

Warsaw School of Economics
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ON MEDIUM-RUN DYNAMICS OF FACTOR SHARES

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The current Ph.D. thesis is preoccupied with medium-term cycles in economic activity, with special focus on dynamic properties of the US labor share. It documents that not just the main macroeconomic aggregates such as real GDP, but also the labor share, exhibit substantial variation which reaches well beyond business cycle frequencies. It also provides a candidate theoretical explanation for the observed patterns of medium-run swings in the labor share, based on labor- and capital-augmenting change under non-unitary elasticity of substitution. It is demonstrated that the proposed stochastic endogenous growth model is able to replicate a range of important medium-term properties of US data with reasonably good accuracy.

The structure of this document is as follows. First, we place the considered Ph.D. thesis in the context of existing literature. Second, we present its main objectives and hypotheses. Third, we summarize its main results and define its contributions to the associated literature. We also provide a few concluding remarks.

Associated Literature

The current Ph.D. dissertation is related both to the macroeconomic literature on medium-term business cycles, and the line of research which aims to characterize and explain the observed dynamics of factor shares. This thesis attempts to bridge these hitherto disconnected research areas.

The first research area, to which the current thesis contributes, is macroeconomics of the medium run. The medium-term perspective has been introduced to economics by an empirical paper on the labor market (Blanchard, 1997). Nine years later, in a now seminal paper, Comin and Gertler (2006) have documented that output, consumption, investment and other fundamental macroeconomic variables display substantial variation in the medium-run frequency range in the postwar period. Following their rigorous definition, according to which medium-term business cycles include all fluctuations with periodicity below 50 years, other authors have delivered broader evidence on these swings: Gradzewicz (2009) has documented a set of *stylized facts* about the US labor market, whereas Correa-López and de Blas (2012) and Comin, Loayza, Pasha, and Serven (2014) have explored international technological spillovers through the lens of the medium-term approach.

As a research field, macroeconomics of the medium run may be placed between economic growth theory and business cycle analysis, for the following reasons. First, it employs the standard business-cycle theory strategy for identifying main cyclical regularities observed in the data, summarized by moment statistics such as persistence, volatility and co-movement (Kydland and Prescott, 1982; King and Rebelo, 1999). On the other hand, it also embodies a range of long-run mechanisms, responsible for generating additional persistence. In previous studies of medium-term business cycles, the theoretical explanations put emphasis on R&D activities as an engine of economic growth (Comin and Gertler, 2006; Gradzewicz, 2009; Comin, Loayza, Pasha, and Serven, 2014).

The second strand of literature, to which the current thesis relates, documents the stability of factor shares. Since the statement of the famous Kaldor's (1961) *stylized facts*, economists have been usually assuming that the labor and capital shares are

stable over time. However, several recent papers have brought new insights which render this paradigm questionable. Firstly, [Arpaia, Pérez, and Pichelmann \(2009\)](#) and [Karabarbounis and Neiman \(2014\)](#) have documented a strong downward tendency of the labor share in many developed economies since the 1970s. Secondly, [Growiec, McAdam, and Mućk \(2015\)](#) have explored the historical series of the US labor share, identifying a hump-shaped long-run trend of this macroeconomic quantity.

Apart from the lively debate on income inequality (see [Piketty, 2014](#); [Acemoglu and Robinson, 2015](#); [Jones, 2015](#)), evolution of the labor share has also important implications for the supply side of the economy. Roughly speaking, stability of factor shares implies that the Cobb-Douglas aggregate production function assumption is empirically motivated. However, the Cobb-Douglas specification is a special case of Constant Elasticity of Substitution (henceforth, CES) production functions, for which the elasticity of substitution (henceforth, EoS) between factors equals unity. At this, it must be remembered that although the Cobb-Douglas aggregate production function assumption persists as a paradigm in macroeconomics, it has been broadly rejected in empirical studies. The discussion on the actual value of elasticity of substitution between capital and labor started with the paper by [Arrow, Chenery, Minhas, and Solow \(1961\)](#) who found that its value is below 0.6. As it has been surveyed by [Klump, McAdam, and Willman \(2012\)](#), many other researchers have also provided estimates of elasticity of substitution below unity, implying gross complementarity between labor and capital for the US economy. These results have been also confirmed by empirical evidence at the industry level ([Young, 2013](#)) and at the micro level [Oberfield and Raval \(2014\)](#). Viewed from the short-run perspective, in a recent study [Cantore, Levine, Pearlman, and Yang \(2014\)](#) have analyzed a DSGE (dynamic stochastic general equilibrium) model and found that the scenario assuming gross complementarity between labor and capital fits US data overwhelmingly better than the Cobb-Douglas case. On the other hand, a different lesson can be drawn from the studies based on cross-country variation ([Duffy and Papageorgiou, 2000](#); [Karabarbounis and Neiman, 2014](#)) whose results indicate gross substitutability between capital and labor (elasticity of substitution above unity). Despite this inconsistency, it should be emphasized that all these works have strongly rejected the Cobb-Douglas production function specification.

