Economic Modelling 59 (2016) 32–45

Contents lists available at ScienceDirect

Economic Modelling

journal homepage: www.elsevier.com/locate/ecmod

On interactions between remittance outflows and Saudi Arabian macroeconomy: New evidence from wavelets

Salem Hathroubi [a], Chaker Aloui [b,*]

[a] College of Economics and Administrative Sciences, Al-Imam Muhammad Bin Saud Islamic University, Riyadh, Saudi Arabia
[b] College of Business Administration, King Saud University, Riyadh, Saudi Arabia

ARTICLE INFO

Article history:
28 December 2015
18 June 2016
Accepted 25 June 2016
Available online xxxx

JEL classification:
C02
C63
E27
F22
F24

Keywords:
Workers' remittances
Economic growth
Government expenditures
Wavelets

ABSTRACT

The effect of workers' remittance outflows on macroeconomic variables of host countries is a controversial issue. The purpose of this paper is to study lead/lag interactions between workers' remittance outflows and macroeconomic leading variables in Saudi Arabia for 1980–2013 within a time–frequency framework. To this end, we perform three wavelet variants, namely, the wavelet power spectrum, the cross-spectrum wavelet, and the coherence wavelet. We show that remittance outflows are strongly associated with the main Saudi aggregates and that their relationships change across time scale and frequency bands. In the short- and mid-term, real output growth and government expenditures guide remittance outflows. More specifically, government expenditures positively affect remittance shares to real outputs. In addition, the wavelet analysis reveals a positive causality link from the active population to remittances over low-frequency bands. These outcomes have several prominent implications and point to practical recommendations in terms of monetary policy coordination and financial stability.

1. Introduction

Immigration patterns and their effects on the economies of host countries are among the most controversial issues in economics. Those who oppose immigration fear its negative impacts on the labor market, on public finance, and on income distribution. Supporters of immigration, however, highlight the positive role it can play in helping remedy labor shortages and problems associated with aging populations.[1] Currently, remittances constitute a large source of foreign transfers to the developing world and are greater than foreign aid and private capital transfers. According to the World Bank (2014a, 2014b), in 2011, they represented three times the amount of aid sent from rich countries to poor ones.[2] Therefore, international organizations and home and host country governments view remittance flows as an engine for development.

In some developing countries of origin, at the macroeconomic level, migrant remittances are viewed as altruistic and as one of the most important sources of financial growth and development. At the microeconomic level, remittances are considered to be motivated by self-interest. They alleviate poverty at the household level, improve family health, and expand durable goods ownership. Remittances can form a "family welfare system" that can help regulate consumption and alleviate liquidity constraints while also serving as a form of mutual assistance (see Orozco and Bryanna, 2007). World Bank Statistics (WB, 2014a, 2014b) show that in these countries, inflows of remittances increased from US$52.6 billion during the 1990s to US$204.3 billion during the 2000s and reached US$297.3 billion in 2010 and US$406 billion in 2013, and they reached a value of roughly US$534 billion in 2015.

In regards to host countries, most studies have mainly focused on the effects of macroeconomic conditions on remittances. Few works have examined the effects of remittances on the macroeconomic variables of emigrant recipient countries. Theoretically speaking, remittances should be procyclical with host country economic growth. Nevertheless, empirical studies have failed to settle the debate on the cyclicality of remittances. For instance, in the case of the Germany–Turkey remittances corridor, some studies show that remittances are

* Corresponding author.
E-mail addresses: shathroubi@yahoo.fr (S. Hathroubi), cmaloui@ksu.edu.sa (C. Aloui).

[1] In this vein, Hatton and Williamson (2002) identify four economic and demographic fundamentals that have driven migration over the past 150 years: (1) gaps between rich high-wage countries and poor low-wage countries, (2) poverty constraints that hinder migration in very poor sending countries, (3) the size of the young-adult share in sending and receiving country populations, and (4) the foreign-born migrant stock from sending countries currently residing in the receiving country.

[2] For some countries, remittances constitute as high a share of GDP as they represented in 2014 (31% for Tajikistan and 29% for Lesotho).

http://dx.doi.org/10.1016/j.econmod.2016.06.018
0264-9993/

procyclical with respect to Turkish outputs and acyclical with respect to German outputs (see, for example, Sayan, 2004; Durdu and Sayan, 2010). Other researchers show that remittances respond positively to German output, having no significant reaction to the economic situation in Turkey (see, among others, Akkoyunlu and Kholodilin, 2008). Vargas-Silva (2008) highlight that remittances vary counter-cyclically with Mexico's outputs, but the authors do not find any effects of the U.S. business cycle. For some authors, workers' remittance outflows, as a share of migrant saving transferred to the origin country, may decrease investment in the host country and then may be negatively linked to economic growth. In this vein, Alkhathlan (2013) argues that remittances may be regarded as withdrawals from circular flows of money, thus limiting economic activity and negatively affecting aggregate demand for the host country.

Therefore, our main research questions are as follows. How are workers' remittance outflows connected to macroeconomic aggregates of Saudi Arabia? Is this connection changing through time frequencies? How are causal lead/lag linkages evolving over time and in terms of frequency? We attempt to provide answers to all of the above listed questions by analyzing time–frequency relationships between workers' remittance outflows and leading macroeconomic variables for Saudi Arabia. More specifically, we examine lead/lag dynamic relationships between workers' remittance outflows and economic growth rates, employment rates, and government expenditures within a time–frequency framework. This investigation may give rise to additional economic and operational recommendations for policy makers and regulators in Saudi Arabia.

Empirically, we use three wavelet approach methods (the continuous wavelet power spectrum (hereafter, WPS), the cross-wavelet power spectrum (hereafter, CWPS), and the wavelet coherence (hereafter, WC)) to investigate lead/lag interactions in co-movements between workers' remittance outflows, real output growth, government expenditures, and active populations. The wavelet methodology is an engineering tool that is commonly used in the fields of image processing, engineering, astronomy, meteorology, and time series analysis. A key feature of wavelets pertains to their capacity to uncover latent processes with changing cyclical patterns, trends and non-stationarity features that generally characterize economic and financial time series. This method is also relevant for modeling economic processes where economic agents have different term (horizon) objectives (see, among others, Aguiar-Conraria et al., 2013).

To the extent that our study is concerned with lead–lag relationships between workers' outflows and key macroeconomic variables for Saudi Arabia across time scales, the wavelet analysis based on the WPS, CWPS, and CW is particularly interesting. Three main factors support our methodological choice. First, as a nonparametric free model, the CW allows for an insightful analysis of potentially nonlinear time series characteristics of aggregates and their lead–lag relationships across different time scales (i.e., short, medium, and long horizons). For instance, some researchers including Alkhathlan (2013) note that the relationship between remittance outflows and output growth in Saudi Arabia is changing across time horizons. This relationship has been found to be negative over short-term horizons but non-significant over long-term horizons. Conversely, Alkhathlan's (2013) study does not consider for lead/lag causality and its changes across different frequencies. Second, the wavelet approach allows for the analysis of power and causality between selected variables in the time–frequency domain. Third, one of the principal features of the wavelet methodology pertains to the way in which it expands underlying time series into a time–frequency space where it will be possible to visualize time and frequency variations of remittances, output growth, government expenditures, and unemployment rates in a highly comprehensive way. More specifically, wavelet coherence and phase differences allow us to jointly assess co-movements and causality linkages over time and frequency levels. Indeed, some main aspects related to lead–lag relationships between remittances and output growth, unemployment, government expenditures, and their time–frequency varying patterns remain undefined in the literature. We argue that such factors require further attention due to ambiguities in existing evidence presented in the remittance literature. Using the wavelet tool, we can effortlessly understand potential lead–lag causal relationships between time series for concurrently high-frequency bands (short-term) and low-frequency bands (long-term). Finally, as Rouef and Sachs (2011) note, the wavelet methodology can be used to effectively extract time and frequency localized information, and it can be applied to non-stationary series, to locally stationary series, and to time series with eventual structural changes. Therefore, when a time series is related to output growth or when other macroeconomic variables are non-stationary or present eventual structural changes, standard empirical methodologies may generate inaccurate results and may therefore point to incomprehensive economic policy recommendations.

Despite the growing body of literature that applies wavelets to economics and finance, no previous studies have focused on the relationship between remittances and macroeconomic variables. To the best of our knowledge, this is the first study that uses continuous wavelets to provide novel insight into the dynamic relationships between workers' remittance outflows and leading macroeconomic variables. Alkhathlan (2013) is the most similar existing study to our paper in terms of research questions. However, our study is unique in its use of the wavelet method to analyze lead–lag dynamics of remittance outflows and other macroeconomic leading variables in the time–frequency domain. Andersson and Karpestam (2013) use a maximum overlap discrete wavelet transform to estimate a Keynesian consumption function where real per capita outputs and real per capita remittances are used as explanatory variables. Their main objective is to determine whether the altruism or insurance hypothesis is supported by data on 50 low- and middle-income countries for 1980–2006. Their results provide more support for the altruism hypothesis than for the insurance hypothesis.

In this work, we investigate the case of Saudi Arabia to determine the economic implications of the wavelet–remittances association. The case of Saudi Arabia is worth examining for at least three main reasons. First, Saudi Arabia is one of the most prominent host countries in terms of immigrant numbers (roughly 10 million and 30% of the total population by the end of 2014), remittances (USD35 billion in 2013, the second country after the USA), and the GDP share. According to the WB Report (2014a, 2014b), workers' remittance outflows accounted for 6.9% of GDP on average from 1980 to 2013. Second, the aging motive cannot explain immigration strategies witnessed in Saudi Arabia since in 2010, with 27.6% of the population being <15 years of age and with 67.6% being 15–64 years of age. Third, the rate of unemployment is relatively high (12.1% by the end of 2014) and may reach roughly 20% among those holding a university diploma. Given these realities of the Saudi economy, a study on lead/lag linkages between remittance outflows and macroeconomic variables in the time–frequency domain can offer new insights into relationships between these variables.

