *International Monetary Fund*, Working Paper WP/06/212.

Wooldridge, Jeffrey M. (2010). Econometric Analysis of Cross Section and Panel Data. *MIT press*.

Yi, Myung Hoon, and Changkyu Choi (2005). The Effect of the Internet on Inflation: Panel Data Evidence. *Journal of Policy Modeling*, 27 (7): 885-89. DOI: 10.1016/j.jpolmod.2005.06.008.

6 Appendix A - Country Coverage

The total sample covers 389 observations from 30 OECD member countries. Due to lacking information about broadband coverage, data points are often missing in the initial years. Korea, Slovenia and Turkey are not considered in the analysis due to lacking information about output-gaps. Observations for Chile were also dropped, because the available time series covers only three years.

Table A1: Country Coverage

Country	Observations
Australia	10
Austria	14
Belgium	15
Canada	15
Czech Republic	13
Denmark	13
Estonia	12
Finland	13
France	15
Germany	13
Greece	10
Hungary	13
Iceland	14
Ireland	11
Israel	12
Italy	13
Japan	15
Luxembourg	12
Mexico	13
Netherlands	13
New Zealand	13
Norway	13
Poland	12
Portugal	14
Slovak Republic	11
Spain	13
Sweden	13
Switzerland	13
United Kingdom	13
United States	15

7 Appendix B – Data Description and Variable Definition

Table B1: Variable description

Variable	Description	Source	
Inflation	Inflation, consumer prices (annual %).	World Development Indicators, World Bank	data.worldbank.org/indicator/FP.CPI.TOTL.ZG
Fixed bb	Fixed-broadband subscriptions as a per cent of total population.	World Telecommunication/ICT Indicators Database 2015, ITU	www.itu.int/pub/D-IND-WTID.OL-2015
Output gap	Output gap. Deviations of actual GDP from potential GDP as a per cent of potential GDP.	OECD Economic Outlook 91 database, OECD	stats.oecd.org/index.aspx
Trade openness	Merchandise trade (% of GDP).	World Development Indicators, World Bank	data.worldbank.org/indicator/TG.VAL.TOTL.GD.ZS
Raw materials	HWWI-Index of world market prices of commodities, base year 2005.	HWWI Consult / Wifo Data System (WDS)	hwwi-rohindex.de/
FX	Real effective exchange rate index (based year varies) from the World Development Indicators and Eurostat, Indices re-calculated to 2005 as the common base-year. Data for Estonia were obtained from the IMF.	World Development Indicators, World Bank. / Own Calculation	data.worldbank.org/indicator/PX.REX.REER
Quasi Money	Money and quasi money (M2) (current LCU)	World Development Indicators, World Bank	data.worldbank.org/indicator/FP.CPI.TOTL.ZG

Table continued on next page

Table B1 continued: Variable description

Variable	Description	Source	
Unemployment	Unemployment, total (% of total labor force) (modeled ILO estimate)	World Development Indicators, World Bank	data.worldbank.org/indicator/FP.CPI.TOTL.ZG
Oil price	Percentage change in theWest Texas Intermediate price	OPEC	www.opec.org/opec_web/en/data_graphs/40.htm
Time effects	Dummy variables taking on the value of one for the periods 1995-1997, 1998-2000, 2001-2003, 2004-206, 2007-2009, 2010-2012 and 2013-2014, and zero otherwise.	Own calculation	
UK	Dummy variable capturing a break in the broadband series for the UK. It takes on the value of one for the the UK in 2007, and zero otherwise.	Own calculation	

8 Appendix C – Descriptive Statistics (First Differences)

Figure C1: CPI and broadband penetration in first differences

Figure C2: Annual change of CPI in % and its first differences; Mexico and Turkey not included as outliers

Figure C3: Fixed broadband penetration and its first differences

Table C1: Descriptive statistics

Variable	Obs.	Mean	Std. Dev.	Min.	Max.
CPI	389	-0.12	-0.02	-10.45	7.61
Fixed broadband	389	2.26	1.85	-12.41	19.03
Output gap	389	-0.3	0.11	-16.14	5.97
Trade openness	387	0.69	0.88	-31.58	24.99
Raw materials	389	10.3	15.02	-61.82	43.52
Foreign exchange	389	0.51	0.82	-21.03	16.77