Turning back to the labor share, one of the possible explanations of its observed evolution under a non-unitary elasticity of the substitution might be directed technical change ([Acemoglu, 2003](#)). According to this hypothesis, it's essential to disentangle the productivity of respective factors of production rather than considering them in their aggregate form, i.e., as TFP (Total Factor Productivity). This hypothesis has been appealingly confirmed by the empirical evidence (see [Klump, McAdam, and Willman, 2007](#), for example) which suggests substantial differences between time trends of labor and capital productivity. Namely, structural estimates of the fundamental characteristics of the supply side of the US economy imply that the growth pattern of labor-augmenting and capital-augmenting technological change is exponential and hyperbolic (or logarithmic), respectively. In line with the standard neoclassical paradigm, labor-augmenting technical change outruns the capital-augmenting one, but contrary to this line of literature, capital-augmenting technical change is non-negligible as well.

Research Objectives and Hypotheses

Based on the above literature survey, the following research objectives are formulated in the current Ph.D. thesis.

The principal objective of the first chapter is to provide a broad assessment of importance of medium-term business cycles in long-dated macroeconomic data. Although a set of stylized facts has been already formulated in the literature (Comin and Gertler, 2006; Gradzewicz, 2009; Correa-López and de Blas, 2012; Comin, Loayza, Pasha, and Serven, 2014) we still know very little about their generality and robustness. To scrutinize the magnitude of medium-run swings of key macroeconomic categories, we explore Maddison's (Bolt and van Zanden, 2014) database which contains long-dated historical series on real GDP per capita in 40 countries since the beginning of the 19th century. In addition, we also document the medium-term features of main other macroeconomic variables, i.e. consumption, investment and government expenditures, in 11 developed countries in the postwar period. Following Comin and Gertler (2006), we define medium-term business cycles as all oscillations with periodicity below 50 years. According to this rigorous definition, medium-run swings can be divided into two subcomponents: medium-frequency fluctuations (periodicity between 8 and 50 years) and high-frequency business cycles (periodicity below 8 years). Apart from an enrichment of the set of known stylized facts about medium-term cycles, an analysis of the sensitivity of the above definition is also provided.

The objective of the second chapter is, in turn, to document the dynamic properties of the US labor share. Several recent papers have questioned the empirical validity of the established "conventional wisdom" implying stability of the labor share (Arpaia, Pérez, and Pichelmann, 2009; Karabarbounis and Neiman, 2014; Growiec, McAdam, and Mućk, 2015). This leaves an open door for a comprehensive study that would broadly explore the dynamics of factor share. To challenge this issue we employ a battery of econometric tests, with special focus on medium- and long-run characteristics of the considered time series. Our analysis includes: (i) unit root tests, (ii) spectral decomposition, (iii) linear autoregressive models, (iv) detecting single (Andrews, 1993; Andrews and Ploberger, 1994) and multiple (Bai and Perron, 2003) structural breaks, (v) Markov-switching autoregressive models (Hamilton, 1989), (vi) a fractional order of integration (Geweke and Porter-Hudak, 1983; Robinson, 1995; Phillips, 2007), (vii) stationarity tests subject to occurrence of a single (Zivot and Andrews, 1992) or a double structural break (Lumsdaine and Papell, 1997), (viii) unit root tests with an alternative hypothesis of ESTAR (exponential smoothed transition process Kapetanios, Shin, and Snell, 2003) or AESTAR (asymmetric exponential smoothed transition process Sollis, 2009), and (ix) stationarity tests embracing a flexible Fourier transformation as a proxy of an unknown deterministic component and number of breaks (Becker, Enders, and Lee, 2006; Christopoulos and León-Ledesma, 2010).