The wavelet analysis shows that co-movements between worker outflows and leading macroeconomic variables for Saudi Arabia are evolving through time and frequency. More specifically, we find a strong positive relationship between remittance outflows and output growth for Saudi Arabia in the high-frequency domain (short-term). This result can be explained by the fact that non-Saudi workers immediately remit their money to their home countries in the high-frequency band (1–4 years).[3] Furthermore, we find strong positive coherence between remittances and real public expenditures per capita for the 1- to 4-year frequency band. The two variables are largely in phase with workers' remittances as a leading variable. In addition, our wavelet analysis shows high levels of time-varying co-evolution between

[3] Three main factors may explain this behavior. First, foreign workers cannot obtain local citizenship in any of the Gulf Cooperation Council (hereafter, GCC) countries. Second, foreigners are not allowed to own property in most GCC countries. Finally, the majority of low-skilled workers are not allowed to bring their families in.

Table 1
Recent literature on the relationship between remittances and macroeconomic variables.

Authors/year	Countries/sample period	Variables	Methods	Main results
Panel A. Studies related to countries of origin				
Lim and Simmons (2015)	Caribbean Community and Common Market 1975–2010	Real per capita GDP. Investment. Consumption.	Panel cointegration test	No relationship between remittances and economic growth or investment in the long run. Long-run relationships between remittances and consumption.
Jouini (2015).	Tunisia, 1970–2010	Economic growth	ARDL cointegration	No impact on economic growth in the long run and bidirectional causality between remittances and growth in the short run.
Nwaogu and Ryan (2015).	53 African and 34 Latin American and Caribbean countries. Many sub-periods.	FDI, foreign aid, and economic growth.	Panel data analysis	For African countries, only FDI affects growth. For Latin America and the Caribbean, foreign aid and remittances affect growth.
Kumar and Stauvermann (2014)	Bangladesh, 1979–2012	Economic growth	ARDL cointegration, Granger causality test.	Positive relationships between remittances and economic growth in the long run and bidirectional causality linkages.
Imai et al. (2014).	24 Asia and Pacific countries, 1980–2009	Economic growth	Panel data analysis.	Positive effects of remittances on growth. Remittances contribute to poverty reduction.
Kumar (2013)	Guyana 1982–2010	Economic growth and financial deepening.	ARDL cointegration	Positive and significant effects of remittances on growth both in the short and long term.
Ahamada and Coulibaly (2013)	20 Sub-Saharan African countries, 1980–2007	Economic growth	Panel Granger causality	No causal linkage.
Andersson and Karpestam (2013)	50 Low- and middle-income countries	Consumption, GDP and remittances. Altruism vs. insurance hypothesis.	Discrete wavelet transform	Negative long-run relationship between consumption and remittances. In favor of altruism.
Ncube and Brixiova (2013)	African countries 1990–2011	GDP, inflation and exchange rate.	Pooled OLS	Positive linkage between GDP and remittances. Negative relationship between remittances, inflation, and exchange rate depreciation.
Beine et al. (2012)	66 Countries 1980–2005	Financial openness (KAOPEN measure, Chinn and Itô, 2008).	Dynamic generalized ordered Logit model	Strong positive effects of remittances on financial openness.
Nyamongo et al. (2012)	36 African countries 1980–2009	Growth and financial development (ratio of credit to the private sector to GDP, ratio of M2 to GDP).	OLS and 2SLS	Countries with relatively developed financial systems attract more remittances.
Narayan et al. (2011)	54 Developing countries 1995–2004	Economic determinants of inflation. Institutional variables. Remittances.	Arellano and Bond panel dynamic estimator and GMM method.	Remittances have a more pronounced effect on inflation in the long term.
Aggarwal et al. (2011)	109 Countries 1975–2007	Bank-deposit-to GDP ratio and bank-credit-to-private-sector--GDP ratio.		Remittances are positively related to measures of financial development.
Bayangos and Jensen (2011)	Philippines 1989–2009	Exchange rate and labor market.	2SLS	Labor market effects of emigration and remittances have a significant impact on competitiveness.
Rao and Hassan (2011)	40 Countries 1960–2007	Rate of growth of per worker output.	Panel data estimation and GMM approach.	Insignificant direct growth effects and positive indirect growth effects through investment and financial development.
Barajas et al. (2009)	84 countries 1970–2004	Per capita GDP growth (control variable: average growth of trading partners).	OLS-IV and fixed effect-IV	No robust and significant positive effect of remittances on long-run growth.
El-Sakka and McNabb (1999).	Egypt 1967–1991	Wages and inflation, black market premium and interest rate differentials.	OLS	Economic activity in the host country has a positive effect on remittances. Domestic and foreign interest rate differentials have a negative effect on remittances. Inflation has a positive and significant impact on remittance inflows.
Panel B. Studies related to host countries				
Islam et al. (2013)	USA 1952–2000	Real per capita GDP	Gregory-Hansen cointegration and VECM	Lon-run bidirectional causality.
Baas and Melzer (2012)	Germany 1996–2009	GDP, exports, imports.	Simulation of a general equilibrium model	An increase in remittances results in a high share of exports, an improvement in trade balance and an increase in GDP.
Ortega and Peri (2009)	OECD countries 1980–2005	Growth, employment, investment, and productivity.	Logit model OLS with year fixed effects. 2SLS.	Increase in GDP and employment. No significant effect on total factor productivity.
Vargas-Silva (2008)	USA–Mexico 1981.1–2006.2	GDP, FDI	Baxter and King Filter. SVAR	Remittances are countercyclical to Mexico's business cycle while FDI is procyclical.
Morley (2006)	USA 1930–2002	Real per capita GDP	ARDL and cointegration	Unidirectional long-run causality from growth to remittances.
Panel C. Studies related to host vs. origin countries				
Vargas-Silva and Huang (2006)	USA, Brazil, Colombia, Dominican Republic, El-Salvador and Mexico 1981.1–2003.4.	Macroeconomic conditions: host country–USA: Federal funds rate, money supply, consumer price index, and unemployment. origin countries: exchange and inflation rate.	VECM and Granger causality	Host country (USA) factors are more important.

Table 1 (*continued*)

Authors/year	Countries/sample period	Variables	Methods	Main results
Panel B. Studies related to host countries				
Cooray and Mallick (2013)	International 1970–2007	Macroeconomic determinants of remittances	Dynamic panel system–GMM method	Remittance inflows decrease with home country volatility and increase with host country volatility
Panel D. Studies related to Saudi Arabia and to other GCC countries				
Alkhathlan (2013).	Saudi Arabia 1970–2010	Real GDP, government expenditures, exportations, and inflation.	ARDL and ECM	Negative and insignificant relationships in the long-term and negative and significant relationships in the short-term between growth and remittances.
Termos et al. (2013).	GCC countries 1975–2008	Inflation, real money less real remittances, real GDP, oil prices, and federal fund rates.	Panel cointegration	Long-term relationship between variables of the model. Remittance outflows reduce inflation by 14%–30%.
Nawfal and Termos (2009)	GCC countries 1971–2004.	Global GDP. Government expenditures in GCC. Oil prices. US federal funds rate.	OLS and fixed effect.	Remittance responses to oil prices are positive and inelastic.
Rahman (2006)	Saudi Arabia 1975–2001	GDP, wages, and interest rates.	Granger causality test	Causality running from remittances to GDP. Wages cause per worker remittances and not the reverse. Remittances affect interest rates and not the reverse.

Notes: ARDL: autoregressive distributed lag model. ECM: error correction model; VECM: vector error correction model. GMM: generalized method of moments; IV: instrumental variables; OLS: ordinary least square; SVAR: structural vector autoregressive model. 2SLS: two-stage least square regression.

remittances and the active population. The two variables are in phase and the direction of the arrows shows that remittance outflows in Saudi Arabia are strongly influenced by changes in the active population over the short- and long-run horizons.

The remainder of the paper is structured as follows. Section 2 presents a review of the related literature. Section 3 describes the data used, presents the results of the standard Granger causality, tests and describes the three wavelet methods employed. The empirical results are summarized in Section 4, and Section 5 presents economic policy implications and the paper's conclusions.

2. Literature review

In the migration literature, the term “migrant remittances” has generally come to refer to transfers in cash or in kind from a migrant to household residents in the country of origin (Migration Policy Institute, MPI[4]). However, according to the International Monetary Fund's (IMF's) classification, migrant remittances must be distinguished from “workers remittances” in that the latter refers to transfers in cash or in kind from migrants to resident households in countries of origin. These are typically enduring transfers made from members of the same family to persons based abroad who are absent for a year or longer. Wages, salaries, and other forms of remuneration (in cash or in kind) paid to individuals who work in a country other than the country where they legally reside are identified as “compensation to employees.”[5]

Over the last decade, workers' remittance outflows have become an increasingly prominent source of external funding for many developing and emerging countries. The effects of workers' remittances on other macroeconomic aggregates such as inflation, economic growth, financial development, government expenditures, unemployment, and foreign exchange rates have become some of the most frequently addressed issues in the migrant literature.

On a practical level, inflows or outflows of workers' remittances are of critical importance to policy making and financial institutions that are required to understand and identify causality linkages and relationships with other macroeconomic factors for both host and remitting countries. For monetary authorities, remittance outflows may be used as implicit monetary tools to exert deflationary pressures on inflation. They may be used as tacit tools for stimulating local investments by convincing foreign workers to invest their money. In Table 1 (Panels A to D), we review previous works focused on the relationship between remittances and key macroeconomic variables. In doing so, we rank these studies according to (A) the country of origin, (B) those studies related to host countries, (C) those studies that compare host and origin countries, (D) those studies focused on Saudi Arabia and/or GCC countries.

