An Econometric Analysis of the Illicit South African Tobacco Market

by

Cassandra Pengelly

Thesis presented in partial fulfilment of the requirements for the degree of Master in Economics in the Faculty of Economic and Management Sciences at Stellenbosch University

Supervisor: Prof. W. H. Boshoff

August 2023

Declaration

By submitting this thesis electronically, I declare that the entirety of the work contained therein is my own, original work, that I am the sole author thereof (save to the extent explicitly otherwise stated), that reproduction and publication thereof by Stellenbosch University will not infringe any third party rights and that I have not previously in its entirety or in part submitted it for obtaining any qualification.

Date: . . . .

Abstract

An Econometric Analysis of the Illicit South African Tobacco Market

C. Pengelly

Thesis: MCom (Economics)

August 2023

Using monthly data This paper investigates the constraint imposed on the legal tobacco market by the presence of illicit cigarettes.

This is the second paragraph of my English abstract.

Contents

Declaration **i**

Abstract **ii**

Contents **iii**

List of Figures **v**

List of Tables **vi**

1 Introduction **1**

2 The Legal and Illicit Tobacco Market in South Africa **3**

3 Methodology **5**
3.1 Theoretical Model 5
3.2 Data 6
3.3 Stationarity and Cointegration 8
3.4 vector error correction model 10

4 Analysis **11**
4.1 Additional models 12

5 Conclusion **14**

Appendices **16**

A Time Series Data **17**
A.1 Time series logged graphs 17
A.2 Seasonality decomposition 18
A.3 Structural breakpoint test 18

B Stationarity Testing **19**

C Cointegration Tests **21**

D Vector Error Correction Results **22**

E Diagnostic Tests **24**

F Additional models **26**

List of References **29**

List of Figures

3.1 Plot for variables at levels 8

A.1 Plot for variables at levels 17
A.2 Decomposisiton and seasonality for quantity of legal cigarettes series 18

E.1 Plot of residuals 25

List of Tables

A.1 Chow structural break test for Real Price Ratio time series 18

B.1 Augmented Dickey Fuller Tests 19
B.2 Phillips-Perron Unit Root Test 19
B.3 KPSS Unit Root Test 19
B.4 Zivot-Andrews Unit Root Test 19
B.5 Augmented Dickey Fuller Tests 20
B.6 Phillips-Perron Unit Root Test for Differenced Series 20
B.7 KPSS Stationarity Test for Differenced Series 20
B.8 Zivot-Andrews Unit Root Test 20

C.1 Johansen Trace Test 21
C.2 Johansen Maximum Eigenvalue Test 21

D.1 Vector Error Correction Model 22
D.2 Vector Error Correction Model Short Run 23

E.1 Portmanteau test 24
E.2 ARCH test 24
E.3 Jarque–Bera normality test 24

F.1 2SLS regression results 26
F.2 Vector Error Correction Model 27
F.3 Vector Error Correction Model Short Run 27
F.4 Portmanteau test 27
F.5 ARCH test 27
F.6 Jarque–Bera normality test 28

Chapter 1

Introduction

This study examines the long-run relationship between legal cigarette consumption and the relative price of legal and illicit cigarettes in South Africa. Between 1993 and 2010, South Africa took significant steps to address tobacco consumption (Republic of South Africa and Department of Planning, Monitoring and Evaluation:2). The Tobacco Products Control Act (TPCA) 83 of 199 was introduced, along with a number of other important pieces of legislation. In addition, more substantial excise taxes on tobacco products were imposed during this period, leading to a significant decrease in smoking prevalence and smoking-related deaths (Republic of South Africa and Department of Planning, Monitoring and Evaluation:2}. However, from 2010, there was a substantial change in the South African tobacco market. There was an influx of smaller cigarette manufacturers into a previously concentrated industry, leading to downward pressure on cigarette prices (Tingum, Mukong and Mdege, 2020:5). At the same time, the trade in illicit cigarettes picked up. Consequently, government and health officials became increasingly concerned with the tobacco market and its effect on tax revenue, illegal activities and public health. To address these concerns, it is important to understand the relationship between consumer behaviour and real and illicit cigarette prices, which is investigated in this study.

The focus of this paper is the extent to which cigarette smokers change their long-run consumption of legal cigarettes in response to a change in the the *relative* real price of legal cigarettes. Several empirical studies have estimated the South African demand function for cigarettes[1], but few have accounted

[1] See for example Mukong and Tingum (2020); Boshoff (2008); Dare *et al.* (2021)

for illicit cigarette *prices* or use monthly observations in the models, which is predominantly due to data-sourcing issues. The present study addresses this gap. The findings show that the long-run elasticity for the relative real price of cigarettes ranges between -0.58 and -0.885, which demonstrates that the illicit tobacco market places a constraint on the legal market. Understanding the relationship between legal cigarette demand and illicit prices is useful for the discussion regarding the efficacy of health and taxation policies aimed at reducing cigarette consumption (Tingum, Mukong and Mdege, 2020:3).

The paper starts with a brief outline of the legal and illicit tobacco market in South Africa in section 2, followed by an overview of the theoretical model in section 3.1. Section 3.2 provides an extensive discussion of the dataset. An econometric approach is taken in this study, utilising several unit root tests, Johansen cointegration tests, a vector error correction model as well as a two stage least square estimation. The unit root and cointegration tests are discussed in section 3.3, and the vector error correction model is presented in section 3.4. Following this, the results of the vector error correction model are analysed, and additional models are estimated and assessed (section 4). The final section (5) concludes.

Chapter 2

The Legal and Illicit Tobacco Market in South Africa

The health problems associated with tobacco consumption are significant and have been well-documented (Tingum, Mukong and Mdege, 2020:62). Worldwide, smoking is one of the leading causes of preventable deaths; and in South Africa 23% of the total deaths in 2018 were smoking-related (Statistics South Africa). Given the large and negative impact of smoking, the tobacco market has come under increasing scrutiny by governments and health organizations. A significant component of the tobacco market is the illicit cigarette trade, which the Financial Action Task Force (2012:7) defines as

> "*... the supply, distribution and sale of smuggled genuine, counterfeit or cheap white tobacco products.*"

The illicit tobacco market gives rise to concern on three main fronts: public health, tax evasion, and criminal activity. From a public health perspective, illicit cigarettes make smoking more affordable and thereby increases tobacco access (van der Zee, van Walbeek and Magadla, 2020:242). Cheaper cigarettes may induce non-smokers to smoke, increase the volume of cigarettes consumed by smokers, and decrease the likelihood that smokers will quit smoking (**?**:pagenumber; van der Zee *et al.*, 2020:242).