To better understand the complex dynamics of the US labor share, we also gauge the impact of the well-known sectoral change in economic activity on the evolution of the US labor share, i.e., the shift from manufacturing and agriculture to services. This question is well motivated because our research interest focuses on the long-dated series which start in 1929. Akin to Elsby, Hobijn, and Sahin (2013) and Karabarbounis and Neiman (2014), we employ a shift-share analysis to identify the between effect

which captures the impact of changes in structure of economic activity on the aggregated labor share. To complement our sectoral analysis we also explore some dynamic properties of the postwar labor share at the industry level.

To illustrate the magnitude of the complex dynamics of the US labor share we also analyze the reaction of this macroeconomic variable to technology shocks. Our application is motivated by contradictory predictions found in the related empirical literature. On the one hand, [Ríos-Rull and Santaeulàlia-Llopis \(2010\)](#) document an overshooting reaction of the labor share to technology shocks. On the other hand, structural estimates of the supply side of the US economy suggest that the elasticity of substitution between capital and labor is below unity and technical change is mostly (but not purely) labor-augmenting ([Klump, McAdam, and Willman, 2012](#)). The above two facts imply an unequivocally negative reaction of the labor share to technology shocks ([Cantore, León-Ledesma, McAdam, and Willman, 2014](#)). Our analysis, which reconciles both findings, is based on a range of alternative models, i.e., a simple autoregressive distributed lag model (ARDL), a Markov-switching ARDL model and a vector autoregression (VAR) model, as well as different proxies of technology shock: we use several transformations of both the standard and capacity-adjusted TFP measure ([Fernald, 2012](#)).

The objective of the third chapter is to determine whether the concept of factor-augmenting technological change is able to explain medium-term business cycle features of fundamental macroeconomic quantities, including the labor share. To answer this question we develop a stochastic endogenous growth model with factor-augmenting R&D activity. The heart of our framework combines (i) two factor-augmenting R&D sectors ([Acemoglu, 2003](#)), (ii) endogenous technology choice at the micro level ([Jones, 2005](#); [Growiec, 2013](#)), and (iii) normalized aggregate CES production function ([Klump and de La Grandville, 2000](#)). Unlike standard practice in economic growth theory ([Romer, 1990](#); [Jones, 1995](#)), we assume that R&D firms deliver innovations that separately increase either unit labor or capital productivities. Consistently with a bulk of empirical literature, we assume that long-run growth in our model is determined exclusively by the labor-augmenting R&D activity.

Having developed our endogenous growth model, the natural question is how different the steady-state values of model variables are between the social planner solution and the decentralized allocation. To achieve this goal we solve our model analytically for both allocations. Then, a set of model parameters is calibrated to match selected long-run properties of the postwar US economy. It allows us to illustrate the derived discrepancies between both allocations quantitatively.

In the next step, we ask what is the reaction of model variables to unexpected stochastic shocks affecting factor-augmenting R&D productivity. Given our baseline calibration of model parameters, we study impulse responses for the log-linear approximation of our model. Contrary to the familiar strategy developed in the business-cycle literature, uncertainty in our model is embodied in productivity processes governing the productivity of factor-augmenting R&D sectors. These unanticipated changes can be perceived as extraordinary inventions and their effect is transmitted on other model quantities through a range of general equilibrium effects.

Finally, we ask whether our model is able to replicate the empirical patterns that characterize medium-term business cycles in main macroeconomic variables, includ-

ing the labor share, in the US. We tackle this issue in two following steps. Firstly, the unknown parameters describing the factor-augmenting R&D productivity processes are estimated. Then, having scrutinized main characteristics of these stochastic processes, stochastic simulations are run. Using selected statistical moments, such as volatility, persistence and co-movement with output, simulated series are compared with the empirical regularities.