From the aforementioned studies, we find that empirical studies are tremendously profuse and that numerous econometric frameworks (e.g., cointegration, causality tests, error correction models, autoregressive distributed lag models (ARDL)) have been used to provide a deeper understanding of workers' remittances and their effects. However, most studies have been concerned with workers' remittance inflows and no specific attention has been paid to economic and financial concerns related to outflows from a country. Previous studies have identified several factors that may interact with workers' inflows or outflows. These factors include the employment rate (Amuedo-Dorantes and Pozo, 2006), inflation (Narayan et al., 2011; Termos et al., 2013; El-Sakka and McNabb, 1999), real economic growth (Ahamada and Coulibaly, 2013; Chami et al., 2008; Jouini, 2015; Gupta et al., 2009; Barajas et al., 2009; Kumar, 2013; Kumar and Stauvermann, 2014; Lim and Simmons, 2015), financial development (Aggarwal et al., 2011; Chowdhury, 2011; Nyamongo et al., 2012), inequality and poverty (Imai et al., 2014), business cycles (Bayangos and Jensen, 2011; Chami et al., 2008; Vargas-Silva, 2008), competitiveness (Bayangos and Jensen, 2011), fiscal policies and debt sustainability (Chami et al., 2008), and foreign exchange rates (Chami et al., 2008; Acosta et al., 2009), but few studies have been conducted in the empirical literature on migration. These studies show that workers' remittances are affected by several macroeconomic factors in both remittent and recipient countries. In their paper, using Granger causality tests, variance decomposition, and impulse response functions, Vargas-Silva and Huang (2006) tested the effects of macroeconomic changes on workers' remittances in remittent and recipient countries. The authors found that workers' remittances respond more to changes in macroeconomic conditions in remittent countries than to changes in recipient countries. Accordingly, foreign workers focus more on the economic conditions of the remittent country relative to

[4] Available at http://www.migrationpolicy.org/article/remittance-data.

[5] For example, wages earned by seasonal or other short-term migrant workers (i.e., abroad for less than a year) are included in this category as well as border workers who work but do not reside in a neighboring country (MPI, Migration Information Sources, 2013). It also includes wages and salaries earned by the local staff of foreign institutions (e.g., embassies and international organizations) and companies that are based abroad but that operate locally.

the economic conditions of the home country when determining how much to remit. Likewise, El-Sakka and McNabb (1999) show that the interest rate differential is a determinant factor of workers' remittances.

Prior studies related to oil-rich countries (e.g., Saudi Arabia) as host countries are scarce. We cite studies conducted by Rahman (2006), Termos et al. (2013), Nawfal and Termos (2009), Taghavi (2012), and Alkhathlan (2013). For instance, Rahman (2006) conducts linear causality tests to identify the main determinants of workers' remittance outflows in Saudi Arabia.[6] The author shows that economic growth is positively associated with workers' remittance outflows. In addition, the author notes that remittance outflows exhibit procyclical patterns. Alkhathlan (2013) applies the ARDL and ECM to analyze the linkage between economic growth and remittance outflows in Saudi Arabia for 1970–2010. The results reveal a negative but statistically non-significant relationship between the two variables in the short-term.

Using a time-varying parameters vector autoregressive, Haddad and Choukir (2015) analyze the time-varying impulse responses of non-oil output, investment, and the current account balance to structural remittance outflows shocks in Saudi Arabia. The authors unveil that responses depend on the magnitude of structural volatilities of remittance outflows. Specifically, highly volatile remittance outflows seem to have persistent negative effects on non-oil GDP, investment, and current account balance levels in the 1970s and the1980s. In another study, Termos et al. (2013) use panel data on six countries of the GCC region for 1972–2010 to analyze the effects of workers' remittance outflows on inflation. They show that remittance outflows exert deflationary pressure on remitting countries and that the staggering volume of remittance outflows may be viewed as a stabilization tacit monetary tool for GCC policy makers.

Overall, the aforementioned studies highlight the multi-pronged effects that remittances have on macroeconomic factors. However, the nexus between these variables remains controversial mainly due to methods and approaches that are performed in studying their interactions. Our study aims to contribute to literature on the relationship between workers' remittance outflows and leading macroeconomic variables for Saudi Arabia. We argue that our contribution is significant for at least two reasons. First, our paper addresses a lack of studies conducted on the Saudi Arabian economy by assessing eventual relationships between remittance outflows and real output growth, employment rates, and government spending for 1980–2013. Second, the present study differs from previous works in its novel use of three wavelet methods to investigate dynamic relationships between workers' remittance outflows and the selected macroeconomic variables in the time–frequency domain.

3. Data and methodology

3.1. Data, variables, and preliminary analysis

We apply the wavelet methodology to analyze lead/lag interactive linkages between workers' remittance outflows and leading macroeconomic variables in the time–frequency domain for Saudi Arabia. To do so, we collect yearly data for 1980–2013[7] from the Saudi Arabia Monetary Agency (SAMA) and World Bank databases (2014a, 2014b). All variables are expressed in real terms (consumer price index, 2010) per capita. As stressed earlier, we examine interactions between remittance outflows, economic growth, government expenditures, and active populations. We use these leading macroeconomic variables in the context of Saudi Arabia for several reasons. In terms of output growth, we stress above that prior studies related to the output growth–remittance nexus are not conclusive and provide occasionally conflicting results. On the one hand, on a large scale, immigrants may positively affect the output growth of a host country through the production mechanism: more workers are likely to generate more goods and services. On the other hand, the outflow of remittances may have a negative impact on economic growth. Indeed, the lack of re-investment opportunities for immigrants' income induced by the many restrictions imposed on foreign workers may hinder economic activity. In regards to government spending, we hypothesize that workers' remittance outflows may have an adverse effect on government spending. Continuous remittances can seriously reduce the government spending multiplier, hence compromising the effectiveness of fiscal policies (see, for instance, Nawfal and Termos, 2009). The growing size of these remittances places downward pressure on the government spending multiplier, especially when governments plan to boost spending in cases of recession; this spending level should be relatively higher to offset remittance leakages.

To analyze interactions between workers' remittance outflows (RM) and the labor market, and due to the unavailability of unemployment time series for the period under study, we refer to the total active population (ACPOP) as a proxy for employment.[8] In Saudi Arabia, the labor market has characteristics similar to those of GCC countries; it is dominated by its foreign workforce. In the mid-2013, immigrants accounted 56.5% of the employed population and for 89% of the private sector workforce. Despite the launch of the *"Nitaqat"*[9] program in June of 2011, which is focused on the "*Saudization"* of the workforce, immigrants continue to constitute a high share of the employed population, and the unemployment level for nationals remained relatively high at 12.2% (28.4% of the 15–29 age group (17.5% for men and 60.3% for women)) by the end of 2014.

The effects of remittances on the labor market in both receiving and sending countries are ambiguous. Economic models expect that labor market effects of immigration depend most prominently on the structure and specificities of the immigrant-receiving economy, as well as the skill mix of the immigrants, relative to the resident population. On the theoretical side, an increase in the labor supply due to immigration is expected to depress wages or raise the unemployment rate of host country. However, on the empirical side, conclusions from prior studies are still unconvincing as researchers were unable to isolate the effects of immigration from those of other factors such as differences in skills, education, and experience. Furthermore, some studies that discriminate between long-run and short-run impact unveil that in response to immigration, while unemployment may increase in the short run, in the long run, the overall rate of unemployment falls permanently. Based on these arguments, we presume that is useful to consider for the unemployment when analyzing the causality linkages between workers' remittance outflows and the key macroeconomic variables in Saudi Arabia. Specifically, at least two main aspects are motivating our choice. First, we conjecture that the relationship between remittances and unemployment is unstable through time horizons (short and long run) since it is affected by several macroeconomic and global risk factors. The use of the wavelet approach may provide more insights to the changing patterns of the causal linkage between remittances and unemployment. Second, according to the last official statistics, Saudi Arabia has a population of 29 million people in 2011 and the estimated foreign

[6] Variables used as determinants in the study include real GDP, wages per worker, returns and parity conditions, and other composite indices pertaining to socio-economic factors and to risk indicators of the Saudi economy.

[7] It is worthily noting that the inception of the sample period was conditioned by two main aspects. First, the availability of the data for all the selected variables for the Saudi economy. Second, our sample period starts from 1980, because before that date remittances constitute a very low percentage of GDP (<2%). Furthermore, the big waves of migrants to GCC countries have started after the first oil boom in 1973 which stirred economic diversification and infrastructure-building, resulting in much larger flows of skilled and semi-skilled workers.

[8] It would be more informative to investigate interactions between workers' remittance outflows and the unemployment rate for Saudi citizens. Unfortunately, for Saudi Arabia, unemployment rate data are only available from 1999.

[9] "Nitaqat" means zones in Arabic.

Table 2
Descriptive statistics.

	GDPg	RMg	GEXg	RM/GDP
Mean	0.00961	0.03184	0.01846	0.06964
Median	0.03123	0.00104	0.00165	0.05757
Maximum	0.21682	0.25775	0.27918	0.13476
Minimum	−0.22625	−0.14197	−0.17513	0.02908
S.D.	0.11681	0.11349	0.10790	0.02866

Notes: S.D. refers to the standard deviation. RMg is the growth rate of workers' remittance outflows. GEXg denotes the growth rate of government expenditures, and GDPg refers to the growth rate of the real GDP.

population at the end of 2014 is 33%.[10] These immigrants represent about 80% of the work force and the employment rate, according to the ministry of labor is about 12.1%. Based on these statistics, it is useful to investigate the relationship between remittance outflows and the unemployment rate in Saudi Arabia with a time–frequency domain.