9 *Appendix D – Robustness Checks*

Table D1: Robustness checks

Estimator	1 Bun & Kiviet Lagged DV	2 FE Other controls	3 RE Other controls	4 FE Inflation in %	5 RE I Inflation in %	6 FE Crisis dummy	7 RE Crisis dummy
Inflation, lag	-0.0233						
	(0.046)						
B.b., fixed in diff.	-0.0548	-0.0644**	-0.0554**	0.0035	-0.0425	-0.0885***	-0.075**
	(0.040)	(0.028)	(0.025)	(0.107)	(0.088)	(0.033)	(0.032)
GDP gr.		0.058	0.0419				
		(0.053)	(0.043)				
GDP p.c.		0	0				
		0	0				
GDP share agriculture		-0.3074	-0.0362				
		(0.293)	(0.045)				
Regulatory Quality		0.2698	0.2683*				
		(0.632)	(0.157)				
Trade of goods, in diff.	0.0222	0.0371	0.0321	-0.1584*	-0.146*	0.0303	0.0234
	(0.019)	(0.028)	(0.022)	(0.093)	(0.087)	(0.031)	(0.023)
Comm., in diff.	0.0327***	0.0312***	0.0328***	0.0487***	0.0442***	0.0312***	0.0319***
	(0.004)	(0.005)	(0.004)	(0.018)	(0.015)	(0.005)	(0.004)
FX, in diff.	-0.0421**	-0.039	-0.0449	-0.1488	-0.165	-0.0442	-0.0467*
	(0.017)	(0.034)	(0.031)	(0.107)	(0.112)	(0.032)	(0.027)
Output gap, diff.	0.0354			-0.2049	-0.1197	0.0328	0.0383
	(0.045)			(0.151)	(0.136)	(0.065)	(0.060)
Period effects	N	Y	Y	Y	Y	N	N
Constant		-0.0969	-0.7916**	-1.2132*	-1.1247*	-0.0991	-0.1337
		(0.940)	(0.312)	(0.673)	(0.676)	(0.156)	(0.148)
Observations	375	350	350	372	372	375	375
R^2		0.423	0.42	0.0292	0.0279	0.377	0.377

Note: This table describes results from robustness checks. Estimation (1) is a lagged dependent variable estimator, estimation (2) and (3) use different control variables, (4) and (5) use an inflation measure in percent and (6) and (7) consider a crisis dummy instead of period effects. Standard errors in parentheses. *** Statistically significant at 1% significance level,** at 5% significance level, and *** at 10% significance level, respectively.

Table D2: Robustness checks (continued)

	1	2	3	4
Estimator	FE	RE	FE	RE
	Outlier	Outlier	UK dummy	UK dummy
Broadband, fixed in diff.	-0.094***	-0.0771**	-0.0765	-0.0621
	(0.035)	(0.034)	(0.049)	(0.045)
Trade openness., in diff.	0.0313	0.0237	0.0296	0.0224
	(0.031)	(0.022)	(0.030)	(0.022)
Commodities, in diff.	0.0332***	0.0340***	0.0333***	0.0341***
	(0.005)	(0.004)	(0.005)	(0.004)
FX, in diff.	-0.0442	-0.0473*	-0.0443	-0.0474*
	(0.033)	(0.027)	(0.033)	(0.027)
Output gap, diff.	0.0463	0.0486	0.0452	0.048
	(0.067)	(0.062)	(0.065)	(0.061)
Period effects	Y	Y	Y	Y
Constant	-0.4896***	-0.5108***	-0.5067***	-0.5252***
	(0.090)	(0.091)	(0.094)	(0.093)
Observations	375	375	375	375
R^2	0.379	0.378	0.377	0.377

Note: This table describes results from robustness checks. Estimation (1) and (2) drop the top and botton one percent percentile outliers. Specification (3) and (4) drop the UK dummy variable. Standard errors in parentheses. *** Statistically significant at 1% significance level,** at 5% significance level, and *** at 10% significance level, respectively.

Table D3: Robustness checks (continued)

Estimator	1 FE Levels	2 RE Levels
Penetration rate, level	-0.0962***	-0.0190*
	(0.017)	(0.011)
Output gap, level	0.1777***	0.2185***
	(0.050)	(0.039)
Openness, level	0.0087	-0.0005
	(0.010)	(0.002)
Commodities index, level	0.0245***	0.0171***
	(0.005)	(0.004)
FX, level	-0.0197**	-0.0205***
	(0.009)	(0.008)
Period effects	Y	Y
Constant	0.2261	0.1943
	(1.257)	(1.028)
Observations	406	406
R^2	0.23	0.197

Note: This table describes results from robustness checks. Estimation (1) and (2) consider all variables in levels instead of first differences. Standard errors in parentheses. *** Statistically significant at 1% significance level,** at 5% significance level, and *** at 10% significance level, respectively.