In accordance with these research objectives, the following research hypotheses are verified in the current Ph.D. dissertation:

1. **Medium-term business cycles are responsible for a substantial part of total volatility of real GDP as well as other main macroeconomic variables.** This general result applies to a large number of countries as well as very long time periods. We can distinguish the following detailed hypotheses:
 - The share of medium-term business cycles in total variance of the long-dated historical series of real GDP per capita exceeds 40%.
 - Main components of GDP exhibit substantial variation in the medium run too. In the postwar period, the medium-term component of consumption, investment and government expenditures has been more persistent and volatile than standard short-run business cycles.
 - Even after the isolating the medium-term component from the long-dated historical series, a nontrivial and nonlinear long-run trend is still observed in GDP per capita of developed countries.
2. **The US labor share displays complex dynamic properties and substantial volatility over the medium run.** The following properties of the US labor share can be identified:
 - existence of a nonlinear, i.e., hump-shaped, long-run trend with a peak in the 1970s;
 - substantial persistence (but not a unit root);
 - susceptibility to multiple structural breaks;
 - occurrence of long-lasting regimes characterized with different volatility;
 - negative response to technology shocks.

In addition, the aforementioned dynamic properties of the US labor share are not caused by the well-known change in composition of economic activity, i.e., shift from manufacturing and agriculture towards services.

3. **The concept of labor- and capital-augmenting technological change is able to explain a substantial fraction of medium-term business cycle features of main macroeconomic variables in the US, including the labor share.** The following detailed hypotheses can be formulated:
 - Responses of main macroeconomic variables to random movements in the productivity of the factor-augmenting R&D sectors are very persistent.
 - A stochastic endogenous growth model based on factor-augmenting R&D activity is able to replicate selected statistical moments, such as volatility,

persistence and co-movement with output, that characterize medium-term business cycles in the labor share and other main macroeconomic quantities in the US.

Results and Contributions

The current dissertation verifies the formulated above research hypotheses. Its contribution to the associated literature is fourfold. Firstly, we show that the nature of medium-term business cycles is nontrivial and distinct from both short-run business cycles and long-run growth. Our empirical evidence adds a compelling argument to the macroeconomic debate on the magnitude of medium-run swings. Namely, the broad results provided here suggest that medium-term business cycles are a universally present economic phenomenon. Our evidence based on long-dated series on real GDP implies that the share of medium-term business cycles in the observed variance exceeds 40%. Moreover, the medium-term component is systematically more persistent and two-three times more volatile than its short-run counterpart. Notwithstanding, even if one extracts both medium- and high-frequency cycles from series, there still remains a nonlinear long-run trend.

These general empirical regularities are strongly robust to changes in the rigorous definition of medium-term business cycles and the choice of data sample. Firstly, allowing low-frequency oscillations to be included in the medium-frequency subcomponent doesn't change our essential findings. In such case, medium-term business cycles are extremely persistent while their variation is on average only 20 % higher than in the baseline case. Secondly, the selected statistical moments as well as the appropriate spectral characteristics of real GDP in a postwar sample of 181 countries confirm the previous results.

Turning to the postwar period, we also document medium-term business cycles in main other macroeconomic categories – consumption, investment, and government expenditures – in 11 developed economies. Several lessons can be drawn from these empirical regularities. Alike real GDP, medium-term fluctuations of consumption, investment and government expenditures display substantially higher volatility and a higher degree of persistence than short-run cycles (King and Rebelo, 1999). In addition, the medium-term component of these variables co-moves with output similarly to the short-run business cycles, i.e., consumption and investment are procyclical while the contemporaneous correlation between government expenditures and output depends on country-specific characteristics (Fiorito and Kollintzas, 1994), e.g. institutions, degree of the interventionism and military expenditures. Furthermore, it is also documented that the relative volatility of consumption over the medium run is around unity and for some countries this measure even exceeds unity. Such observation suggests that over the medium run, the consumption smoothing mechanism might not work as well as at high frequency. It also highlights the relevance of factors which are absent in the short run, e.g. demographic changes or switches in consumption preferences.