In Table 2, we report descriptive statistics on the growth rate of the selected time series: the growth rate of the real GDP per capita (GDPg), the growth rate of real remittances per capita (RMg), the growth rate of real government expenditures per capita (GEXg), and the ratio of remittances to GDP (RM/GDP). From these statistics, we show that the ratio of remittances to Saudi Arabian GDP ranges between a maximum of 13.5% for 1994 and a minimum of 2.9% for 2007, measuring at 6.96% on average for 1980–2013.

Fig. 1 reports the annual time movement of the real GDP growth rate and changes in workers' remittance outflows for the sample period. From this figure, we find that during the 1980–1990 sub-period, the two variables change in the same manner, and changes in the real GDP rate are followed by similar remittance outflow trends. The workers' remittance growth rate increased in 1987 when the real GDP growth rate also increased. During the 1990–2008 sub-period, the remittance growth rate and real GDP fluctuated in response to crude oil price volatility.

Fig. 2 presents the share of remittance outflows and government expenditures to GDP overtime. From this figure, we find that the two variables change in the same manner throughout the sample period, suggesting the presence of an eventual strong causality linkage between the share of government spending relative to GDP and of remittance outflows relative to GDP. More specifically, it is well known that Saudi Arabia has the largest budget deficit among the GCC countries. Empirically speaking, it has been frequently shown (see Ghali, 1997; Joharji and Starr, 2010; Alshahrani and Alsadiq, 2014) that output growth in Saudi Arabia has a positive impact on government expenditures, although empirical evidence is inconclusive in regards to the causality linkage between government expenditures and economic growth. From Fig. 2, we can conclude that the remittance outflow share relative to GDP responds to changes in the government spending share relative to GDP. More precisely, we believe that remittance outflows are lagging (i.e., government expenditures to the GDP share are leading) government expenditures to the GDP share. It is worth noting that this preliminary analysis should be interpreted with caution, and we believe that the phase difference analysis employing the wavelet coherence approach will help shed light on the interactive link between both variables in time–frequency dimensions.

3.2. Results of the Granger causality tests

In this sub-section, we present the results of standard causality tests (recommended by Granger, 1969) conducted to identify causality linkages between real output growth, workers' remittances, government expenditures, and the active population. Our main objective is to compare the results of the linear standard approach to those obtained from wavelet methods. Before performing Granger's (1969) standard

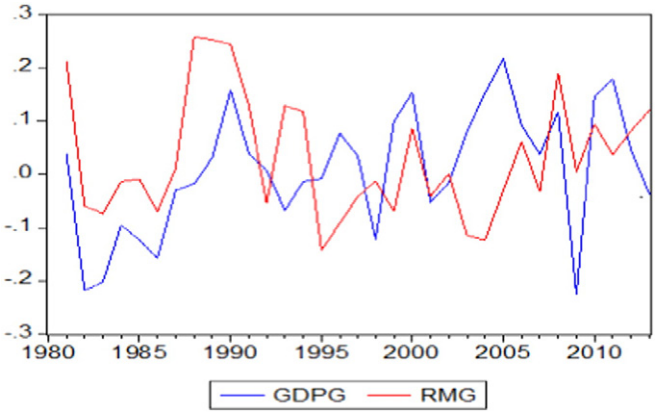

Fig. 1. Time movements of the growth rate of real GDP per capita and of the growth rate of real remittance outflows per capita.

causality test, we test for the existence of eventual cointegration relationships between the selected time series. When there is cointegration between the selected variables, at least one directional causality exists. Granger causality tests are based on the following equations,[11] which are designed to detect the causality relationship between each time series pairwise. Explicitly, we test for:

Output growth-remittances linkages:

$$GDP_t = \alpha_0 + \sum_{i=1}^{n} \alpha_i GDP_{t-i} + \sum_{i=1}^{n} \beta_i RM_{t-i} + \varepsilon_t \quad (1)$$

$$RM_t = \alpha_0 + \sum_{i=1}^{n} \delta_i RM_{t-i} + \sum_{i=1}^{n} \lambda_i GDP_{t-i} + \varepsilon_t \quad (1a)$$

Remittance-government expenditure linkages:

$$GEX_t = \alpha_0 + \sum_{i=1}^{n} \alpha_i GEX_{t-i} + \sum_{i=1}^{n} \beta_i RM_{t-i} + \varepsilon_t \quad (2)$$

$$RM_t = \alpha_0 + \sum_{i=1}^{n} \delta_i RM_{t-i} + \sum_{i=1}^{n} \lambda_i GEX_{t-i} + \varepsilon_t \quad (2a)$$

Remittance-active population linkages:

$$RM_t = \alpha_0 + \sum_{i=1}^{n} \alpha_i RM_{t-i} + \sum_{i=1}^{n} \beta_i ACPOP_{t-i} + \varepsilon_t \quad (3)$$

$$ACPOP_t = \alpha_0 + \sum_{i=1}^{n} \delta_i ACPOP_{t-i} + \sum_{i=1}^{n} \lambda_i RM_{t-i} + \varepsilon_t \quad (3a)$$

In Eqs. (1) and (1a), n refers to the lag length, and it was selected based on the Akaike and Schwartz information criteria. t designates time and ε_t are the uncorrelated residual terms. In Eqs. (1) and (1a), we determine the causality relationship between the real output growth per capita (GDP) and remittance outflows (RM). $H_0: \beta_i = 0$ and $\lambda_i = 0$, and any i refers to the null hypothesis of no causality. Conversely, when $H_1: \beta_i \neq 0$ and $\lambda_i \neq 0$ for i, there is unidirectional/bidirectional causality relationship between real output growth and remittances. If the β_i parameter is significant while λ_i (Eq. (1a)) is not, remittance outflows cause real output growth, and output growth does not cause remittances. If the β_i and λ_i parameters are statistically significant, so there is a bidirectional causality relationship between the two variables. The null hypothesis is tested by means of the Fisher (F) statistics, which follows the F-distribution with n and $(T-n-1)$ degrees of freedom, where n is the number of lags selected for each regression test and where T is the length of the series. If the calculated F statistic value is higher than the critical value for a given level of significance, the null hypothesis is rejected, thus confirming the existence of a causal link

[10] Saudi Arabia's Central Department of Statistics & Information: http://cdsi.gov.sa/english/.

[11] Due to space limitations, the equations inherent to the other pairwise relationships are not presented here. The cointegration results are also not reported here but are available upon request from the corresponding author.

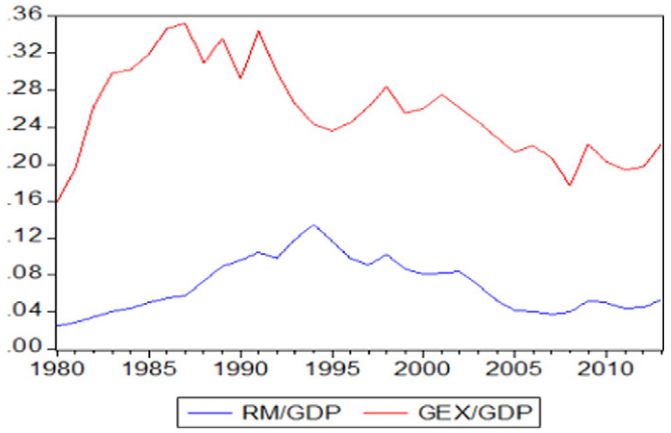

Fig. 2. Time movements of the share of workers remittances and government expenditures to GDP.

between the selected variables. The causality test results are presented in Table 3.

As shown in Table 3, we identify a strong bidirectional causality relationship between output growth and remittance outflows. The reported results present causality linkages from remittance outflows to government expenditures that are significant at the 5% level. Furthermore, another bidirectional causal relationship is identified between the active population and remittances. Overall, these Granger causality test results are consistent with those of previous work that use standard econometric tools. However, the lack of prominent insights made into causality linkages in the time–frequency domain suggest that the applied approach cannot be used to generate practical recommendations for policy makers and regulators in Saudi Arabia. Wavelet methods may generate a more comprehensive understanding of interrelationships between remittance outflows and the selected macroeconomic variables for the Saudi economy.

In what follows, we present the results of the Morlet wavelet method tests. This method allows one to not only detect patterns of evolutionary paths between selected variables but to also examine how variables are related at different frequencies and how such relationships evolve over time and across different time scales.

3.3. Wavelet methods

As stated above, previous empirical studies on dynamic co-movements between workers' remittance outflows on economies of home and remitting countries are mostly based on standard time series techniques involving cointegration, linear causality tests, ECM, SVAR, VAR, and ARDL models. Such analyses disregard the frequency dimensions of time series and their lead/lag interrelationships within time scales and frequencies. By contrast, the wavelet methodology allows for the study of co-movements between variables and serves as a prominent alternative tool for examining inter-temporal causal relationship in time and frequency domains, thus permitting a deeper understanding of directions, strength, and extents of such causal relationships. In the present study, the wavelet methodology is used to separate a time series into more elementary functions with information on the series. Formally, wavelets are derived from a single function referred to as the mother wavelet $\psi_{u,s}(t)$, which is defined as a function of time positioning (u) and scale (s). Following previous studies by Torrence and Compo (1998), Grinsted et al. (2004), and Kiviaho et al. (2014), our wavelet method involves feature extraction and a multi-resolution analysis whereby wavelets are defined as

$$\psi_{u,s}(t) = \frac{1}{\sqrt{s}}\psi\left(\frac{t-u}{s}\right) \tag{4}$$

Wavelets are assumed to be the square-integrable function, i.e., $\psi(.) \in L^2(\mathbb{R})$. In Eq. (1), $1/\sqrt{s}$ denotes the normalization factor that ensures the unit variance of the wavelet, and $\|\psi_{u,s}\|^2 = 1$. u refers to the location parameter that gives the exact position of the wavelet. s is the scale dilatation parameter of the wavelet that specifies how the wavelet is stretched. Accordingly, a higher scale implies a more stretched wavelet, which is appropriate for the detection of lower frequencies.