According to the International Agency for Research on Cancer (2011), tobacco use is more prevalent among low socio-economic groups, and the poor are more sensitive to cigarette prices (IARC, 2011:276). Consequently, the health problems linked to smoking are disproportionately higher among the poor, which results in a greater burden on the public healthcare sector (). In South Africa, the healthcare costs associated with smoking amounted to R14.48 billion in 2016, which accounted for 4.1% of health spending (). In addition to the healthcare costs, there are indirect costs linked to smoking such as the loss of productive lives and loss of productive days due to illness (Boachie, Rossouw and Ross, 2020:pg). In 2016, the total cost of smoking to South Africa was R42.32 billion (0.97% of GDP).

Evidently, the public health and economic costs of tobacco use are extensive. In an effort to reduce tobacco use, many countries have implemented tax and price policies on tobacco products (Chaloupka, Straif, Leon). For a middle-income country, South Africa was considered to be at the forefront of tobacco control policies, including excise duties, for many years (Vellios, van Walbeek and Ross, 2022). From a fiscal perspective, excise tax on cigarettes is a source of government revenue, which is undermined by the illicit tobacco industry. **Blah ble** estimates the loss of income due to the illicit market to be R123123 The loss of income

Chapter 3

Methodology

3.1 Theoretical Model

This paper makes use of the demand model to estimate the effect of a relative price change, between licit and illicit cigarette price,on cigarette consumption in South Africa from January 2012 to March 2020. The relationship between cigarette consumption, price and income is well-documented (for example, see Boshoff (2008); Tingum *et al.* (2020); World Health Organization and WHO Tobacco Free Initiative, 2010) and is typically expressed as:

$$Q_t = f(P_t, Y_t, D_t) \tag{3.1.1}$$

Where Q_t represents cigarette consumption volume in period t, P_t is the price of cigarettes adjusted for inflation, Y_t is disposable income, and D_t is is the dummy variable for the change in market structure that occurred in 2018.

Two sets of prices are used in this study; the first is the legal cigarette price, which is the price of cigarettes for which duties have been paid. The second is the illicit cigarette price, which is the price of cigarettes for which duties have been paid. For this study, cigarette consumption, as represented by Q_t, is the quantity of legal cigarettes consumed (cigarettes for which duties have been paid).

3.2 Data

The sample period for this study runs from January 2012 to March 2020. Monthly data is used such that there are 99 observation points for each variable in the data set. One of the advantages of using monthly data rather than annual data is that it allows for more degrees of freedom. The data used in this study include figures for South Africa for the average prices of legal cigarettes, the average prices of illicit cigarettes, volume of legal cigarettes consumed, tobacco excise duties, Value Added Tax (VAT), and real disposable income. The data for legal and illicit prices, and legal cigarette consumption are provided by a prominent South African cigarette manufacturer. The other data are extracted from the South African Reserve Bank (SARB) and Statistics South Africa (StatSA).

To prepare the legal price data for analysis, the most popular price category (MPPC) is identified as the 20-cigarette pack. A weighted average of before-tax 20-pack prices is used as a base price. The excise duty per 20's pack and VAT are then added to the base price to calculate the price of legal cigarettes. The legal and illicit prices, and disposable income values, are adjusted for inflation, taking December 2016 as the base month and year, respectively. For the statistical analysis in sections 3.3 and 3.4, all of the variables have been transformed into log form to reduce variability.

For the model specification, the two price series are combined to form a single price-ratio series. The price ratio is calculated as the real legal price divided by the real illicit cigarette price ($P_{legal}/P_{illicit}$). Consumer theory suggests that individuals consider relative price differences between substitutes in addition to the absolute price of the good when making consumption decisions (Azar, 2011:450). Thus, it makes intuitive sense to model the effect of a relative change in prices on the quantity of legal cigarettes. Gross national income is taken as a proxy for the disposable income of smokers.

The series are plotted in levels in figure 3.1 below. The general downwards trend of the graph depicting the real price of legal cigarettes suggests that inflation has been outstripping nominal cigarette prices. Real legal prices decreased slightly over the period 2012 - 2018. On the other hand, real prices for illicit cigarettes remained fairly constant from 2012 until late 2014. Following a small and sharp uptick, illicit prices slowly decreased from late 2014 until November

2018 when prices increase rapidly. The real price ratio is generally flat from 2012 - 2016, and then trends upwards slightly, implying that real legal prices were decreasing more slowly than real illicit prices were decreasing over the same period. There is a sudden drop in the price ratio in November 2018, reflecting the spike in real illicit prices. The graphs of the respective logged series (shown in appendix A.1) illustrate similar patterns.

The plot of the real price ratio suggests that there is a structural break in the series, in late 2018. To test for this[1], the Chow structural test (based on the work by Chow, 1960) is employed for November 2018; the results are presented in table A.1. The p-value is less than 0.05; thus, the null hypothesis is rejected and there is sufficient evidence to conclude that the data contains a structural breakpoint. To control for this in the model, a dummy variable is used to capture the change in the illicit price (and therefore the price ratio) that occurred in November 2018. The variable is labelled '*Structural change*' and is coded 0 for periods before November 2018, and 1 otherwise.

The graph for the quantity of legal cigarettes in figure 3.1 shows a general downwards trend from 2012 to March 2020, and the series exhibits strong signs of seasonality. The series is decomposed and its separate components are graphed in appendix A.2, which confirm the presence of seasonality. While the series could be seasonally adjusted to account for the seasonality, this may change the outcome of conventional unit root tests, according to Ghysels, 1990, and lead to bias in the estimation of relationships between series (Bell and Hillmer, 2002:110). Therefore, this study uses the unaltered data for this consumption variable in the model estimation.

The overall trends and shapes of the graphs suggest that the series are not stationary, which is formally tested below in section 3.3.