Secondly, we offer a comprehensive insight into the evolution of the US labor share in 1929-2012. In the first step, we carefully construct this macroeconomic quantity, ad-

justing it for mixed income of the self-employed as well as other ambiguous income (see [Mućk, Growiec, and McAdam, 2015](#), for a detailed discussion). Our comprehensive study of dynamics of the labor share reveals that this macroeconomic variable is driven by a nontrivial and complex data generating process. The following dynamic properties have been documented: (i) appearance of a pronounced hump-shaped long-run trajectory, (ii) high degree of persistence, with a substantial fraction of total variation observed within the medium-run frequency range, (iii) susceptibility to multiple (2-3) structural breaks, (iv) occurrence of long-lasting regimes characterized with different volatility, and (v) possible nonlinear adjustment toward equilibrium level. Naturally, each econometric method used here may have its pros and cons but our results jointly highlight the nontrivial nature of the labor share dynamics.

Importantly, the identified dynamic characteristics of the US labor share cannot be explained by the well-known change in the sectoral composition of economic activity, i.e., the shift from manufacturing and agriculture toward services. Namely, the results of a shift-share analysis suggest that the contribution of between effects, which capture the impact of changes in gross value added, is slight. Furthermore, there is substantial heterogeneity in patterns of labor share evolution at the industry level. There are at least two reasons for the explored diversity in dynamics of the labor share at the industry level. The first one refers to the differences in key characteristics of the supply side, such as the elasticity of substitution between capital and labor or the role of factor-augmenting technical change ([Young, 2013](#)). According to the second explanation, the magnitude of the globalization and offshoring has been asymmetric across the US sectors over the postwar period. Namely, in some US industries production has been systematically reallocated from domestic labor-intensive sectors to foreign economies offering relatively lower labor costs ([Elsby, Hobijn, and Sahin, 2013](#)).

As an important empirical application, we also carefully study the response of factor shares to technology (TFP) shocks. It is shown that the reaction of the US labor share is unambiguously negative in the short run. Consistently with broad empirical evidence in favor of the elasticity of substitution between capital and labor below unity ([Klump, McAdam, and Willman, 2012](#)), this pattern implies that labor-augmenting (as opposed to capital-augmenting) technical change has been dominant in the postwar US economy. However, the estimated impulse responses differ in the longer horizon and are sensitive to the choice of TFP measure. On the one hand, the effect of technology shock gradually dies out when capacity-adjusted TFP series are employed. On the other hand, the labor share overshoots if TFP is unadjusted. This empirical regularity strongly questions the conclusions of [Ríos-Rull and Santaaulàlia-Llopis \(2010\)](#) who don't take capacity utilization into consideration in their TFP measure – which likely leads to a bias caused by short-run demand factors. Moreover, our Markov-switching evidence on this relationship reveals an interesting and intuitive story, according to which the slowdown in TFP growth in the 1970s can partially explain the simultaneous peak in the US labor share.

These findings have important implications for the supply side of the economy. The documented complex dynamics of the labor share justify the doubts placed on the aggregate Cobb-Douglas production function in the literature, consistent, i.e., with the structural estimates of elasticity of substitution between capital and labor which are usually below unity ([Klump, McAdam, and Willman, 2012](#)). In this vein, these non-

trivial dynamic properties also highlight the role of non-negligible capital-augmenting technical progress that has been identified in the postwar US economy alongside the standard labor-augmenting one (Klump, McAdam, and Willman, 2007).

Thirdly, we develop a theoretical model aiming to explain the empirical regularities documented above. Our proposed framework combines the following micro-founded assumptions: (i) two factor-augmenting R&D sectors (Acemoglu, 2003), (ii) endogenous technology choice at the micro level (Jones, 2005; Growiec, 2013), and (iii) normalized aggregate CES production function (Klump and de La Grandville, 2000). It is also assumed that all uncertainty is embodied in the productivity of the two factor-augmenting R&D sectors. In the long-run (steady-state) growth context, we provide a comparison between the social planner solution and the decentralized allocation of the model. Under our baseline calibration, the social planner allocation offers a substantially higher long-run growth and a higher labor share. This is due to the presence of monopoly mark-ups in sectors producing differentiated intermediate goods as well as the fact that markets fail to internalize duplication externalities in R&D and external effects of factor-augmenting patents.