It is worth noting that several types of wavelets have been proposed in the wavelet literature. Wavelets have different specifications and are frequently used in diverse research areas. In this study, we use three variants of the wavelet methodology: the continuous wavelet coherence, the wavelet power spectrum, and the cross-wavelet power spectrum. Moreover, we refer to the phase difference analysis to investigate dynamic co-movements between remittance outflows and the selected macroeconomic variables for Saudi Arabia in the time–frequency domain. As stated by Addison (2002), the Morlet wavelet is a complex and analytic wavelet within a Gaussian envelope with good time–frequency localization. Formally, the Morlet wavelet is given by

$$\psi^M(t) = \frac{1}{\pi^{1/4}} e^{i\omega_0 t} e^{-t^2/2} \tag{5}$$

where ω_0 is the central frequency of the wavelet. As in Grinsted et al. (2004) and Rua and Nunes (2009), we set $\omega_0 = 6$. This ω_0 value strikes a good balance between time and frequency localizations. The Morlet wavelet is centered at the $(0, w_0/2\pi)$ point in the time–frequency domain (see Aguiar-Conraria et al., 2008).

3.3.1. Continuous wavelets

According to Aguiar-Conraria et al. (2008, pp. 2865), one unique facet of wavelet applications to economics lies in the almost exclusive use of the discrete wavelet transform. This tendency is difficult to understand, as the same type of analysis can be conducted more easily using the continuous wavelet transform. Following Rua and Nunes (2009), the continuous wavelet transform is given by

$$W_x(u,s) = \int_{-\infty}^{\infty} x(t) \frac{1}{\sqrt{s}} \overline{\psi\left(\frac{t-u}{s}\right)} dt \tag{6}$$

More specifically, $W_x(u,s)$ is obtained by projecting the specific wavelet $\psi(.)$ onto the selected time series. The main benefit of the continuous wavelet transform lies in its aptitude to decomposing and then consequently reconstructing the $x(t) \in L^2(\mathbb{R})$ function as follows:

$$x(t) = \frac{1}{C_\psi} \int_0^{\infty} \left[\int_{-\infty}^{\infty} W_x(u,s) \psi_{u,s}(t) du \right] \frac{ds}{s^2}, \quad s>0 \tag{7}$$

It is worth noting that the main advantage of the wavelet transform lies in its capacity to preserve energy levels of the selected time series. This property is used here for the power spectrum analysis, which specifies the variance as follows:

$$\|x\|^2 = \frac{1}{C_\psi} \int_0^{\infty} \left[\int_{-\infty}^{\infty} \left| W_x(u,s)^2 \right| du \right] \frac{ds}{s^2} \tag{8}$$

Table 3
Standard Granger causality tests.

Real output growth–Remittances		Government expenditures–Remittances		Active population–Remittances	
GDP→*RM*	RM→*GDP*	*GEX*→*RM*	*RM*→*GEX*	ACPOP-RM	RM→*ACPOP*
0.10***	1.84**	3.92*	1.66**	0.63**	0.2**

Notes: This table presents the uni-/bidirectional Granger causality test results for the selected variables.
* 10% significance level.
** 5% significance level.
*** 1% significance level.

3.3.2. Wavelet power spectrum

As shown in Torrence and Compo (1998) and Aguiar-Conraria et al. (2008), the wavelet power spectrum can be simply defined as $|W_n^x|^2$, and this measure assesses the local variance of each variable. Statistical significance, according to Grinsted et al. (2004), can be tested in relation to the null hypothesis that the variable under consideration has a significant power spectrum, i.e., the signal is generated by an AR (0) or AR(1) stationary process with a mean background power spectrum (P_f). Based on Monte Carlo simulations involving the computation of white- and red-noise wavelet powers, Torrence and Compo (1998) show that, for each time period n and scale s, the corresponding distribution of the local wavelet power spectrum can be written as

$$D\left(\frac{\left|W_n^X(s)\right|^2}{\sigma_X^2} < p\right) \Rightarrow \frac{1}{2} P_f \chi_v^2 \tag{9}$$

where P_k is the mean of the spectrum at the Fourier frequency f that corresponds to the wavelet scale s ($s \approx {}^1/_f$), and v takes a value of 1 or 2 for real or complex wavelets, respectively.

3.3.3. Cross-wavelet power, wavelet coherence, and phase differences

The CWP shows the area in the time scale space where the time series shows a high common power. As noted by Aguiar-Conraria et al. (2008), the CWP captures the local covariance of two time series at each frequency and shows quantitative similarities of power between them. In our study, the CWP allows us to locate regions where two selected variable rates co-move in the time–frequency space. For Hudgins et al. (1993), for each signal X and Y, individual wavelet spectra are specified as $W_n^X(s)$ and $W_n^Y(s)$, respectively. In the time–frequency analysis, the cross-wavelet between two signals is represented by the cross-wavelet spectrum $W_n^{XY}(s)$, which is defined as shown in Eq. (10).[12]

$$W_n^{XY}(s) = W_n^X(s) W_n^{Y^*}(s) \tag{10}$$

where $W_n^{Y*}(s)$ is the complex conjugate of $W_n^Y(s)$ and * denotes complex conjugation. The CWP is therefore given by $|W_n^{XY}|$ and it measures the local covariance of two variables at each scale. Torrence and Compo (1998) show that the theoretical distribution of the CWP for two signals with background power spectra P_k^X and P_k^Y generates the following form:

$$D\left(\frac{\left|W_n^X(s) W_n^{Y*}(s)\right|}{\sigma_X \sigma_Y} < p\right) = \frac{Z_v(p)}{v} \sqrt{P_k^X P_k^Y} \tag{11}$$

where σ_X and σ_Y designate standard deviations of x and y, respectively. $Z_v(p)$ is the confidence interval level related to the probability p for a *pdf* (probability density function), which is defined by the square root of the product of two χ^2 distributions.

On the other hand, the wavelet coherence of two time series $x = \{x_n\}$ and $y = \{y_n\}$ is defined as the localized correlation coefficient between these series in the time–frequency space (Torrence and Compo, 1998). It is thus a very useful tool for detecting time series co-movements. Following Torrence and Webster (1999), the wavelet coherence is computed as the shared absolute value of the smoothed cross-wavelet spectra normalized by the product of the smoothed individual wavelet power spectra of each time series:

$$R^2(u,s) = \frac{\left|S\left(s^{-1} W_{xy}(u,s)\right)\right|^2}{S\left(s^{-1}\left|W_x(u,s)\right|^2\right) S\left(s^{-1}\left|W_y(u,s)\right|^2\right)} \tag{12}$$

where S denotes the smoothing parameter. In the no-smoothing case, the wavelet coherence is equal to one. Additionally, the squared wavelet coherence coefficient satisfies the following inequality $0 \le R^2(u,s) \le 1$. A value close to zero denotes a weak correlation, while a value close to one signifies the presence of a high correlation. Thus, the wavelet coherence tool is an appropriate tool for investigating joint dynamics of remittance outflows, GDP growth rates, employment patterns, and government expenditures over time and across frequencies.

Finally, the phase difference offers insight into the lateness of oscillations between two variables as a function of frequency. The phase difference of two time series, $\phi_{x,y}$, characterizes the phase connectedness between them. It effectively provides information on time series positions in the pseudo-cycle. The phase difference is given as

$$\phi_{x,y} = tan^{-1}\left(\frac{\Im\{W_n^{xy}\}}{\Re\{W_n^{xy}\}}\right) \text{with } \phi_{x,y} \in [-\pi, \pi]. \tag{13}$$

We interpret the phase difference in terms of arrow directions. Arrows pointing to the right (left) indicate that variables are in phase (out of phase). When arrows point to the right and up (down), the first variable x is leading (lagging). Conversely, if arrows point to the left and up (down), the variable x is lagging (leading).

4. Empirical results and discussion

In this section, we present the wavelet results. Wavelets allow one to not only detect configurations of co-movements between selected time series but to also examine how these variables are related at different frequencies and how such relationships evolve through time and across different frequencies.

4.1. WPS analysis

The WPS delivers information on the time–frequency characteristics of original time series. Fig. 3 (Fig. 3a–e) shows the WPS plots for workers' remittance outflows and for the related macroeconomic time series for Saudi Arabia. Blue (red) regions denote low (high) intensity levels (power) in the local variance. High intensity levels denote extreme movements. Subsequently, the power increases from the blue regions to the red regions. The statistical significance of the wavelet power is tested against the null hypothesis of a stationary process with a background power spectrum, which is estimated from the Monte Carlo simulations based on phase-randomized surrogate series. The thick black contour denotes the significance level of the WPS at the 5% level. The cone of influence (COI), which is denoted by light-colored regions, separates the high-power regions from the rest. For Torrence and Compo (1998), the COI is defined as the region of the wavelet spectrum wherein edge effects are important.

The graphs presented in Fig. 3 show a resemblance to wavelet power concentrations at low frequencies for all of the selected variables with the exception of the remittance outflow share to real GDP. We find, for example, a moderate wavelet power for real GDP per capita, real government expenditures per capita, and the active population. These regions are located within the 8- to 10-year frequency level and are distributed across the 1980–1988 period. Real government expenditures per capita present a significant high wavelet power spectrum at the 8- to 9-year time scale and over the 1990–2003 period as denoted by the solid black contour, which isolates regions in which the spectrum is significant at the 5% level. Another commonality pertains to the existence of another island of the high wavelet power spectrum at the end of the sample period, which is found at the 1- to 2-year frequency scale. The presence of such a region suggests that real GDP, real public expenditures, and real workers' remittance outflows show significant vicissitudes during 2013. Taken together, the evidence regarding the localized variance of workers' remittances and other macroeconomic

[12] See Torrence and Compo (1998) for more information on the CWS hypothesis and on confidence levels.