[1]The test was conducted using the programming language *'R'*, using the *'strucchange'* package by Zeileis, Leisch, Hornik and Kleiber (2002) and Zeileis, Kleiber, Krämer and Hornik (2003)

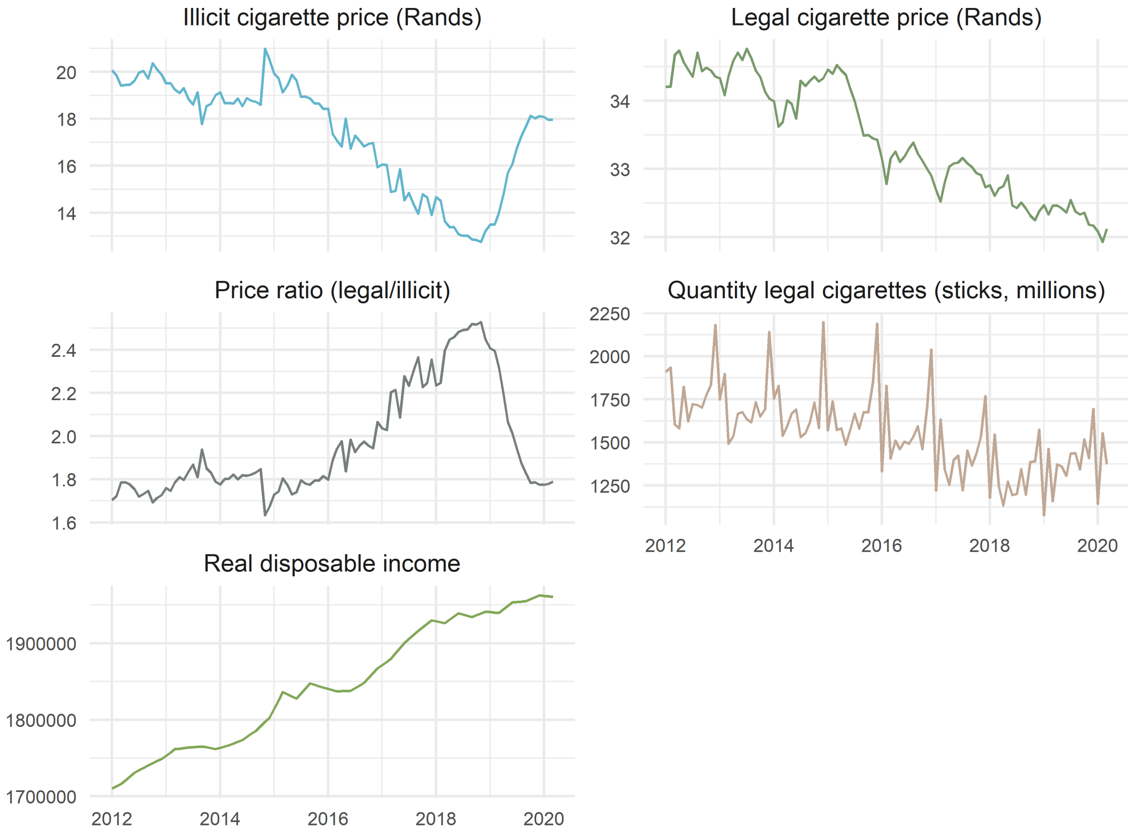

Figure 3.1: Plot for variables at levels

3.3 Stationarity and Cointegration

To test whether the series are stationary, three tests were employed: the Augmented Dickey-Fuller[2] (ADF) and Phillip-Perron[3] (PP) unit root tests, and the Kwiatkowski–Phillips–Schmidt–Shin[4] (KPSS) stationarity test. The results are presented in appendix B.

The results of the ADF tests in table B.1 show that the log of cigarette consumption, log of the real price ratio, and log of real disposable income all contain a unit root since the null hypothesis cannot be rejected, even at a 10% signifiance level. The KPSS stationarity tests (B.3) confirm these results, where the null hypothesis of stationarity is rejected at a 1% level of signifiance for each series. The results of the PP tests are presented in table B.2, which

[2]Based on the work of Dickey and Fuller (1979), using the '*urca*' package by Pfaff (2008*a*)

[3]Based on the work of Phillips and Perron (1988) and using the '*tseries*' package by Trapletti and Hornik (2018)

[4]Based on the work of Kwiatkowski, Phillips, Schmidt and Shin (1992), using the '*tseries*' package by Trapletti and Hornik (2018)

shows that the log of cigarette consumption does not contain a unit root at 1% significance level but that the other two series do contain unit roots.

Given that there is a structural break point in the price ratio series, standard unit root testing may not be appropriate for this series. Consequently, the Zivot-Andrews Unit Root test is used as a robustness check for the stationarity of the price ratio. The results are presented in table B.4 and show that the null of a unit root cannot be rejected, at even 10% level of significance. Thus confirming the original test results.

Based on the unit root test results, the variables are assumed to be non-stationary in levels.

After first differencing each of the series, all tests indicate that the variables are stationary at a 5% level of significance. These results are presented in tables B.5, B.6, B.7, and B.8 for the ADF, PP, KPSS and Zivot-Andrews tests respectively. Given that the series are non-stationary in levels but are stationary in first differences, a cointegration approach can be used to evaluate whether a long-run relationship exists among the variables.

Cointegration

To test for conintegrating relationships, two tests were employed: the Johansen Trace test for Cointegration, and the Johansen Maximum Eigenvalue test for Cointegration based on the work of Johansen and Juselius, 1990.

The Johansen Trace Test for Cointegration indicates that there is one cointegrating vector. As shown in table C.1, the test statistic of 80.8 is larger than 60.2 (the critical value at a 1% level of significance). Thus, the null hypothesis is rejected, where the null hypothesis is that there are zero cointegrating vectors. However, the test statistic 41 is lower than 41.1 (the critical value at a 1% level of significance). This means that the null hypothesis cannot be rejected even at a 1% signicance level, where the null hypothesis is that there is 1 or fewer cointegrating vectors.

The results of the Johansen Maximum Eigenvalue test are presented in table C.2. Similar to the Trace test, the Maximum Eigenvalue test shows that there is a single cointegrating vector. Both cointegration tests were run with a lag length of 3, indicating that the appropriate number of lags to use in the vector error correction model is 2 lags. The presence of a cointegrating vector indicates that a long-run relationship exist among the variables. A vector error correction model is used to combine the long and short-run dynamics. This model is specified and estimated in the following section (3.4).