Moving to the medium-term perspective, which is the main focus of this analysis, we also study the transitional dynamics of our model. We find that, under any empirically reasonable calibration, the responses of model variables to stochastic disturbances in R&D productivity are very persistent, stretching well beyond usual business cycle frequencies. It should be also emphasized that these shocks have a permanent effect on nonstationary variables, such as output, consumption, capital and investment. Naturally, with only labor-augmenting technical change in the long run, the reaction of model variables is larger to shocks in the productivity of the labor-augmenting R&D sector.

Fourthly, we confront our model with US data. Having estimated the underlying parameters of the productivity processes in both factor-augmenting R&D sectors, stochastic simulations are run in order to provide a quantitative assessment of the predictions of our framework. It turns out that the proposed model is able to generate time series whose key moment characteristics are consistent with key medium-run characteristics of US data. Our framework is particularly successful in matching the medium-run properties of the US labor share. Namely, it predicts its paradoxical co-movement with output, i.e., significantly positive and statistically insignificant contemporaneous correlation of the labor share with output at the medium and high frequency, respectively.

Some of the above results are closely related to other studies. In particular, Growiec, McAdam, and Mućk (2015) have constructed a similar but purely deterministic theoretical model that explains the hump-shaped long-run trend in the US labor share. On the other hand, Young (2004) has developed an economic mechanism that is able to replicate the short-run characteristics of this macroeconomic quantity. To our best knowledge, this dissertation is the first study which successfully attempts to provide a technological explanation for the medium-run features of the labor share.


Concluding Remarks

Apart from providing some clear answers, the current dissertation also leaves a few doors open for future research. Firstly, our international evidence highlights the relevance of the medium-term business cycles. The natural further step would be to enrich the set of known empirical regularities and identify their implications for economic modelling.

Secondly, our research interest has focused only on a purely technological explanation of the medium-run labor share cycles. Although the main results are attractive, a few extensions can be proposed to improve the performance of our framework. For example, our workhorse model abstracts from short-run frictions, e.g. labor market frictions, and, as a result, it predicts a very high volatility of the labor allocation. Therefore, introducing wage rigidities might be an attractive strategy to tackle this counterfactual prediction.

Thirdly, technology adoption in our model is costless. It means that new patents are immediately absorbed in the aggregate production function. It would be interesting to extend our framework by introducing adjustment costs or some mechanism related directly to technology adoption.

Fourthly, introducing the government sector in our framework is also an attractive perspective for future research. It would allow the researcher to study the medium-run effects of certain public policies, such as intellectual property rights or research subsidies. These interesting questions are left for future research.

A handwritten signature in blue ink that reads "Jakob Muir". The signature is written in a cursive style with a large initial 'J' and 'M'.

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Appendix Research and Academic Activity

EDUCATION:

1. **M.A. in Economics, Warsaw School of Economics, 2009-2011**
Major: Quantitative Methods in Economics and Information Systems;
Thesis title: *Analiza reakcji wybranych modeli długookresowego wzrostu gospodarczego na szoki stochastyczne (An investigation of the response of selected long-run growth models to stochastic shocks);*
Advisor: dr hab. Jakub Growiec, prof. SGH.
2. **B.A. in Economics, Warsaw School of Economics, 2006-2009**
Major: Quantitative Methods in Economics and Information Systems;
Thesis title: *Analiza wrażliwości dekompozycji Solowa na zmianę parametru α (Sensitivity Analysis of Solow's Decomposition);*
Advisor: dr hab. Jakub Growiec, prof. SGH.

AWARDS:

1. **"Bank and Credit" award:** 2nd place (2012).
2. **Econometric Game (AKA The World Championship of Econometrics):** 3rd place (2013), TOP10 (2014 & 2012).
3. **Participation in 5th Lindau Meeting on Economic Sciences**

PUBLICATIONS (IN POLISH):

1. Mućk J., (2012), *Analiza reakcji wybranych modeli długookresowego wzrostu gospodarczego na szoki stochastyczne (An investigation of the response of selected long-run growth models to stochastic shocks)*, Bank i Kredyt, 43 (4), p. 85-118.