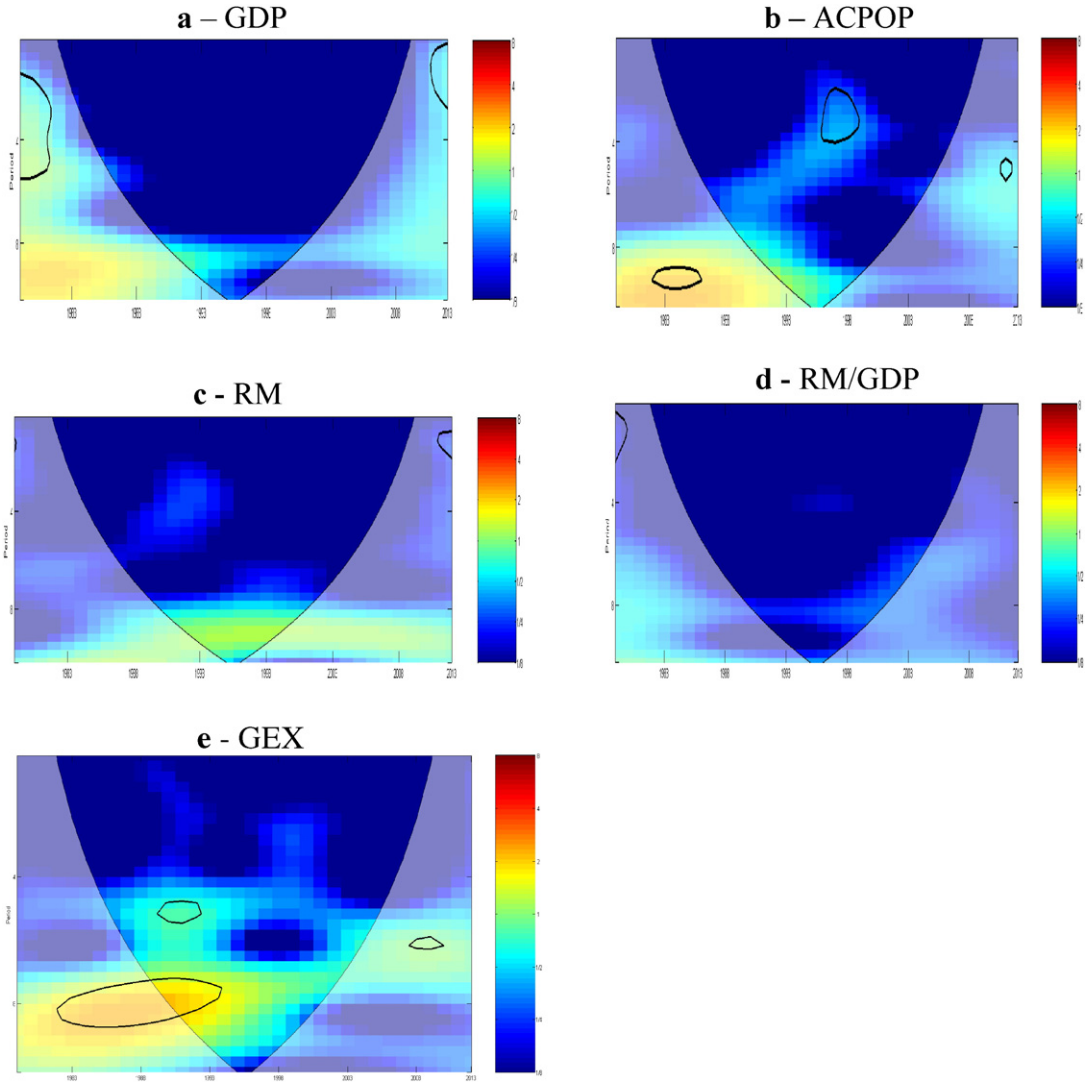

Fig. 3. Continuous WPS of the remittance outflows and related macroeconomic variables. Notes: The black contour denotes regions in which the spectrum is significant at the 5% level against red noise. The cone of influence (COI), denoted by light-colored regions, delimits the high-power regions. Time and frequency (years) are represented on the horizontal and vertical axes, respectively.

variables appears to suggest that they present a degree of co-movement across the time–frequency dimensions.

4.2. CWPS analysis

The WPS is still not the most suitable tool for examining the degree of coherence (i.e., correlation), as it does not allow one to easily interpret potential co-phases between workers' remittance outflows and other macroeconomic variables across time and frequency (see, for more information, Aguiar-Conraria and Soares, 2011). Information inherent to the phase is lost when using the absolute value of local covariance between two time series. Consequently, two macroeconomic variables involving the same high-power regions may not be alike. The CWPS of the selected variables reported in Fig. 4 (Fig. 4a–j) is very expedient, as it allows on to solve this problem by presenting co-evolution through time and frequency among workers' remittance outflows and the other macroeconomic variables.

These plots show that six out of ten pairs show in-phase variations across the main time scales, as arrows point to the right in several significant regions (i.e., Figs. 4a, 4b, 4d, 4e, 4g and h). For example, from Fig. 4g which presents the CWPS between real GDP per capita and real government expenditures, we can identify two yellow areas that enclose regions where the CWP is significant at the 5% level. The first region of high CWP corresponds to the 1980–1988 sub-period at the 8- to 10-year frequency levels, and arrows are pointed to the right, indicating that real GDP per capita and government expenditures per capita are in phase. The second region corresponds to the 2009–2013 sub-period at the 4- to 6-year time scale. For the two regions, arrows are pointed to the right and down, suggesting that the government expenditure variable is lagging behind the real GDP growth rate. This means that an increase in real GDP is followed by an increase in government spending. In the literature, there are two opposing theoretical views on the dynamic linkage between government expenditures and output growth: Wagner's law and Keynesian theory. According to Wagner's law, public expenditures are endogenous to economic growth and causality runs from growth to public expenditures. Keynesian theory assumes that causality runs from government expenditures to economic growth, especially during recession periods. In this discipline, empirical studies have yielded conflicting results. According to Levine and Renelt (1992), results are contingent on model specifications and on components of government expenditures considered in each study. Here, our findings support Keynesian theory. Given its role in financing investment and consumption activities, government spending is a key element of macroeconomic policies. Available statistics for Saudi Arabia show that over the last two decades, government expenditures have grown from 26.7% in 2008 to 39.3% in 2014 as a share of GDP. Similar

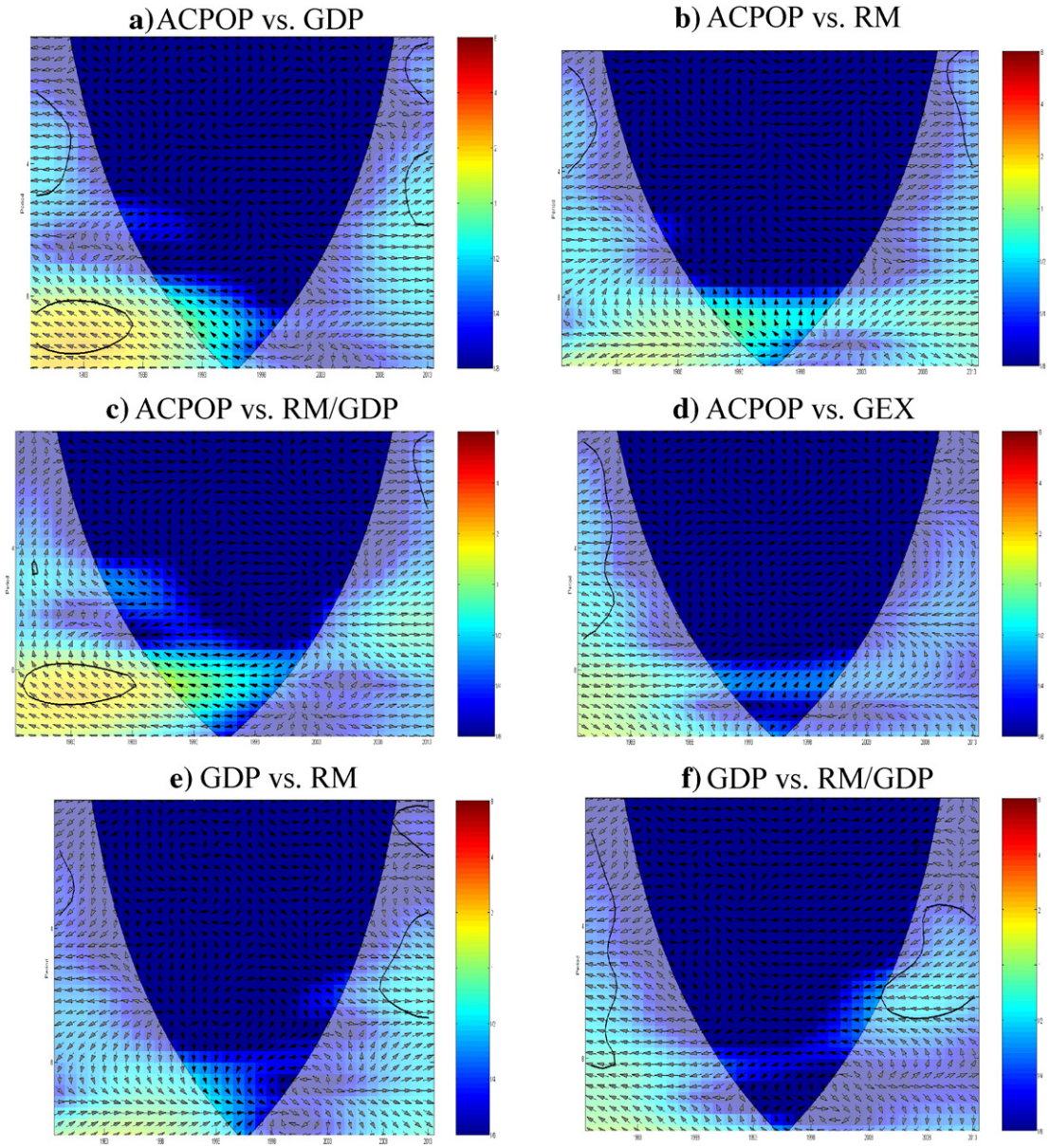

Fig. 4. CWPS of workers' remittance outflows and the other macroeconomic variables. Notes: The dashed black contour encloses regions where cross-wavelet power spectra are significant at the 5% level against red noise estimated from Monte Carlo simulations based on phase randomized surrogate series. The cone of influence (COI) is denoted by light-colored regions that delimit important power regions. The arrows denote the phase difference between the two time series. The directions of the arrows mark phase differences between two time series. Arrows pointed to the right (left) indicate that variables are in phase (anti-phase). For arrows pointed to the right and up (down), the first variable is leading (lagging), and for arrows pointed to the left and up (down), the first variable is lagging (leading). Time and frequency (year) are represented on the horizontal and vertical axes, respectively.