3.4 vector error correction model

The target variable in this model is the quantity of legal cigarettes consumed. The explanatory variables are the price ratio, disposable income, and the structural shift dummy. The equation representing the long-run equilibrium model is a double-logarithmic demand equation, given by:

$$lnQ_t = \alpha_0 + \alpha_1 lnP_t + \alpha_2 lnY_t + \alpha_3 lnD_t + \mu_t \tag{3.4.1}$$

where $i = 0, 1, 2, 3,$
lnQ_t is the log of legal cigarette consumption,
lnP_t is the log of real price ratio for cigarettes,
lnY_t is the log of real disposable income,
D_t is the dummy variable for the structural break
μ_t is the random error term

The Vector Error Correction model specification is given by:

$$dLnQ_t = \beta_0 + \beta_1 \sum_{i=1}^{n-1} dLnQ_{t-i} + \beta_2 \sum_{i=1}^{n-1} dLnP_{t-i} + \beta_3 \sum_{i=1}^{n-1} dLnY_{t-i} \tag{3.4.2}$$

$$+ \beta_4 D_t + \lambda_i ECT_{t-1} + \mu_t \tag{3.4.3}$$

where $n - 1$ is the lag length, reduced by 1 due to the loss of a lag when differencing a Vector Autoregression (VAR),
d is the difference operator,
β_i represents model's short-run coefficients,
λ_i is the speed of adjustment parameter,
ECT_{t-1} is the error correction term, and
μ_t is the random error term

Chapter 4

Analysis

The VECM uses stationary data at first differences, and is estimated with 1 cointegrating vector and at lag length of 2. The lagged residuals of the long-run relationship are used as an explanatory variable. The results of the model are reported in appendix D. The long run coefficients are summarised in table D.1, where the long run coefficient for the price ratio is 0.885. The positive coefficient sign demonstrates that there is a negative relationship between the number of legal cigarettes consumed and the price ratio. This makes intuitive sense: if the real price of legal cigarettes decreases at a greater rate than the real price of illicit cigarettes, the price ratio shrinks and legal cigarettes are relatively cheaper (than illicit cigarettes); if legal cigarettes are relatively cheaper, the theory of demand predicts that more legal cigarettes will be bought.

Because the model is specified as a double logarithmic model, the long-run coefficients can effectively be interpreted as price and income elasticities. Thus, for a 10% decrease in the real price ratio, cigarette consumption increases by 8.9% in the long run, *ceteris paribus*. The relationship established in the model between legal cigarette quantity demanded and the price ratio demonstrates that the illicit tobacco market places a constraint on the legal market. The negative correlation in the long run between cigarette consumption and the price ratio shows that consumers buy fewer legal cigarettes when the price of illicit cigarettes decreases at a rate that's faster than a decrease in the legal cigarette price.

The long run coefficient for real disposable income is -0.679. The negative coefficient sign signifies that there is a positive, long-run relationship between cigarette consumption and real disposable income, which is consistent with economic theory **REFERENCE**. In the long run, a 10% increase in real disposable income will lead to a 6.8% increase in cigarette consumption, *ceteris paribus*. The model indicates that real prices have a stronger effect on legal cigarette consumption than income does.

The coefficients of the error correction term (ECT), set out in table D.2, measure the speed of convergence to the long run equilibrium. These adjustment coefficients all lie between -1 and 0, with the coefficients for price and quantity being statistically significant. For quantity, the previous month's deviation from long -run equilibrium is corrected in the current month at an adjustment speed of 48.8%. The price ratio converges to steady state equilibrium more slowly at a speed of 14.9%.

The post-estimation diagnostics[1] of the VECM model are presented in appendix F. The Portmanteau test with asymptotic critical values shows there is serial correlation amongst the errors when testing at 15 lags but no serial correlation when using 30 lags (see table E.1). This is problematic as failing the test at 15 lags reduces the reliability of the t-statistics of the model. The ARCH test indicates that the residuals exhibit no conditional heteroscedasticity (see table E.2). Lastly, the Jarque–Bera test for normality shows that the residuals are not normally distributed, which is similar for the individuals series as seen in the residual graphs in figure E.1. The residuals not being normally distributed may indicate bias in the estimation of the coefficients. The results of the diagnostic tests could be due to

4.1 Additional models

Three additional models are estimated to measure the price ratio elasticity in addition to the main VECM model. Given that the supply and demand for cigarettes jointly determine cigarette prices (Viet Nguyen, Le and Nguyen, 2021:7), there may be price endogeneity in the main VECM model. A lower cigarette price increases demand for cigarettes; however, a high cigarette demand will later result in higher cigarette prices. To address this possible endogeneity bias (Deaton, 1997), two specifications of a two-stage least regression (2SLS) model[2] are presented in table F.1.

[1] The diagnostic tests were run in R using the package '*vars*' by Pfaff, 2008*b*.

[2] The regressions were run in R using the package *'ivreg'* by Fox, Kleiber, Zeileis and Kuschnig, 2023.

Both 2SLS models employ the lag of the price ratio as an instrument variable for determining the real price ratio. The lag of the price ratio affects consumer behaviour but is independent of an individual's decision to smoke (Tingum *et al.*, 2020:6). The first 2SLS model ('Model 1') includes cigarette consumption of legal cigarettes as the dependent variable, and the real price ratio (instrumented by its lag), real disposable income and the structural change dummy as the explanatory variable. Table F.1 shows that the real price ratio is significant and has a coefficient of -0.58. Similar to the main VECM model, this coefficient can be interpreted as an elasticity. Thus for a 10% decrease in the price ratio, legal cigarette consumption increases by 5.8%. This is slightly lower than the 8.9% suggested in the main VECM model. The coefficient for real disposable income is not statistical significant, and also has a negative sign, which is counterintuitive. This could be caused by issues with employing gross national income as a proxy for disposable income.

The second 2SLS model ('Model 2') excludes real disposable income as an explanatory variable. The coefficient for the real price ratio is given as -0.771, which has the correct sign and is statistically significant. Without controlling for the influence of disposable income, the elasticity for the price ratio has increased. This model suggests that a 10% decrease in the relative price of legal and illicit cigarettes results in a 7.7% increase in legal cigarette consumption.

The third model is another VECM, which only includes the real price ratio and the structural dummy as explanatory variables. The model is estimated with 1 cointegrating vector and at lag length of 1. The results are summarised in tables F.2 and F.3. The long-run cointegrating vector suggests the price ratio elasticity is -0.798, which is slightly lower than the main VECM value of -0.885. The error correction terms have the correct signs and are statistically significant for cigarette consumption and the price ratio, demonstrating that the short-run deviations from the long-run equilibrium are corrected. The post-estimation tests - reported in tables F.4, F.5, and E.3 - indicate the presence of serial correlation, and normality of residuals.