Table D4: Robustness checks (continued)

	1	2	3	4
Estimator	FE	RE	OLS	OLS
	Mobile b.b.	Mobile b.b.	Mobile b.b.	Mobile b.b.
Broadband, mobile in diff.	-0.0123	-0.0116	-0.0116	-0.0116
	(0.010)	(0.011)	(0.011)	(0.012)
Trade openness., in diff.	0.0446	0.0041	0.0041	0.0041
	(0.082)	(0.036)	(0.033)	(0.030)
Commodities, in diff.	0.0177	0.0299**	0.0299***	0.0299**
	(0.015)	(0.013)	(0.011)	(0.013)
FX, in diff.	-0.1018*	-0.1006***	-0.1006***	-0.1006**
	(0.053)	(0.038)	(0.037)	(0.037)
Output gap, diff.	0.1793	0.1330	0.1330	0.1330
	(0.184)	(0.119)	(0.153)	(0.112)
Period effects	Y	Y	Y	Y
Constant	-0.4327**	-0.5131***	-0.5131**	-0.5131***
	(0.212)	(0.166)	(0.203)	(0.157)
Observations	88	88	88	88
R^2	0.449	0.434	0.467	0.467

Note: This table describes results from an expansion exercise. The estimations use mobile broadband instead of fixed broadband. Due to missing data, the sample size drops substantially. None of the results are statistically significant, even though the signs point into the same direction. Specification (3) uses bootstrapped standard errors with 2,000 replications, and specification (4) uses clustered standard errors. The coefficients are therefore the same, but differ marginally in the significance levels. However, this difference is not strong enough to shift them into different brackets with respect to the significance levels. Standard errors in parentheses. *** Statistically significant at 1% significance level,** at 5% significance level, and *** at 10% significance level, respectively.

Table D5: Robustness checks (continued)

Estimator	1 FE Dummy miss.	2 RE Dummy miss.	3 OLS Truncated	4 OLS Truncated
Broadband, fixed in diff.	-0.1004***	-0.0704**	-0.0715**	-0.0592*
	(0.033)	(0.035)	(0.033)	(0.030)
Trade openness., in diff.	0.0235	0.0124	0.0336	0.0226
	(0.023)	(0.017)	(0.033)	(0.024)
Commodities, in diff.	0.0358***	0.0372***	0.0343***	0.0354***
	(0.004)	(0.003)	(0.005)	(0.004)
FX, in diff.	-0.0551*	-0.0608**	-0.0362	-0.0403
	(0.028)	(0.025)	(0.037)	(0.030)
Output gap, diff.	0.0254	0.0247	0.0206	0.0271
	(0.074)	(0.072)	(0.072)	(0.066)
Missing Dummy	-0.2969	-0.2521		
	(0.322)	(0.302)		
Constant	-0.512***	-0.5402***	-0.5439***	-0.5538***
	(0.096)	(0.097)	(0.092)	(0.089)
Observations	454	454	340	340
R^2	0.313	0.312	0.391	0.391

Note: This table describes results from robustness checks addressing missing values. Estimation (1) and (2) test if there is a systemic bias by the relatively large number of missings, which is rejected, however. Specification (3) and (4) truncate the sample to a (largely) balanced panel. Standard errors in parentheses. *** Statistically significant at 1% significance level,** at 5% significance level, and *** at 10% significance level, respectively.

Table D6: Robustness checks (continued)

	1	2	3	4	5	6	7	8
Estimator	OLS	OLS	OLS	OLS	RE	RE	RE	RE
Fixed broadband (log)	-0.2666*	-0.4238**	-0.2654*	-0.4374**	-0.1055	-0.2425	-0.0973	-0.2523
	(0.155)	(0.188)	(0.149)	(0.176)	(0.161)	(0.252)	(0.144)	(0.217)
Quasi money (growth)	8.2187***	7.5665***	8.0068***	7.2988***	4.6309***	4.0748***	3.9752***	3.3869**
	(2.464)	(2.462)	(2.314)	(2.281)	(1.189)	(1.510)	(1.267)	(1.551)
Unemployment			-0.0685	-0.0754			-0.1105	-0.0956
			(0.072)	(0.075)			(0.073)	(0.088)
Oil price (growth)			-0.0018	-0.0005			0.0029	0.0032
			(0.012)	(0.013)			(0.007)	(0.007)
Time Effects	N	Y	N	Y	N	Y	N	Y
Constant	2.7883***	2.6782***	3.2644***	3.1794***	2.6121***	2.8448***	3.3195***	3.5466***
	(0.455)	(0.478)	(0.563)	(0.574)	(0.612)	(0.848)	(0.712)	(0.893)
Observations	133	133	133	133	133	133	133	133
R^2	0.138	0.156	0.143	0.162	0.0369	0.0756	0.054	0.0887

Note: This table describes the regression results for fixed broadband penetration on the annual change of the consumer price index (in percent)in the period 1996-2014. The low number of observations is due to missing values in the money supply indicator (quasi money growth). The estimations replicate the results of Yi and Choi 2005. Regressions (1), (2), (3) and (4) are pooled OLS estimations, and regressions (5), (6), (7) and (8) are estimated as random-effects (RE). Estimations (2), (4), (6) and (8) include time effects. Standard errors in parentheses. *** Statistically significant at 1% significance level,** at 5% significance level, and *** at 10% significance level, respectively.