features have been found for the relationship between real GDP and workers' remittance outflows (Fig. 4e). More specifically, we identify two islands of high and statistically significant CWS for the beginning and end of the sample period. For these two regions, arrows are pointed down and to the right, meaning that the two variables are in phase with real GDP as a leading variable. Put differently, an increase in the real GDP growth rate is followed by an increase in workers' remittance outflows. These results may suggest that remittance outflows are determined by macroeconomic conditions of the Saudi economy.

4.3. The WC analysis

As noted above, the wavelet coherence of two variables $x = \{x_n\}$ and $y = \{y_n\}$ can be defined as the localized correlation coefficient between these variables in the time–frequency space. The development of wavelet coherence thus shows how the selected variables interact over time and across time frequencies. In Fig. 5, we present the estimated wavelet coherence for pairs of the selected variables and we determine the potential co-evolution of these variables. In this sub-section, we analyze co-movements for each couple. As in previous works, we distinguish between short- (1- to 5-year frequency) and long-term trends (frequency of >5 years). As noted above, we focus on co-movements between workers' remittance outflows and the other Saudi aggregates and on lead–lag relationships in the time and frequency dimensions.

4.3.1. Remittance outflows and real economic growth

In Fig. 5a, we present the wavelet coherence between workers' remittances per capita and real economic growth per capita. From this plot, we find that co-movements between the two variables are changing through time and frequency. We identify two red-colored regions for the 1980–1988 and 2003–2013 sub-periods that show a strong and significant positive relationship between workers' remittance

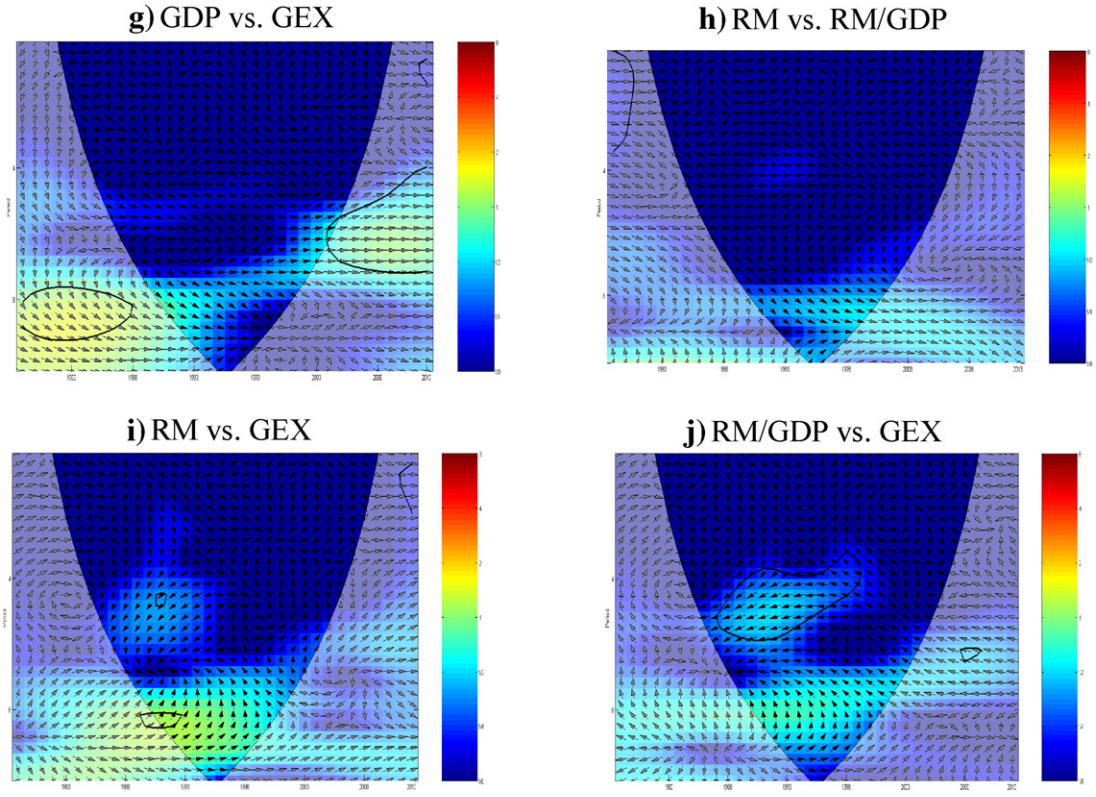

Fig. 4 (*continued*).

outflows and real GDP growth for Saudi Arabia in the high-frequency (short-term) domain. The interactive link between remittance outflows and real economic growth seems to be more evident in the short term. This result may be attributable to the fact that non-Saudi workers remit their money immediately to their home countries as denoted by red-colored regions in the high-frequency band (1–4 years). This result corroborates some previous study results that are restricted to standard time series modeling but that do not provide information on frequency differences. For instance, Alkhathlan (2013) finds a negative but non-significant relationship between remittances and real economic growth for Saudi Arabia. The direction of the arrows captures the phase difference and lead–lag interactions between the two time series. For the first 1980–1988 sub-period, the arrows are pointed downward and to the left, indicating that the two variables are out of phase with real GDP as a leading variable. The increase in workers' remittances follows the increase in real economic growth in Saudi Arabia. Conversely, for the 2003–2013 sub-period, arrows are pointed downward and to the right, showing that real GDP and workers' remittance outflows are in phase with real GDP as a lagging variable.

4.3.2. Remittances and government expenditures

Fig. 5b presents the wavelet coherence plot between real workers' remittances and government expenditures per capita. We find that the relationship between the two variables varies over time and frequency domains. In addition, we find two red-colored regions that show strong and statistically significant coherence between the two variables for the 1- to 4-year frequency band. The first island corresponds to the first 2 years of the sample period, and the second covers the last 5 years of the 2009–2013 sample period. For the two sub-periods, the two variables appear to be in phase, as the arrows are pointed upward and to the right with workers' remittances serving as a leading variable. In other words, the increase in workers' remittance outflows is followed by an increase in government expenditures per capita. Furthermore, we find positive but non-significant coherence (ranging between 0.6 and 0.7) between workers' remittance outflows and government spending for the entire sample period within the low-frequency band (frequency band for >8 years). We extend our analysis of co-evolutionary patterns between remittance outflows and government spending by considering real GDP. Fig. 5c presents wavelet coherences between government expenditures per capita and remittance outflow shares to GDP. We note the existence of a large red-colored area for the 1998–2013 period, denoting a positive and significant linkage between the two variables for the 4- to 8-year frequency band. When observing the directions of the arrows, we find that the two variables are out of phase, as the arrows are clearly pointed upward and to the left with remittances as part of real GDP serving as the lagging variable (i.e., government expenditure is the leading variable). Put differently, the causal relationship moves from government expenditures per capita to the share of remittance outflows to GDP. In the long term, the remittance outflow share of the GDP is positively affected by an increase in government expenditures per capita for the Saudi economy. From an economic perspective, the increase in government expenditures increases the real GDP, which in turn raises workers' remittance outflows. Our results are in line with those of previous studies (e.g., Alkhathlan, 2013).