Chapter 5

Conclusion

This paper evaluates the relationship between legal cigarette consumption and the relative price of legal and illicit cigarettes in South Africa. The results of the vector error correction model demonstrate that the illicit cigarette price imposes a constraint on the legal cigarette market. The estimates of the long-run elasticity for the relative real price of cigarettes range between -0.58 and -0.885. This suggests that a 10% increase in the relative real price is associated with a decrease in legal cigarette consumption of 5.8% - 8.9%. The main VECM findings are consistent with economic theory and literature that cigarette consumption is negatively correlated with price and positively correlated with disposable income (**?**:8). The relative price elasticity is between -1 and 0, which indicates that legal cigarettes are an inelastic good, which is also in line with theoretical expectations.

The results of the study show that the decision to buy legal cigarettes is not only influenced by the price of legal cigarettes and disposable income, but also by the price of illicit cigarettes. If the price of illicit cigarettes decreases at a faster rate than the price of legal cigarettes, there is a decrease in legal cigarette consumption. This suggests that some consumers are willing to substitute legal cigarettes with illicit products, if the relative price of illicit cigarettes decreases. This has implications for health policymakers who are interested reducing cigarette consumption: if an excise tax is increased for cigarettes, all else remaining constant, the price of legal cigarettes will increase relative to illicit cigarettes and become comparatively less attractive. There will be a decrease in legal cigarette consumption (as intended), but some consumers will switch to purchasing illicit tobacco products, thereby reducing the efficacy of the policy. As raised by Boshoff (2008:130) and **?** (**?**:9), health awareness and non-price policies are important tools for reducing smoking, without distorting the relative prices of legal and illicit cigarettes. In addition, the curtailment of the legal tobacco market due to illicit cigarettes undermines the fiscal regime. The government loses revenue from tobacco excise duties when consumers switch from buying legal cigarettes to illicit products.

This study highlights that both legal and illicit cigarette prices affect the demand for legal cigarettes, which should be taken into account when setting health and tax policies in the South African tobacco market.