WORKING PAPERS:

1. Mućk J., McAdam P. and Growiec J., (2015), *Will the True Labor Share Stand Up?*, European Central Bank Working Papers, forthcoming.
2. Growiec J., McAdam P. and Mućk J., (2015), *Endogenous labor share cycles: theory and evidence*, European Central Bank Working Papers, No. 1765.
3. Ca' Zorzi M., Mućk J. and Rubaszek M., (2013), *Real exchange rate forecasting: a calibrated half-life PPP model can beat the random walk*, European Central Bank Working Papers, No. 1576.
4. Mućk J. and Skrzypczyński P., (2012), *Can we beat the random walk in forecasting CEE exchange rates?*, National Bank of Poland Working Papers, No. 127.

TEACHING EXPERIENCE:

1. **Econometrics** (Fall 2011/2012, Fall 2012/2013, Fall 2013/2014, Fall 2014/2015; in Polish)
2. **Operational Research** (Spring 2012/2013, Fall 2013/2014, Spring 2013/2014; in Polish)
3. **Mathematical Economics & Dynamic Optimization** (Spring 2013/2014, Spring 2014/2015; in Polish)
4. **Applied Econometrics** (Spring 2013/2014; in English)

INTERNATIONAL CONFERENCES & WORKSHOPS:

1. **Warsaw International Economics Meeting**, Warsaw, Poland, July 2-4, 2015:
Endogenous Labor Share Cycles: Theory and Evidence [joint work with Jakub Growiec and Peter McAdam].

2. **Society for Computational Economics, 21th International Conference on Computing in Economics and Finance**, Taipei, Taiwan, June 20-22, 2015:
Will the True Labor Share Stand Up? [joint work with Jakub Growiec and Peter McAdam].
3. **14th IWH-CIREQ Macroeconometric Workshop**, IHW, Halle(Saale), Germany, December 2-3, 2013:
Real exchange rate forecasting: a calibrated half-life PPP model can beat the random walk [joint work with Michele Ca'zozzi and Michał Rubaszek].
4. **40th Anniversary Macromodels International Conference**, Warsaw, Poland, October 21-24, 2013:
Real exchange rate forecasting: a calibrated half-life PPP model can beat the random walk [joint work with Michele Ca'zozzi and Michał Rubaszek].
5. **2nd Summer Workshop of the National Bank of Poland**, NBP, Warsaw, Poland, July 1-5, 2013:
Real exchange rate forecasting: a calibrated half-life PPP model can beat the random walk [joint work with Michele Ca'zozzi and Michał Rubaszek].

OTHER WORKSHOPS, CONFERENCES & SEMINARS:

1. **Warsaw Economic Seminar**, SGH, Warsaw, May 7, 2015:
Will the True Labor Share Stand Up? [joint work with Jakub Growiec and Peter McAdam].
2. **National Bank of Poland, Economic Institute Seminar**, Warsaw, September 30, 2014:
Endogenous Labor Share Cycles: Theory and Evidence [joint work with Jakub Growiec and Peter McAdam].
3. **Economic growth - Labor market - Innovation (Wzrost gospodarczy - Rynek pracy - Innowacyjność gospodarki)**, Łódź, June 2014:
O własnościach dynamicznych udziału wynagrodzenia w pracy (Understanding the Dynamics of the US labor share) [joint work with Jakub Growiec and Peter McAdam].
4. **Econometric modeling seminar (SENAMEK)**, Warsaw, May, 2014:
Econometric Game 2014: Welfare analysis with incomplete expenditure data.
5. **Econometric modeling seminar (SENAMEK)**, Warsaw, May, 2013:
Econometric Game 2013: Effect of fiscal policy on economic growth.

GRANTS:

1. **Research grant OPUS 3 No. 2012/05/B/HS4/02236 from the National Science Center (2013-14): Medium-run fluctuations of the labor share: theory and empirical evidence**; co-authors: Jakub Growiec (principal investigator), Peter McAdam.

OTHERS ACADEMIC ACTIVITIES:

1. Teaching GUI R and economic growth theory in open courses.
2. Case maker of the student competition *Wygraj z Analizą Danych* (2013, 2014).