4.3.3. Employment and remittance outflows

We report wavelet coherences between workers' remittance outflows per capita and our employment proxy in Fig. 5d. For this pair, we identify two red-colored regions for 1980–1985 and 2003–2013, denoting significant and positive co-evolution between the two variables. For 1980–1985, we find high levels of co-movement between workers' remittance outflows and the active population for the 1- to 4-year time scale, and arrows are pointed upward, suggesting that the two variables are in phase with that active population as a leading variable. This means that the active population precedes an increase in workers' real remittance outflows. A similar pattern is found for the second sub-period for the 1- to 8-year frequency band. The two variables

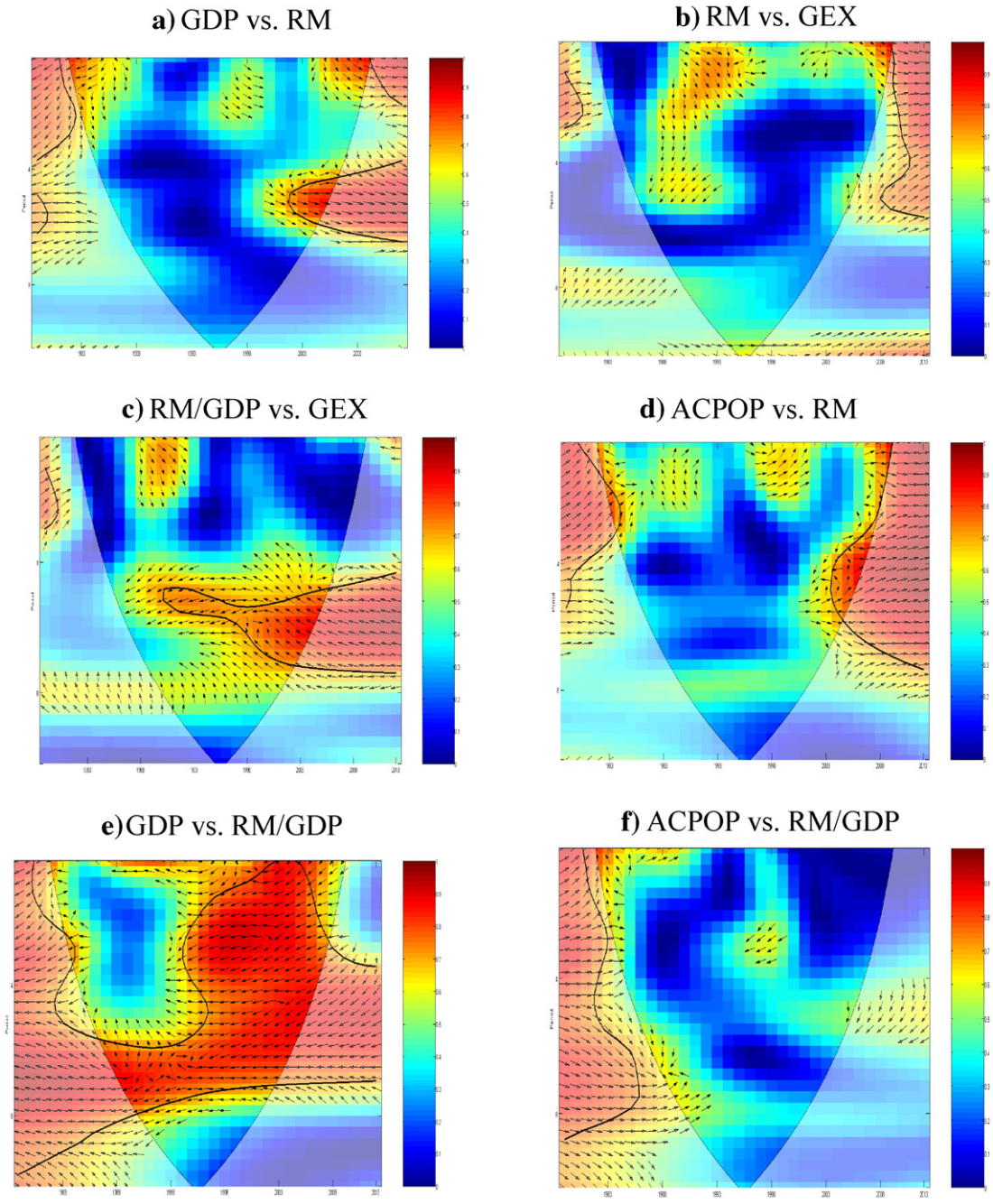

Fig. 5. Wavelet coherences between remittance outflows and the other aggregates. Notes: The dashed black contour encloses regions where wavelet coherence is significant at the 5% level against red noise estimated from Monte Carlo simulations using phase randomized surrogate series. The COI is denoted by light-colored areas, which delimit the important power regions. The arrows denote the phase difference between the two time series. The directions of the arrows capture the phase difference between two time series. Arrows pointed to the right (left) indicate that variables are in phase (out of phase). For arrows pointed to the right and up (down), the first variable is leading (lagging), and for arrows pointed to the left and up (down), the first variable is lagging (leading). Time and frequency (year) are represented on the horizontal and vertical axes, respectively.

are in phase and the direction of the arrows shows that remittance outflows in Saudi Arabia are strongly influenced by changes in the active population. Overall, we find positive and significant effects between the two variables for the short- and long-run horizons. In addition, we reveal a lead–lag relationship through time and frequency between workers' remittance outflows and the active population by applying the wavelet coherence method. Fig. 6 summarizes the main causality relationships between remittances and the pertaining macroeconomic variables obtained from the wavelet methodology. Such results would not have been drawn through the use of standard models of time series.

5. Summary and policy implications

Recent trends indicate that workers' remittance outflows are affected by changes in the macroeconomic conditions in remittent countries that include, among other factors, changes in real growth rates, real exchange rates, inflation, government expenditures, and unemployment rates. While several empirical studies have been conducted on this subject, more emphasis has been placed on developed economies, leaving other emerging and frontier economies disregarded. Existing studies present unconvincing and occasionally contradictory results regarding interactive linkages between workers' remittance outflows and other

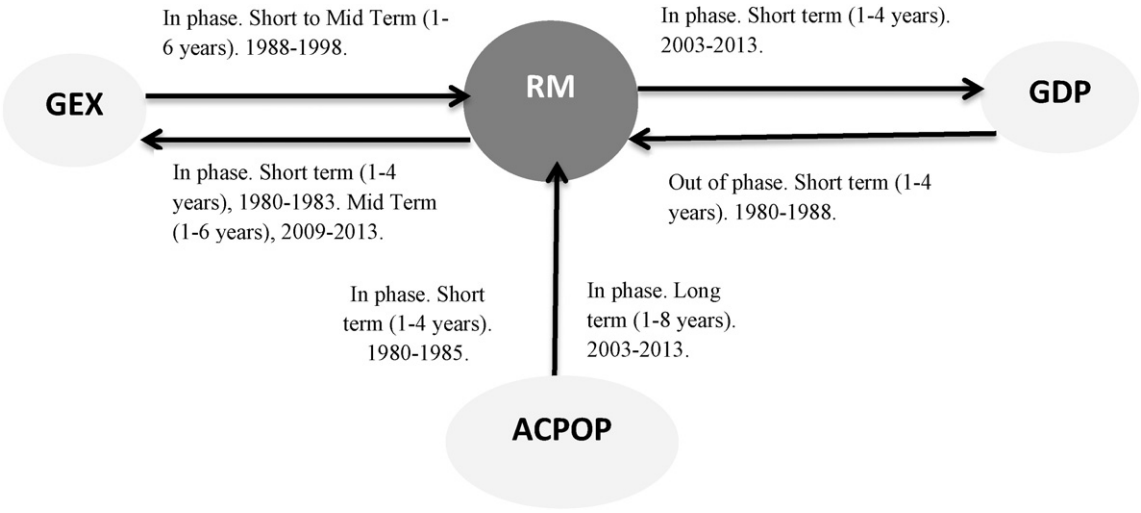

Fig. 6. Causality relationships between remittances and macroeconomic variables over time and frequency domains. Notes: GDP refers to the Saudi real output growth per capita. RM denotes workers' remittance outflows and GEX denotes Saudi government expenditures. ACOP refers to the active population. Thin black arrows denote the direction of causality.

macroeconomic aggregates. Such results may be attributed to the use of several standard linear and nonlinear empirical frameworks that are restricted to time as one dimension and that are prone to the time series non-stationarity problem and to other empirically stylized facts.

Based on the aforementioned considerations, we analyzed the dynamic relationship between workers' remittance outflows and other macroeconomic variables across time–frequency dimensions. More specifically, we assessed lead–lag interactive linkages between workers' remittance outflows and global macroeconomic aggregates for Saudi Arabia for 1980–2013. Unlike prior studies dedicated to this issue, we use three variants of the wavelet methodology (the wavelet power spectrum, the cross-wavelet power spectrum, the coherence wavelet) to identify their co-evolution in the time and frequency space.

Our wavelet analysis shows that workers' remittance outflows are strongly related to real growth rates, employment and government expenditures for Saudi Arabia. Moreover, directions and types of relationships over frequency bands and time are not the same across variable combinations. We find that workers' remittance outflows are positively related to real economic growth and that co-movement is more evident at higher-frequency bands (short run). A similar pattern of co-movement is found for the relationship between remittance outflows and government expenditures. In addition, the wavelet analysis shows that Saudi remittance outflows are positively affected by changes in government spending. Our findings may help policy makers better understand dynamic relationships between remittance outflows and changes in macroeconomic conditions in Saudi Arabia.

From a financial stability perspective, our results will be of use to policy makers when designing economic policies, and especially during turbulent periods. In this vein, policies should account for both pessimistic and optimistic points of view. Pessimistic views contend that remittances drain host country economies and have adverse effects on external balance of payment outcomes. Among host country citizens, remittance outflows are often viewed as outflows of purchasing power. However, according to the optimistic view, remittances form part of an immigrant's earnings that reflect a person's incremental contributions to host country outputs. Immigrants can offer skills that have been previously unavailable in host countries, and this can change the output mix while providing host countries with a comparative advantage in exporting new tradable items. This can in turn increase a country's foreign exchange earnings, improve its balance of payment outcomes, and improve its domestic product. In order to benefit more from migrant contributions, Saudi Arabia should establish more encouraging legislation that allows immigrants to settle in a sustainable manner, as it has been shown in the literature that remittance outflows are determined by migrants' plans for temporary or permanent migration. Temporary migrants are likely to remit more than twice the amount of money than permanent migrants. According to this perspective, as an open economy, Saudi Arabia could benefit from an opposite Dutch disease effect by which the competitiveness of tradable goods sectors increases.

Acknowledgements

The authors would like to thank the Co-Editor Prof. P. Narayan and an anonymous referee for thoughtful comments and suggestions. This research has been financed by Scheikh Al-Fawzan Research Chair for Expectations of Saudi Macro-economy at Al-Imam Muhammad Ibn Saud Islamic University (IMSIU), Riyadh, Saudi Arabia. The authors would like to thank Prof. M. Khaled for his help and cooperation.

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