Appendices

Appendix A

Time Series Data

A.1 Time series logged graphs

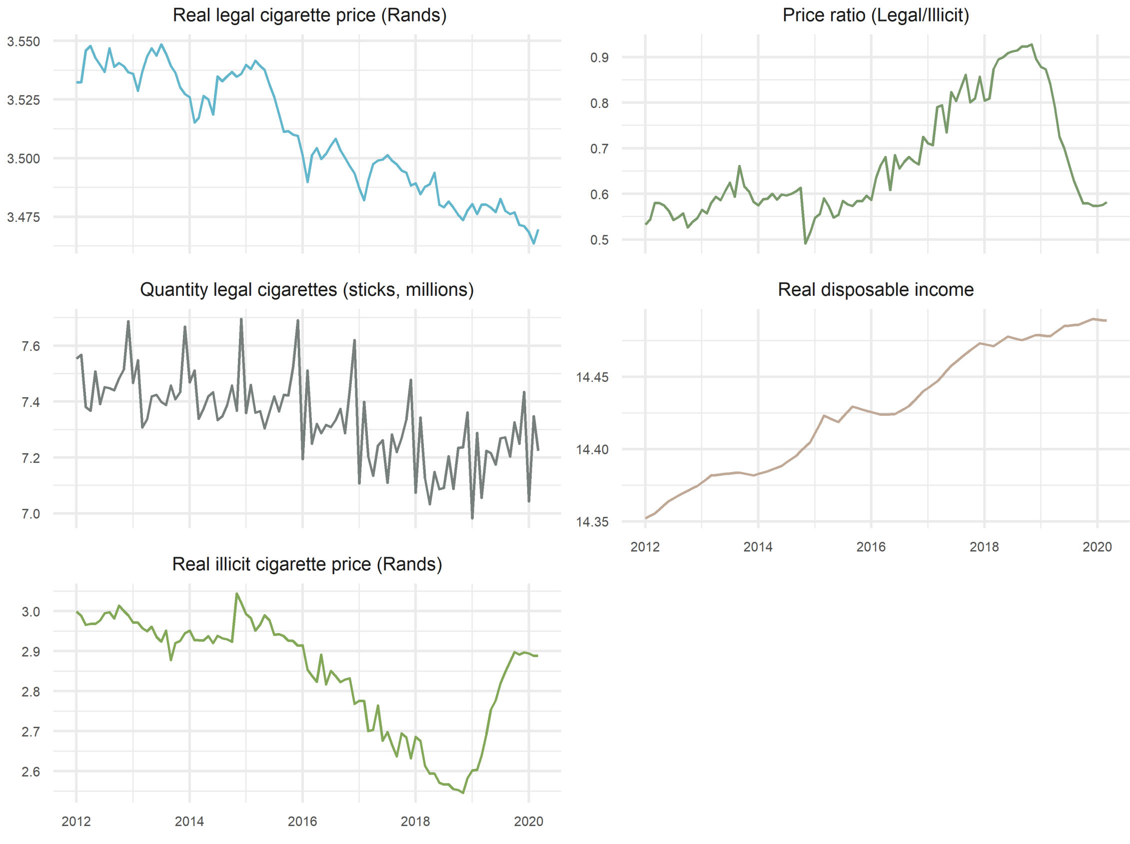

Figure A.1: Plot for variables at levels

A.2 Seasonality decomposition

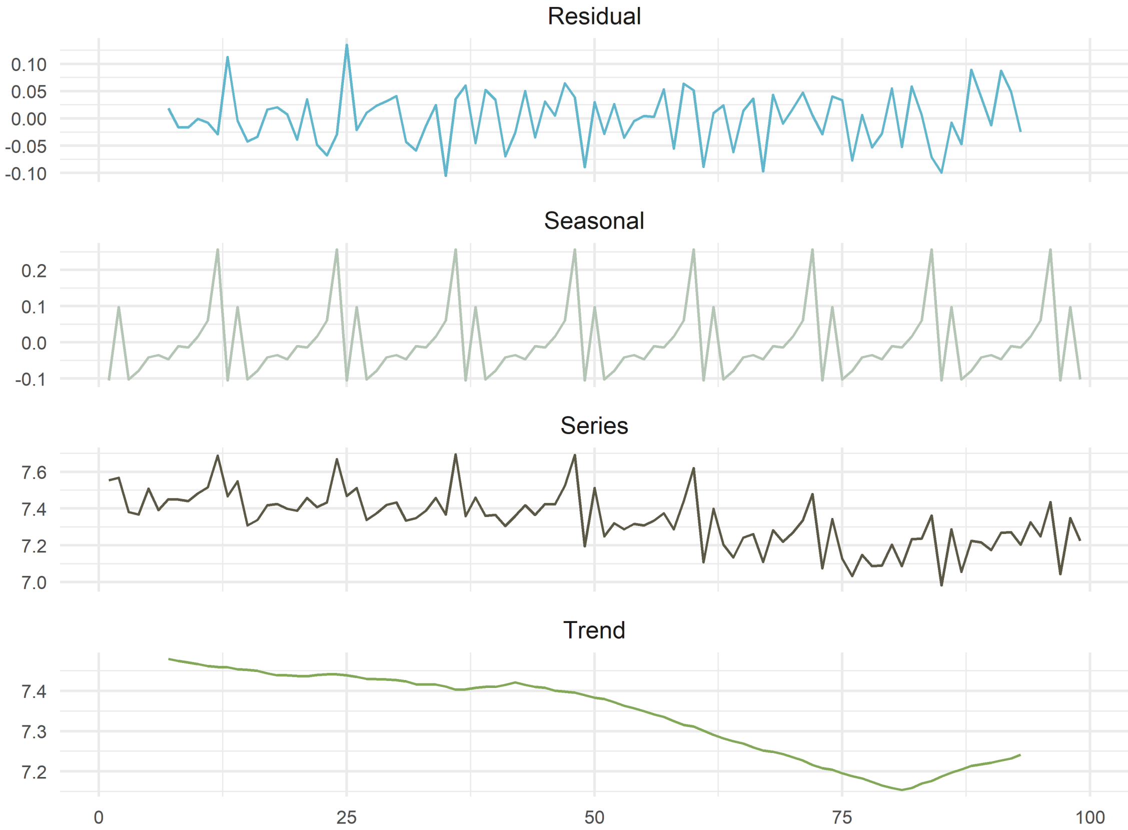

Figure A.2: Decomposisiton and seasonality for quantity of legal cigarettes series

A.3 Structural breakpoint test

Table A.1: Chow structural break test for Real Price Ratio time series

	Statistic	p-value	Alternative
Chow test	67.13	0	Structural breakpoint

Appendix B

Stationarity Testing

Table B.1: Augmented Dickey Fuller Tests

	Test statistic	1%	5%	10%	Alternative
Quantity legal cigarettes	-0.445	-2.6	-1.95	-1.61	stationary
Price ratio	-0.0835	-2.6	-1.95	-1.61	stationary
Disposable income	2.63	-2.6	-1.95	-1.61	stationary

Table B.2: Phillips-Perron Unit Root Test

	Statistic	p-value	Alternative
Quantity legal cigarettes	-119	0.01	stationary
Price ratio	-2.54	0.952	stationary
Disposable income	-6.73	0.726	stationary

Table B.3: KPSS Unit Root Test

	Statistic	p-value	Alternative
Quantity legal cigarettes	1.89	0.01	non-stationary
Price ratio	1.35	0.01	non-stationary
Disposable income	2.55	0.01	non-stationary

Table B.4: Zivot-Andrews Unit Root Test

	Test statistic	1%	5%	10%	Alternative
Price ratio	-3.64	-5.57	-5.08	-4.82	stationary

Table B.5: Augmented Dickey Fuller Tests

	Test statistic	1%	5%	10%	Alternative
Quantity legal cigarettes	-11.8	-2.6	-1.95	-1.61	stationary
Price ratio	-7.7	-2.6	-1.95	-1.61	stationary
Disposable income	-3.47	-2.6	-1.95	-1.61	stationary

Table B.6: Phillips-Perron Unit Root Test for Differenced Series

	Statistic	p-value	Alternative
Quantity legal cigarettes	-153	0.01	stationary
Price ratio	-120	0.01	stationary
Disposable income	-33	0.01	stationary

Table B.7: KPSS Stationarity Test for Differenced Series

	Statistic	p-value	Alternative
Quantity legal cigarettes	0.0229	0.1	non-stationary
Price ratio	0.275	0.1	non-stationary
Disposable income	0.149	0.1	non-stationary

Table B.8: Zivot-Andrews Unit Root Test

	Test statistic	1%	5%	10%	Alternative
Price ratio	-13.2	-5.57	-5.08	-4.82	stationary

Appendix C

Cointegration Tests

Table C.1: Johansen Trace Test

	Statistic	**10%**	**5%**	**1%**
r<=3	4.86	7.52	9.24	13
r<=2	19.2	17.9	20	24.6
r<=1	41	32	34.9	41.1
r=0	80.8	49.6	53.1	60.2

Table C.2: Johansen Maximum Eigenvalue Test

	Statistic	**10%**	**5%**	**1%**
r<=3	4.86	7.52	9.24	13
r<=2	14.3	13.8	15.7	20.2
r<=1	21.8	19.8	22	26.8
r=0	39.9	25.6	28.1	33.2

Appendix D

Vector Error Correction Results

Table D.1: Vector Error Correction Model

	Long run coefficient
Quantity cigarettes	1
Price ratio	0.885
Real income	-0.679
Structural change	0.354
Constant	1.79

Table D.2: Vector Error Correction Model Short Run

	dQuantity Cigarettes	dPrice ratio	dReal income	dStructural Change
ECT	-0.488 ***	-0.149 ***	-0.002	-0.042
	(0.114)	(0.035)	(0.002)	(0.124)
Quantity Cigarettes (dl1)	-1.068 ***	-0.081 *	-0.001	0.035
	(0.101)	(0.031)	(0.001)	(0.111)
Price ratio (dl1)	-2.156 ***	-0.334 **	-0.003	-0.105
	(0.339)	(0.105)	(0.005)	(0.370)
Real Income (dl1)	2.502	-0.195	0.896 ***	11.068
	(7.578)	(2.351)	(0.106)	(8.270)
Structural change (dl1)	0.176	-0.026	0.000	0.001
	(0.097)	(0.030)	(0.001)	(0.106)
Quantity Cigarettes (dl2)	-0.649 ***	-0.154 ***	-0.001	-0.042
	(0.123)	(0.038)	(0.002)	(0.134)
Price ratio (dl2)	-1.465 ***	-0.330 **	-0.007	0.102
	(0.397)	(0.123)	(0.006)	(0.433)
Real Income (dl2)	-6.350	-0.389	-0.123	-10.916
	(7.563)	(2.346)	(0.106)	(8.253)
Structural change (dl2)	-0.290 **	-0.012	-0.001	-0.007
	(0.098)	(0.030)	(0.001)	(0.107)
N	96	96	96	96
R2	0.694	0.224	0.657	0.035

*** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$.

Appendix E

Diagnostic Tests

Table E.1: Portmanteau test

	Statistic	Parameter	p-value	Lags
Portmanteau Test (asymptotic)	265	196	0	15
Portmanteau Test (asymptotic)	468	436	0.14	30

Table E.2: ARCH test

	Statistic	Parameter	p-value	Lags
ARCH (multivariate)	810	1500	1	15

Table E.3: Jarque–Bera normality test

	Statistic	Parameter	p-value
JB-Test (multivariate)	29175.0802324414	8	0

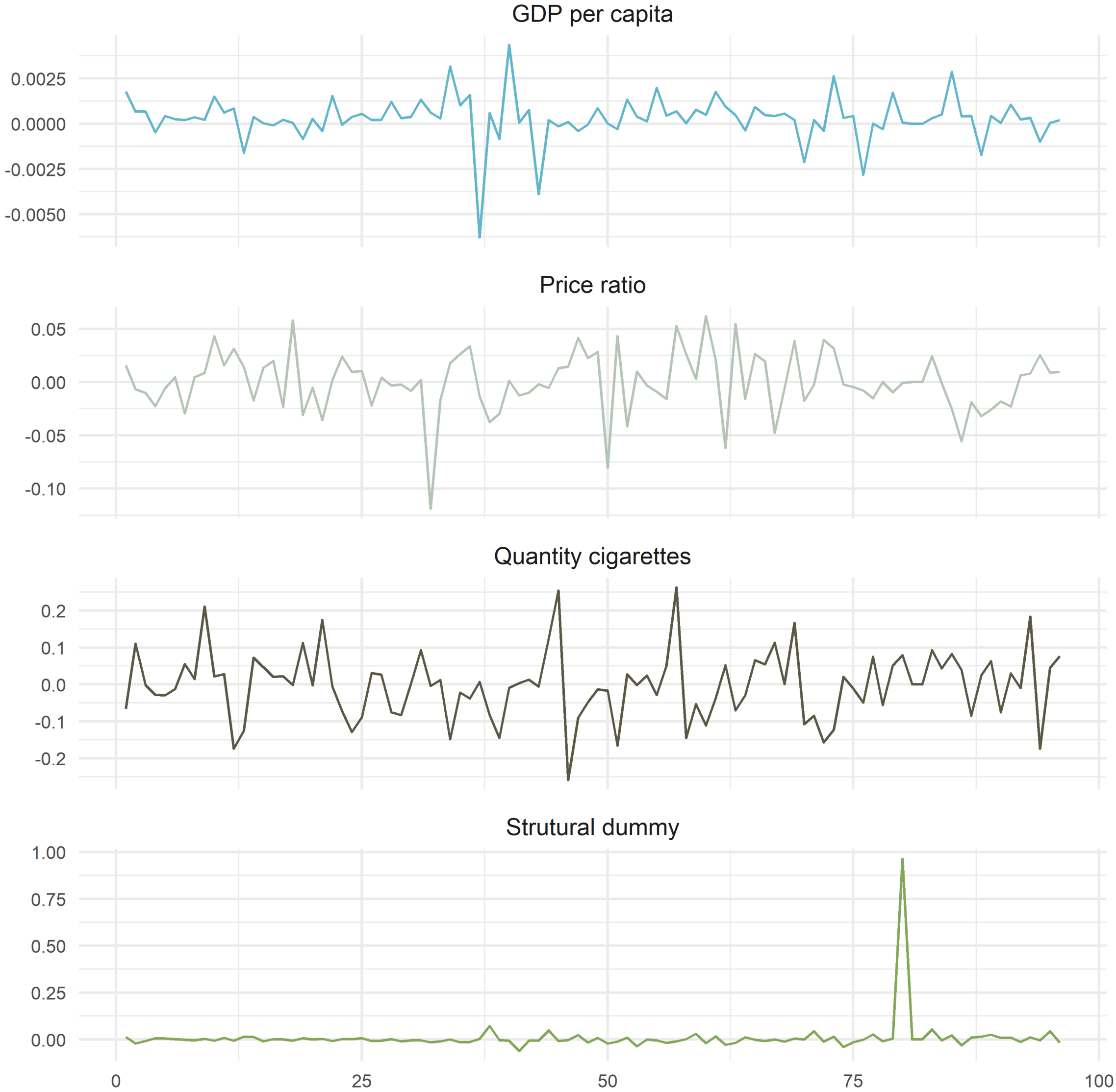

Figure E.1: Plot of residuals

Appendix F

Additional models

Table F.1: 2SLS regression results

	Model 1	Model 2
(Intercept)	20.986 **	7.871 ***
	(7.275)	(0.065)
log_PRATIO	-0.580 ***	-0.771 ***
	(0.146)	(0.096)
log_YR	-0.918	
	(0.510)	
dummy	-0.045	-0.098 **
	(0.042)	(0.030)

*** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$.

Table F.2: Vector Error Correction Model

	Long run coefficient
Quantity cigarettes	1
Price ratio	0.798
Structural change	0.182
Constant	-7.9

Table F.3: Vector Error Correction Model Short Run

	dQuantity Cigarettes	dPrice ratio	dStructural Change
ECT	-0.840 ***	-0.111 **	0.002
	(0.125)	(0.041)	(0.137)
Quantity Cigarettes (dl1)	-1.082 ***	-0.046	0.056
	(0.086)	(0.028)	(0.094)
Price ratio (dl1)	-1.936 ***	-0.214 *	-0.025
	(0.303)	(0.100)	(0.331)
Structural change (dl1)	0.199 *	-0.023	-0.000
	(0.095)	(0.031)	(0.104)
N	97	97	97
R2	0.691	0.107	0.008

*** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$.

Table F.4: Portmanteau test

	Statistic	**Parameter**	**p-value**	**Lags**
Portmanteau Test (asymptotic)	183	120	0	15
Portmanteau Test (asymptotic)	319	255	0	30

Table F.5: ARCH test

	Statistic	**Parameter**	**p-value**	**Lags**
ARCH (multivariate)	492	540	0.931336725796412	15

Table F.6: Jarque–Bera normality test

	Statistic	**Parameter**	**p-value**
JB-Test (multivariate)	32878.7524921968	6	0

List of References

Azar, O.H. (2011). Do people think about absolute or relative price differences when choosing between substitute goods? *Journal of Economic Psychology*, vol. 32, no. 3, pp. 450–457.

Bell, W.R. and Hillmer, S.C. (2002). Issues involved with the seasonal adjustment of economic time series. *Journal of Business & Economic Statistics*, vol. 20, no. 1, pp. 98–127. ISSN 07350015.
Available at: http://www.jstor.org/stable/1392153

Boachie, M.K., Rossouw, L. and Ross, H. (2020). The Economic Cost of Smoking in South Africa, 2016. *Nicotine & Tobacco Research*, vol. 23, no. 2, pp. 286–293. ISSN 1462-2203.

Boshoff, W.H. (2008). Cigarette Demand in South Africa Over 1996-2006: The Role of Price, Income and Health Awareness. *South African Journal of Economics*, vol. 76, no. 1, pp. 118–131. ISSN 1813-6982.

Chow, G.C. (1960). Tests of equality between sets of coefficients in two linear regressions. *Econometrica: Journal of the Econometric Society*, pp. 591–605.

Dare, C., Boachie, M.K., Tingum, E.N., Abdullah, S. and van Walbeek, C. (2021). Estimating the price elasticity of demand for cigarettes in south africa using the deaton approach. *BMJ open*, vol. 11, no. 12, p. e046279.

Deaton, A. (1997). *The analysis of household surveys: a microeconometric approach to development policy*. World Bank Publications.

Dickey, D.A. and Fuller, W.A. (1979). Distribution of the estimators for autoregressive time series with a unit root. *Journal of the American statistical association*, vol. 74, no. 366a, pp. 427–431.

Fox, J., Kleiber, C., Zeileis, A. and Kuschnig, N. (2023). *ivreg: Instrumental-Variables Regression by '2SLS','2SM',or '2SMM', with Diagnostics*. R package version 0.6-2.
Available at: https://cran.r-project.org/web/packages/ivreg/ivreg.pdf

Ghysels, E. (1990). Unit-root tests and the statistical pitfalls of seasonal adjustment: The case of u.s. postwar real gross national product. *Journal of Business & Economic Statistics*, vol. 8, no. 2, pp. 145–152. ISSN 07350015.
Available at: http://www.jstor.org/stable/1391976

International Agency for Research on Cancer (2011). *IARC Handbooks of Cancer Prevention, Tobacco Control: Effectiveness of Tax and Price Policies for Tobacco Control*, vol. 14. World Health Organization Press. Lyon, France.

Johansen, S. and Juselius, K. (1990). Maximum likelihood estimation and inference on cointegration—with appucations to the demand for money. *Oxford Bulletin of Economics and statistics*, vol. 52, no. 2, pp. 169–210.

Kwiatkowski, D., Phillips, P.C., Schmidt, P. and Shin, Y. (1992). Testing the null hypothesis of stationarity against the alternative of a unit root: How sure are we that economic time series have a unit root? *Journal of econometrics*, vol. 54, no. 1-3, pp. 159–178.

Mukong, A.K. and Tingum, E.N. (2020). The demand for cigarettes: new evidence from south africa. *Development Southern Africa*, vol. 37, no. 1, pp. 40–54.

Pfaff, B. (2008*a*). *Analysis of Integrated and Cointegrated Time Series with R*. 2nd edn. Springer, New York. ISBN 0-387-27960-1.
Available at: https://www.pfaffikus.de

Pfaff, B. (2008*b*). Var, svar and svec models: Implementation within R package vars. *Journal of Statistical Software*, vol. 27, no. 4.
Available at: https://www.jstatsoft.org/v27/i04/

Phillips, P.C. and Perron, P. (1988). Testing for a unit root in time series regression. *biometrika*, vol. 75, no. 2, pp. 335–346.

Republic of South Africa and Department of Planning, Monitoring and Evaluation (). Socio-economic impact assessment system (seias) on the control of tobacco products and electronic delivery systems bill. final impact assessment (phase 2).
Available at: https://static.pmg.org.za/180322seias_-_ndoh_tpc_bill.pdf

Tingum, E.N., Mukong, A.K. and Mdege, N. (2020). The effects of price and non-price policies on cigarette consumption in South Africa. *Tobacco Induced Diseases*, vol. 18. ISSN 2070-7266.

Trapletti, A. and Hornik, K. (2018). *tseries: Time Series Analysis and Computational Finance*. R package version 0.10-43.
Available at: https://CRAN.R-project.org/package=tseries

van der Zee, K., van Walbeek, C. and Magadla, S. (2020). Illicit/cheap cigarettes in South Africa. *Trends in Organized Crime*, vol. 23, no. 3, pp. 242–262. ISSN 1936-4830.

Vellios, N., van Walbeek, C. and Ross, H. (2022 July). Measuring the illicit cigarette market in the absence of pack security features: A case study of South Africa. *Tobacco Control*, vol. 31, no. 4, pp. 580–585. ISSN 0964-4563, 1468-3318.

Viet Nguyen, C., Le, T.T. and Nguyen, N.H. (2021). The impact of cigarette prices on smoking participation and tobacco expenditure in vietnam. *Plos one*, vol. 16, no. 12, p. e0260415.

World Health Organization and WHO Tobacco Free Initiative (2010). Economics of tobacco toolkit: economic analysis of demand using data from the global adult tobacco survey (gats).

Zeileis, A., Kleiber, C., Krämer, W. and Hornik, K. (2003). Testing and dating of structural changes in practice. *Computational Statistics & Data Analysis*, vol. 44, no. 1–2, pp. 109–123.

Zeileis, A., Leisch, F., Hornik, K. and Kleiber, C. (2002). strucchange: An r package for testing for structural change in linear regression models. *Journal of Statistical Software*, vol. 7, no. 2, pp. 1–38.